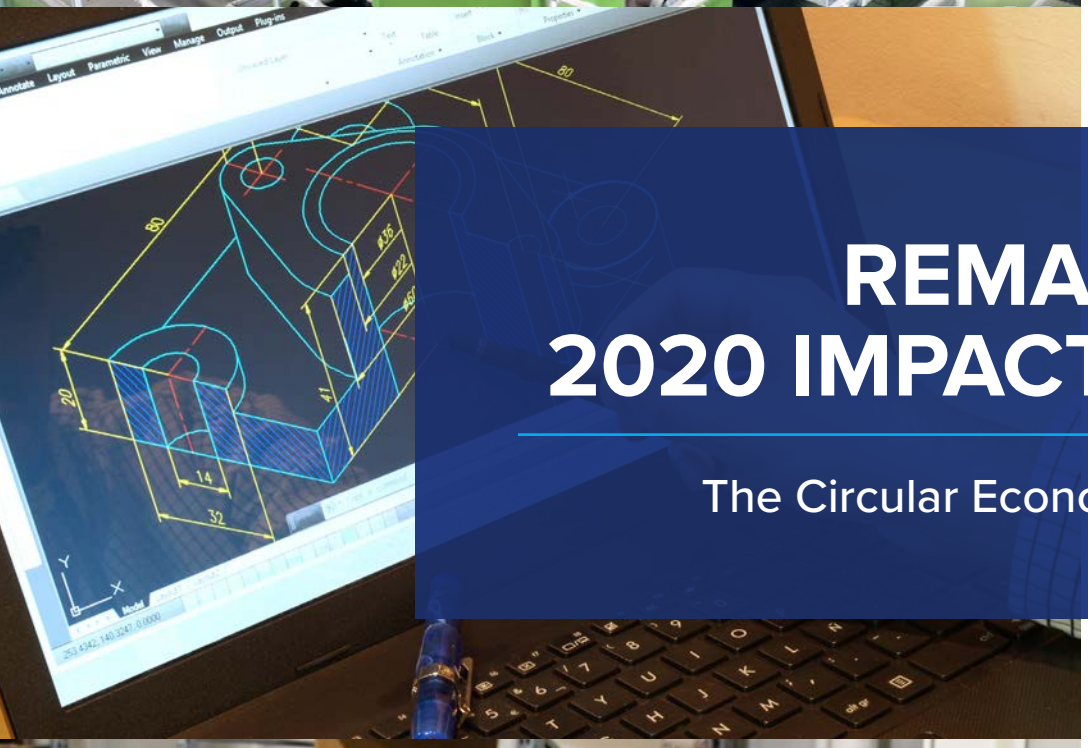

REMADE INSTITUTE®

REMADE 2020 IMPACT REPORT:

The Circular Economy Institute

Proud member of Manufacturing USA®

Reducing Embodied Energy and Decreasing Emissions

Table of Contents

Acknowledgment: "This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under the Advanced Manufacturing Office Award Number DE-EE0007897."

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Bottom image provided courtesy of Alex Tong of RIT

A Message from the CEO

Our world has changed dramatically over the last year, and the impacts from COVID-19 have affected most aspects of our professional and personal lives. During these uncertain times, I am heartened by REMADE members and their continued commitment to sustainability. On behalf of the entire REMADE team, we thank you for your partnership.

In 2020, we continued our mission of innovation, and together, we embarked on new projects while successfully completing others. We transformed our workforce development program to meet your rapidly changing needs, adjusting to virtual format and now offering more than 30 hours of training online. To date, our workforce development program has trained more than 2,100 industry professionals on a wide variety of topics, ranging from reuse and remanufacturing, to recovery and recycling, and more.

We also welcomed many new and diverse members to REMADE. By the end of 2020, our fourth year of operation, our experts were collaborating with more than 90 consortium partners — including manufacturers, universities and national labs — on 39 projects. These projects, representing more than $20 million in investment, are reducing embodied energy, decreasing emissions, removing barriers, and increasing the U.S.'s manufacturing competitiveness for decades to come.

REMADE's projects are also driving innovation and economic activity. Our research is expected to lead to **more than 200,000 direct new jobs**, approximately **500,000 indirect new jobs**, and **up to $50 billion in new business opportunities**. That's a significant return on investment.

Today, REMADE is the only institute in the U.S. dedicated to leading the transition from an unsustainable linear economy to a sustainable Circular Economy. Thanks to the U.S. Department of Energy, New York's Empire State Development, and all of our consortium partners, we are at the forefront of accelerating our nation's transformation to a world without waste.

The U.S. must be ready to lead in a new, more circular future. With REMADE and our partners, we will be.

Nabil Nasr | Chief Executive Officer
REMADE Institute

Accelerating the Transition to a Circular Economy

The Problem:

For the last 150 years, our economic growth has depended on our ability to extract resources from the ground, convert them into products we use, and eventually throw them away. This “Take, Make, Dispose” approach, referred to as the linear economy, is no longer sustainable.

The Solution:

To solve this problem, we must transition to a Circular Economy, where we fundamentally alter how we consume materials, design and use products, and preserve and extend the life of what’s already been made. This “Make, Use, Recycle” approach is truly sustainable.

The Circular Economy Could Add $1 Trillion Per Year To The U.S. Economy

– US Chamber of Commerce Foundation Circular Economy Best Practices.pdf (uschamberfoundation.org)

For Every 1,000 Tons of Materials Recycled, A Job Is Created

– U.S. Environmental Protection Agency Recycling Basics | Reduce, Reuse, Recycle | US EPA

Consumption of Primary Materials Could Be Reduced by 32% Within A Decade

– Ellen MacArthur Foundation The Circular Economy In Detail (ellenmacarthurfoundation.org)

Reducing Embodied Energy and Decreasing Emissions (REMADE)

Founded in 2017, the REMADE Institute is a **$140 million Manufacturing USA® institute** and public-private partnership established by the United States Department of Energy. The institute leads a consortium of more than 90 manufacturers, universities and national labs to **accelerate the U.S.’s transition to the Circular Economy**.

From reuse and remanufacturing, to recovery and recycling, REMADE’s work criss-crosses the country to address the nation’s most pressing economic and sustainability challenges. Within the first five years, REMADE’s research is expected to reduce the U.S.’s greenhouse gas emissions considerably. Today, manufacturing accounts for **25% of U.S. energy consumption**. To meet the U.S.’s climate targets, we need to deploy renewable energy technologies AND reduce energy consumption. Renewable energy cannot do it alone.

REMADE will help manufacturers reduce on-site emissions by 8%.

REMADE’S research and expertise are also integral to meeting the **U.S.’s additional top energy and environmental goals**, including:

- Creation of **good-paying clean energy jobs**, ensuring that **environmental justice** and **equitable economic opportunities** are key considerations
- **A carbon pollution-free power sector by 2035**
- **Net zero emissions economy-wide by 2050**

Advancing the Circular Economy Through Innovation

Within a five-year period, REMADE’s research is projected to enable:

saving 1 quad of energy, which equates to the **electrical use by all U.S. households** per year

creating up to **700,000 direct and indirect jobs** to increase the nation’s competitiveness

reducing 50M metric tons/yr GHG emissions, which equates to the combined emissions of **3.2 million people in the U.S. per year**

generating up to **$50 billion in new opportunities** or about **2.5%** increase in U.S. contribution to manufacturing GDP

Public-Private Partnership

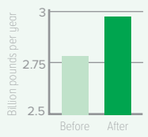
REMADE works with over 90 manufacturers, universities, trade organizations, and national labs with **more than 1,000,000 employees** worldwide. Our corporate partners include small manufacturers, national consumer brands and large multinationals. Our academic partners represent frontline community colleges and the nation’s largest public universities, as well as some of the most prestigious educational institutions in the world. In addition, our trade partners represent a cross-section of industry sectors, from metals and chemicals to paper, plastics and more.

Multinational Corporations • Leading Research Universities
National Laboratories • Trade Associations
Small Businesses • Community Colleges • Local Municipalities

Learn more at remadeinstitute.org/membership

USE waste as a resource

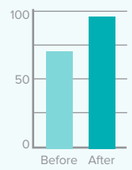
The U.S. recycles 2.8 billion pounds of plastic bottles annually



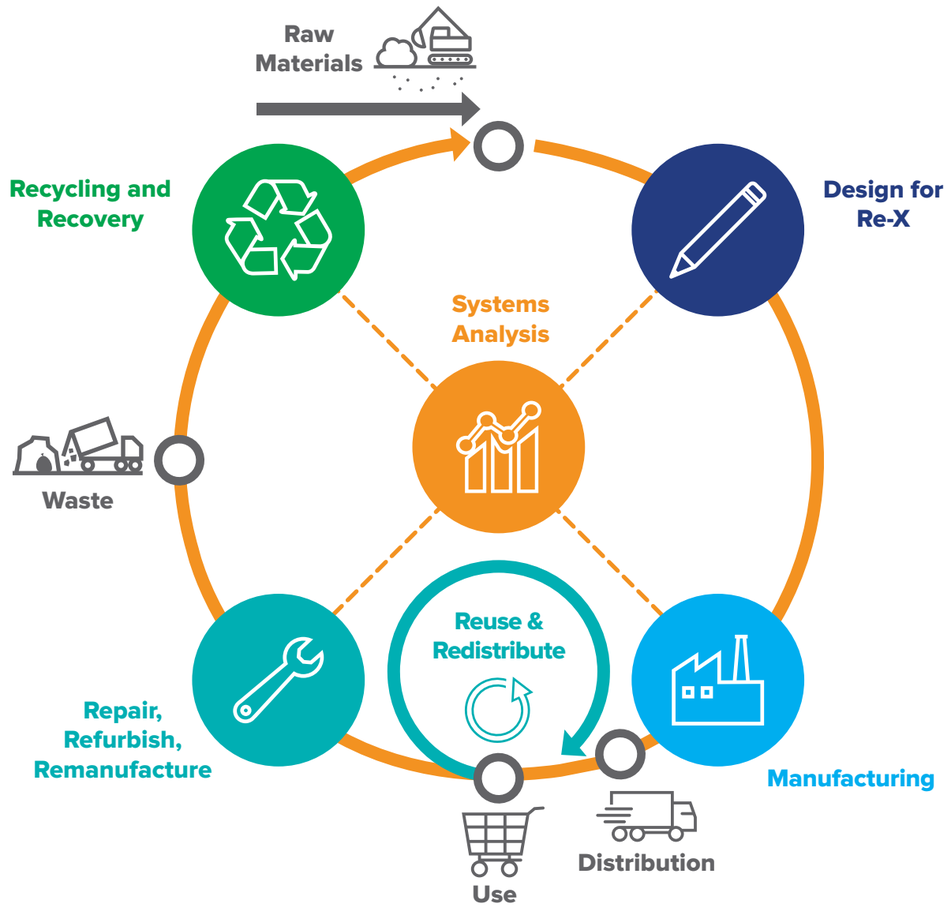
Oklahoma State University, Niagara Bottling LLC, and Shaw Industries are working to increase recycling of bottles and carpeting materials by **5% each** by combining both materials into desirable composite materials.

PRESERVE and EXTEND the life of products and materials

Remanufacturing can decrease materials use compared to new products by **80-98%**

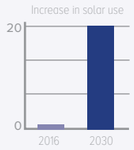


Rochester Institute of Technology (RIT), Caterpillar Inc., and Synergy Additive Manufacturing are developing a new approach to adding metal that will result in increasing the reuse rate in engine remanufacturing from **70% to 95%.**



DESIGN products that can be reused, remanufactured, and recycled

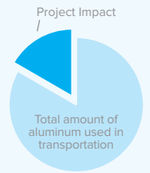
80% of environmental impacts are affected by decisions made at the design stage



University of Pittsburgh, University of California-Irvine, National Renewable Energy Laboratory, and First Solar's project worked to optimize solar performance and total cost of ownership to accommodate a U.S. solar market that is estimated to **increase by more than 20 times** between 2016 and 2030.

REDUCE raw materials consumption

About **30%** of aluminum used globally is used in the transportation sector



University of Illinois at Urbana-Champaign and Eck Industries Inc., as well as Ohio State University, Alcoa USA Corp., and North American Die Casting Association are working to develop new processes for recycling aluminum that lead to **secondary feedstock to account for 1/6 of the need**.

ADOPT a systems-level perspective

The shift from a linear economy to a Circular Economy requires tools and methods for evaluating materials

By mapping the material flows for metals, polymers, fibers and electronic waste, REMADE developed scenarios for consumption that support our efforts for a Circular Economy.

Learn more at remadeinstitute.org

REMADE's Five-Year Target Metrics

↓30%
Primary Materials Consumed

↑30%
Recycled Materials Consumed

↑25%
Embodied Energy Efficiency

↓20%
GHG Emissions

Promote
Cross-Industry Reuse

Achieve
Cost and Energy Parity

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More Than The Power of One

As a consortium of over 90 manufacturers, universities, trade organizations and national labs, REMADE addresses challenges and removes barriers, increasing U.S. manufacturing competitiveness and leading the transition to a Circular Economy. Together, we have the power to accomplish what no one organization could on its own.

Learn more at remadeinstitute.org/membership

37 Industry Members

Light Metal Consultants, LLC

5 National Labs

25 Academic Partners

University of Michigan Michigan State University Ohio State University

25 Affiliate Organizations

Kent County Department of Public Works

The Power of a Technology Portfolio:

Films & Flexibles Recycling

Films and Flexibles are one of the fastest growing packaging types, are not readily recyclable, and currently contaminate the U.S.'s curbside recycling system. REMADE is exploring ways to make them fully recyclable.

Project Team Members

NREL Transforming ENERGY

Michigan Technological University 1885

Unilever

American Chemistry Council

UMASS LOWELL

INL Idaho National Laboratory

RRS

Learn more at remadeinstitute.org/projects

Optimization

REMADE Project: Systems Analysis for PET and Olefin Polymers in a Global Circular Economy

This cost-shared exploratory research project, which has been completed, established a foundation for the systems analysis (SA) of the U.S. and global plastics Circular Economy (CE) to enable identification of technology gaps. With this, one can be able to evaluate the cost, energy and environmental benefits of proposed technology solutions to fill the technology gaps. A linear programming optimization model has been developed, revealing that both mechanical and chemical recycling technologies are needed to achieve a Circular Economy of PET bottles with lower GHG emissions. The basic model concept developed in this project confirms the value of the tool.

Film & flexible packaging is projected to expand at a compound annual growth rate of 3%. Today, much of this material is sent to landfills. And even in places where it's collected, much of it is lost.

- The Recycling Partnership, (https://recyclingpartnership.org/press-release-the-recycling-partnership-launches-film-and-flexibles-task-force/)

Collection

REMADE Project: Determining Material, Environmental and Economic Efficiency of Sorting and Recycling Mixed Flexible Packaging and Plastic Wrap

This project is developing technology to recover flexible plastic film from a material recovery facility (MRF). Market opportunities for the recovered film is being examined and the resulting economic and environmental impacts are being evaluated. The technology being developed in the project, if implemented broadly, has the potential of capturing almost 11 billion pounds of flexible plastic packaging and plastic wrap that is currently landfilled each year.

Separation

REMADE Project: Scalable High Shear Catalyzed Depolymerization of Multilayer Plastic Packaging

Industry is increasingly combining layers of different polymer materials to construct highly functional, lightweight packaging (e.g. to extend food life). These multilayer films are unfortunately less recyclable than single layer films. This project, which has been completed, investigated catalytic depolymerization as a cost-effective approach to process these films into higher value products suitable for use in a variety of applications.

Projected Annual Impacts of REMADE's Films & Flexible Plastic Projects

Up to
50 Petajoules
Embodied Energy Savings

Up to
2 Million
Metric Tons in Material Savings

Reduce Up to
2 Million
Metric Tons in GHG Emissions

The Power of a Technology Portfolio:

Paper & Cardboard Recycling

In our current curbside recycling system, paper and cardboard are frequently contaminated, resulting in more than 17.2 million tons, or 25%, of MSW paper and paperboard being landfilled. REMADE seeks to remove contaminants and increase recycling rates.

Project Team Members

Virginia Tech · Thiele Tailored Mineral Solutions · Graphic Packaging International · WestRock · University of Miami · Massachusetts Institute of Technology · Western Michigan University · Idaho National Laboratory · American Forest & Paper Association

Learn more at remadeinstitute.org/projects

Systems Analysis | **Manufacturing** | **Collection** | **Recycling**

REMADE Project: Identifying Strategies to Maximize Benefit of Fiber Recovery Through Systems Quantification

This project is analyzing the system-wide economic and environmental implications of changes in the recovery of fibers. The project is using a dynamic modeling framework that integrates material flow analysis, life cycle inventories, and technical cost modeling to inform potential ideas for cost-effective fiber recovery approaches.

NEW

REMADE Project: Biological & Bio-Mechanical Technologies for Recycled Fibers to Regain Fiber Quality and Increase Secondary Feedstock in High Value-Added Paper Grades

This project is developing new technologies for removing contaminants from recycled paper, bringing them to less than 0.5%, and developing technologies for regaining fiber quality without using only mechanical refining. The new technologies that are being developed will help the paper recycling industry produce much cleaner pulp and higher quality fibers so more recycled fibers can be used in place of virgin fibers in high grade paper.

Manufacturing paper and paperboard with recycled materials uses up to 68% less energy than using virgin materials.

- Institute of Scrap Recycling Industries, inc.

REMADE Project: Assessment of the Impact of Single Stream Recycling on Paper Contamination in Recovery Facilities and Paper Mills

The objectives of this project, which has been completed, were to 1) quantify the contamination rates of recovered fiber from single-stream materials recovery facilities (MRF) across the U.S. and 2) to develop recommended “best practices” to minimize and/or control contamination in recycled materials. Best practices that were identified include installing equipment such as a rotating trommel in the fiber recovery circuit to screen out small glass particles.

REMADE Project: New Approaches to Improve Deinking Flotation to Increase the Availability of High-Quality, Low-Cost Recycle Paper Fibers

This project is helping industry to further increase economically competitive recycling rates to those achieved in Europe by developing more efficient separation technologies that can produce higher brightness fibers by removing impurities more efficiently from spent wood fibers. The project could enable the use of an additional 1.3 million metric tons per year of secondary fiber.

Projected Annual Impacts of REMADE’s Paper & Cardboard Projects

Up to **150 Petajoules** Embodied Energy Savings

Up to **8 Million** Metric Tons in Material Savings

Reduce Up to **8 Million** Metric Tons in GHG Emissions

The Power of a Technology Portfolio:

Electronic Waste Recycling & Reuse

The U.S. generated 6.9 kt of e-waste in 2019, recycling only 15% of that amount. E-waste can result in serious harm to human health and the environment, so REMADE is working to increase recycling rates. Recovering e-waste's precious metals will also reduce dependence on finite raw materials.

Project Team Members

Idaho National Laboratory

CoreCentric Solutions

The University of Utah

CATERPILLAR®

SUNNKING We Rule Electronics Recycling

RIT

Learn more at remadeinstitute.org/projects

Collection | **Condition Assessment** | **Recycling**

REMADE Project: Evaluation of Logistics Systems for the Collection, Preprocessing and Production of Secondary Feedstocks from E-waste

This project is developing an e-waste logistics model that integrates transportation, manufacturing processes, and markets to enable optimal recovery and recycling of e-waste. The model is enabling identification of least cost options for increasing e-waste collection and recycling.

REMADE Project: Condition Assessment of Used Electronics

Detecting solder joint and interconnection failures on used electronics presents a serious cost challenge for remanufacturers because detection is currently completed manually. Several automated methods for detection of these failures are being examined to determine their feasibility for use in the remanufacturing industry.

REMADE Project: Low-Cost, High-Value Metal Recovery from Electronic Waste to Increase Recycling and Reduce Environmental Impact

The objective of this exploratory project, which has been completed, was to establish a proof-of-concept for an environmentally benign bio-leaching process for recovering copper and precious metals from e-waste scrap. Cost-effective recovery of high-value metals from e-waste significantly enhances the value proposition for recycling of the balance of materials from e-waste. Today, precious metals that are recovered from e-waste are processed offshore due to the environmental challenges of conventional precious metal recovery processes.

Many electronic parts or products are remanufactured, including consumer products such as smartphones and PCs. The global market is estimated at $80 billion, and demand has surged during the COVID pandemic.

- EE Times (https://www.eetimes.com/why-the-refurbished-electronics-market-is-thriving/#)

Projected Annual Impacts of REMADE's Electronic Waste Projects

Up to **27 Petajoules** Embodied Energy Savings

Up to **0.2 Million** Metric Tons in Material Savings

Reduce Up to **1.8 Million** Metric Tons in GHG Emissions

The Power of a Technology Portfolio:

Heavy Duty Off-Road Remanufacturing

The U.S. is the largest remanufacturer in the world, supporting 180,000 full-time jobs and generating nearly $12 billion in exports. Heavy-duty off-road equipment is one of the most reman-intensive sectors. REMADE seeks to increase reman intensity in the sector, creating even more jobs and more exports.

Project Team Members

University of Illinois Urbana-Champaign · Iowa State University · Synergy Additive Manufacturing, LLC. · John Deere · RIT · PennState · Caterpillar®

Learn more at remadeinstitute.org/projects

Design for Re-X | **Inspection & Condition Assessment** | **Repair/Restoration**

REMADE Project: Data-Driven Design Decision Support for Re-X of High-Value Components in Industrial and Agricultural Equipment

This project created a tool to evaluate and recommend the optimal designs of components in industrial and agricultural equipment. By designing components with optimum material utilization and end-of-life in mind, there is a 60% reduction in carbon emissions.

REMADE Project: Quantitative Non-Destructive Evaluation of Fatigue Damage Based on Multi-Sensor Fusion

Current single-sensor non-destructive fatigue damage evaluation techniques have limited accuracy in predicting actual fatigue damage and the remaining useful life of a recovered part. The integration of multiple sensors which respond differently to fatigue damage has the potential of increasing the predictive accuracy of remaining useful life of materials to enable higher remanufacturing rates of parts.

REMADE Project: High Speed Laser Cladding for Hard Surface Replacement

This project lays out a novel technique - high speed laser cladding - for remanufacturing high-strength components such as crankshafts and camshafts. While cladding is a proven technique for applying wear-resistant metal coatings in manufacturing, high-speed laser cladding increases productivity and significantly reduces the cost of applying the layers that will enable use of this technology in remanufacturing.

Buying a remanufactured product or service part can save 90% of the energy compared to buying a new part.

- IRP (2018). Re-defining Value – The Manufacturing Revolution

Projected Annual Impacts of REMADE's Remanufacturing Projects

Up to **50 Petajoules** Embodied Energy Savings

Up to **1 Million** Metric Tons in Material Savings

Reduce Up to **2.5 Million** Metric Tons in GHG Emissions

REMADE Projects

****COMPLETE** Low-Cost, High-Value Metal Recovery from Electronic Waste to Increase Recycling and Reduce Environmental Impact** | University of Utah, Sunnking, Inc.

New Approaches to Improve Deinking Flotation to Increase the Availability of High-Quality, Low-Cost Recycle Paper Fibers | Virginia Polytechnic Institute

Material Characterizations and Sorting Specifications That Can Allow the Development of Advanced Tire Constructions with High Incorporation of Recovered Rubber Materials | Michelin, Northwestern University, Nike

Reinforced Recycled Polymer Composites | Oklahoma State University, Niagara Bottling LLC, Shaw Industries

****COMPLETE** Chemical Recycling of Mixed Plastics and Valuable Metals in the Electronic Waste Using Solvent-Based Processing** | University of Massachusetts-Lowell, Sunnking, Inc., Institute of Scrap Recycling

****COMPLETE** Development of New Cost-Effective Methods for Removing Trace Contaminants in Recycled Metals** | The Ohio State University, Alcoa, Computherm

****COMPLETE** Pushing the State of the Art in Steel Recycling through Innovation in Scrap Sorting and Impurity Removal** | Colorado School of Mines

Determining Material, Environmental and Economic Efficiency of Sorting and Recycling Mixed Flexible Packaging and Plastic Wrap | American Chemistry Council, Resource Recycling Systems, Idaho National Laboratory

Evaluation of Logistics Systems for the Collection, Preprocessing and Production of Secondary Feedstocks from E-waste | Idaho National Laboratory, Sunnking, Inc.

****COMPLETE** Demineralization of Carbon Black Derived from End-of-Life Tires** | University of Utah, OTR Wheel Engineering/Green Carbon Inc., and Idaho National Laboratory

****COMPLETE** Scalable High Shear Catalyzed Depolymerization of Multilayer Plastic Packaging** | University of Massachusetts-Lowell, Michigan State, Unilever, American Chemistry Council, National Renewable Energy Laboratory

****COMPLETE** Assessment of the Impact of Single Stream Recycling on Paper Contamination in Recovery Facilities and Paper Mills** | University of Miami

****COMPLETE** Rapid Sorting of Scrap Metals with Solid State Device** | University of Utah

Low-Concentration Metal Recovery from Complex Streams Using Gas-Assisted Microflow Solvent Extraction (GAME) | Virginia Polytechnic Institute and State University, Phinix, LLC

Development and Validation of Metal Separation Technology for Complex Metal Systems | The Pennsylvania State University, CHZ Technologies LLC

Advanced Education and Workforce Training in Fibers Recycling | Western Michigan University, Graphic Packaging International, Recourse Recovery Systems

High Speed Laser Cladding for Hard Surface Replacement | Rochester Institute of Technology, Caterpillar Inc., Synergy Additive Manufacturing

In-situ Nondestructive Evaluation of In-flight Particle Dynamics and Intrinsic Properties for Thermal Spray Repairs | Iowa State University, John Deere

Remaining Life Determination | Rochester Institute of Technology, University of Illinois at Urbana-Champaign, Caterpillar Inc.

Non-Destructive In-process Assessment of Thermal Spray Repairs | Rochester Institute of Technology, University of Pittsburgh, ITAMCO, Caterpillar Inc.

****COMPLETE** Quantitative Non-Destructive Evaluation of Fatigue Damage Based on Multi-Sensor Fusion** | University of Illinois at Urbana-Champaign, Pennsylvania State University

Epoxy/Silicon Potting Material Removal for Greater Recovery of Circuit Boards | Rochester Institute of Technology, Caterpillar Inc., CoreCentric Solutions

Condition Assessment of Used Electronics | Rochester Institute of Technology, Caterpillar Inc., CoreCentric Solutions

Low Heat Repair of Cast Iron | Rochester Institute of Technology, John Deere Reman

Rapid Damage Identification to Reduce Remanufacturing Costs | Iowa State University, John Deere & Company

Development of a Castable High Strength Secondary Aluminum Alloy from Recycled Wrought Aluminum Scrap | University of Illinois at Urbana-Champaign, Eck Industries Inc.

Cross-Industry Utilization of Ground Tire Rubber for Energy Efficient Pavements | Iowa State University, Michelin, Lehigh Technologies (Subsidiary of Michelin)

Increasing Melt Efficiency and Secondary Alloy Usage in Aluminum Die Casting | The Ohio State University, Alcoa USA Corp., North American Die Casting Association

CombiClean™: Facilitating Contaminant Removal in Recycled Plastics | Michigan State University, Sealed Air

Biological & Bio-Mechanical Technologies for Recycled Fibers to Regain Fiber Quality and Increase Secondary Feedstock in High Value-Added Paper Grades | Western Michigan University, Idaho National Laboratory, Graphic Packaging International, WestRock Company

****COMPLETE** Data-Driven Design Decision Support for Re-X of High-Value Components in Industrial and Agricultural Equipment** | Iowa State University, John Deere

Design for Remanufacturing | Rochester Institute of Technology, Caterpillar Inc., Remanufacturing Industries Council

****COMPLETE** Development of an Industrially Relevant RE-SOLAR Design Framework** | University of Pittsburgh, University of California-Irvine, National Renewable Energy Laboratory, First Solar

Quantification of Financial and Environmental Benefits Tradeoffs in Multi-Generational Product Family Development Considering Re-X Performances | University of Illinois at Urbana-Champaign, Iowa State University, Deere and Company, Green Electronics Council

Design Iteration Tool to Sustain Remanufacturability | Iowa State University (ISU), Danfoss

A Dynamic Techno-economic Systems Modeling Framework for U.S. Fiber Recycling | Northwestern University, Yale University, Institute of Scrap Recycling Industries

Identifying strategies to maximize benefit of fiber recovery through systems quantification | Massachusetts Institute of Technology, The American Forest & Paper Association, WestRock, Graphic Packaging

****COMPLETE** Systems Analysis for PET and Olefin Polymers in a Global Circular Economy** | Michigan Technological University, American Chemistry Council, Idaho National Laboratory

Mapping the Materials Base for REMADE | Yale University, Unilever, Institute of Scrap Recycling Industries, Sunnking, Massachusetts Institute of Technology

Pending New Projects*

Selective Recovery of Elements from Molten Aluminum Alloys | Phinix, LLC, Worcester Polytechnic Institute, Kingston Process Metallurgy, Smelter Service Corporation, Certified Flux Solutions, LLC

Dynamic Crosslinking to Enable EVA Recycling | Braskem America, Case Western Reserve University, Allbirds, Inc.

Diverting Mixed Polyolefins from Municipal Solid Waste to Feedstocks for Automotive and Building Applications | Michigan State University, National Renewable Energy Laboratory, PADNOS

Chemical Recycling of Mixed PET/Polyolefin Streams Through Sequential Pyrolysis and Catalytic Upgrading | The Pennsylvania State University, Northwestern University, Shaw Group Industries, Inc., Process Systems Enterprise, Inc. - A Siemens Business

Smart Additive Manufacturing Towards Use of Recycled Paper Fibers for Producing High-quality Fiber-Reinforced Plastic (FRP) Composites | University of Iowa, Impossible Objects, Inc.

Identification of Mixed Plastics and Valuable Electronics at the Source | University of Miami, Lid Vizion, LLC

Recycling of PET in Sustainable Food Packaging Systems | MuCell Extrusion LLC, Plastilene SAS a Plastilene Group Company, Wingate Packaging, Sugar Creek Packaging Co., Center for Innovative Food Technology, The Ohio State University

Reprocessing and Upcycling of Mixed Polyurethane Waste Streams | Northwestern University, BASF

Efficient Purification and Reuse of Carbon Black Recovered from End-of-Life Tires | University of Utah, Idaho National Laboratory, OTR Wheel Engineering/Green Carbon

Delamination as Key Enabler for the Recycling of Polymer-based Multilayer Packaging | The Research Foundation for SUNY - University of Buffalo, Pacific Northwest National Laboratory, Modern Corporation, Honeywell (Performance Materials Technologies)

Zero-Waste Recycling of Blended PET Fiber to Transform Polymer Sourcing | Circ, Fiber Industries, SeaChange Technologies, National Renewable Energy Laboratory, Pacific Northwest National Laboratory, lululemon

Development of Instruments and Techniques That Can Assess Tire Life and Increase Re-Manufacturing of Commercial Vehicle Tires | Michelin North America, Northwestern University

Development of Additive Manufacturing Material and Process Technologies to Improve the Re-Manufacturing Efficiency of Commercial Vehicle Tires | Virginia Polytechnic Institute, Arizona State University, Michelin North America, Nike Inc., Sealed Air Corporation

Remanufacturing of Surface-Hardened Steel Components by Ultrasonic Surface Modification | Rochester Institute of Technology, Caterpillar, Inc., University of Pittsburgh

Repurposing of FRP Composites Using Next-Generation Technology | American Composites Manufacturing Association, West Virginia University, Polynt Composites, AOC Resins, Strongwell Corporation, Owens Corning, Rhode Island Marine Trade Association

Supramolecular Interfacial Reinforcement for Manufacture Utilizing Mixed Secondary Plastic Feedstock | The University of Akron, Braskem

Achieving 100% Recycling Aluminum in Die Casting Applications | The Ohio State University, Alcoa USA Corp., North American Die Casting Association, CompuTherm LLC

Enabling Cross-industry Reuse of Comingled Waste Plastics as Quality Asphalt Modifier for Sustainable Pavement | University of Tennessee - Knoxville, Oak Ridge National Laboratory, Paragon Technical Services Inc. (a subsidiary of Ergon Asphalt and Emulsions, Inc.)

Sustainable Automotive Manufacturing | Michigan State University, American Chemistry Council, BASF

Chemical Conversion and Process Control for Increased used of Polyethylene and Polypropylene Secondary Feedstocks | University of Massachusetts Lowell, Massachusetts Institute of Technology, SER North America LLC, iMFLUX Inc.

Material and Vehicle Design for High-Value Recycling of Aluminum and Steel Automotive Sheet | University of Michigan, Ford Motor Company, Novelis, Argonne National Laboratory, The Institute of Scrap Recycling Industries, The Aluminum Association, Light Metal Consultants

Analysis and Design for Sustainable Circularity of Barrier Film in Sheet Molding Composites | The Ohio State University, Kohler Co., National Renewable Energy Laboratory, Arizona State University

Building Re-X (BREX): Data, Methodology, and Design Integration | National Renewable Energy Laboratory, Building Transparency, Skidmore Owings & Merrill

Dynamic Systems Analysis of PET and Olefin Polymers in a Circular Economy | Michigan Technological University, Idaho National Laboratory, Resource Recycling Systems, Yale University, Chemstations, Honeywell UOP

Read about all of the projects at remadeinstitute.org/projects

* Projects are selected for award pending final negotiation and DOE approval.

REMADE Academy

The Institute engages a broad audience by hosting numerous training opportunities ranging from events focused on offering high-level overviews to launching its Tiered Certificate Pathways program.

▶ Outreach Training

REMADE is actively providing training through project webinars, conference presentations, and sponsored workshops. The goal of this training is to deliver brief overviews of REMADE relevant technology, industry, and best practices.

▶ Tiered Certificate Pathways

Tiered Certificate Pathways are developed by grouping similar short courses together to provide a deeper level of understanding of a broad topic. Short Courses cover a single or multiple concepts, technologies, and practices and are tailored for the incumbent workforce at three competency levels: Awareness, Practitioner, or Expert. To achieve a formal certificate from the REMADE Institute, students need to complete each of the short courses for the associated Tiered Certificate Pathways.

REMADE will continue to leverage opportunities to incorporate R&D project results into all levels of EWD training.

Awareness Training

Awareness training is intended to provide participants a high-level introduction to the subject matter.

Practitioner Training

Practitioner level training is intended for incumbent workers that currently work with the technologies or in adjacent technology domains who wish to broaden their knowledge.

Expert Training

Expert level training is intended to provide in-depth coverage of advanced concepts or technology and is targeted toward engineers or scientists trying to expand their skill set.

Learn more at remadeinstitute.org/ewd

REMADE is creating the next generation workforce and preparing incumbent workers to support the growth in U.S. Clean Economy jobs.

2020 Virtual Remanufacturing Bootcamp

In response to the rapid shift from in-person to remote learning caused by Covid-19, REMADE hosted a 3 day virtual “Remanufacturing Bootcamp.” Content was developed by 7 subject matter experts and attracted over 250 participants. This provided a much needed resource for the U.S. incumbent workforce to increase their skills and knowledge of remanufacturing technologies.

Education & Workforce Development Impacts

2,100+
people trained

300+
trainers

30+
hours of online training available on-demand

24
training events

20+
subject matter experts collaborated on training development

Available On-Demand via Member Portal

Remanufacturing and End-of-Life Reuse

▶ Outreach Training

Available On-Demand:

- Design for Reman - Real World Challenges and Opportunities
- New Technology Recovers Aluminum from Industrial Scrap Metal
- Quantitative Non-Destructive Evaluation of Fatigue Damage Based on Multi-Sensor Fusion
- Redefining Value
- Pushing the State of the Art Through Innovation in Scrap Sorting and Impurity Removal
- Data-Driven Design Support for Re-X of High Value Components in Industrial and Agricultural Equipment

Previous Live Workshops:

- RIT Reman Testbed Workshop
- Workshop on Remanufacturing, Repair and Reuse
- Determining Environmental Benefits of Remanufacturing
- Condition Assessment for Remanufacturing

▶ Short Courses

Available On-Demand (Can be taken individually or as a full set for a Certificate Pathway):

- **Introduction to Remanufacturing:** Introduction to reman and EOL reuse, related technologies, and environmental impacts
- **Condition Assessment for Reman:** Overview of inspection technologies: methods, capabilities and limitations
- **Cleaning Technology for Reman:** Overview of cleaning principles, equipment, and processes for remanufacturers
- **Additive Repair Technology for Reman:** Overview of additive repair principles and technologies
- **Design Capture and Design for Reman:** Understand design capture, integration, and remanufacturing design framework

▶ Tiered Certificate Pathways

Now Available: Fundamentals of Remanufacturing Awareness Level

This five-part short course series offer insights to advance capabilities in remanufacturing, as well as a comprehensive dive into the technological advancements delivering widespread benefits to businesses that depend on remanufacturing.

- Designed for manufacturers new to the reman industry, skilled engineers and technicians, and veteran remanufacturers looking for a deeper, technical dive

We host numerous training opportunities, including: webinars, short courses and certificate programs.
These educational resources are open to everyone within any Institute membership organization.
Go to **remadeinstitute.org/online-training** for detailed information.

Available On-Demand via Member Portal

Recycling and Recovery

▶ Outreach Training

Available On-Demand:

- E-waste Challenges and Opportunities
- Paper Recycling: Challenged by Both Quality and Convenience
- Flexible Plastic Packaging: Industry Landscape, Challenges and Opportunities
- Plastic Waste Valorization for a Circular Economy: Perspective on Chemical Recycling
- Metals Recycling
- Recycling in a Medium-Sized City

▶ Short Courses

Available On-Demand (Can be taken individually or as a full set for a Certificate Pathway):

- **Crash Course in Plastics Recycling:** Overview of existing recycling technologies capable of converting plastic waste into high-value products
- **End-of-Life and the Circular Economy:** Discover options for recovering end-of-life plastics and areas where there is opportunity to improve
- **Mechanical Recycling, Testing, Extruding, and Recovery:** Overview of mechanical recycling technologies
- **Mechanical Recycling Limitations and Ways to Overcome Limitations:** Learn process steps of mechanical recycling and its limitations
- **Plastic Flows Through a MRF:** Overview of processes followed at Material Recovery Facilities (MRF) as it relates to current recycling rates
- **Chemical Recycling of Plastic Waste 101:** Discover the state-of-the-art of plastic recycling technologies
- **Flexible Plastic Packaging: Industry Landscape, Challenges and Opportunities:** Overview of typical flexible packaging types and current options for recycling these materials
- **Product Design Considerations:** Provides participants an overview of design options that better enables plastics recycling

▶ Tiered Certificate Pathways

Now Available: Fundamentals of Mechanical Recycling of Plastics Awareness Level Certificate

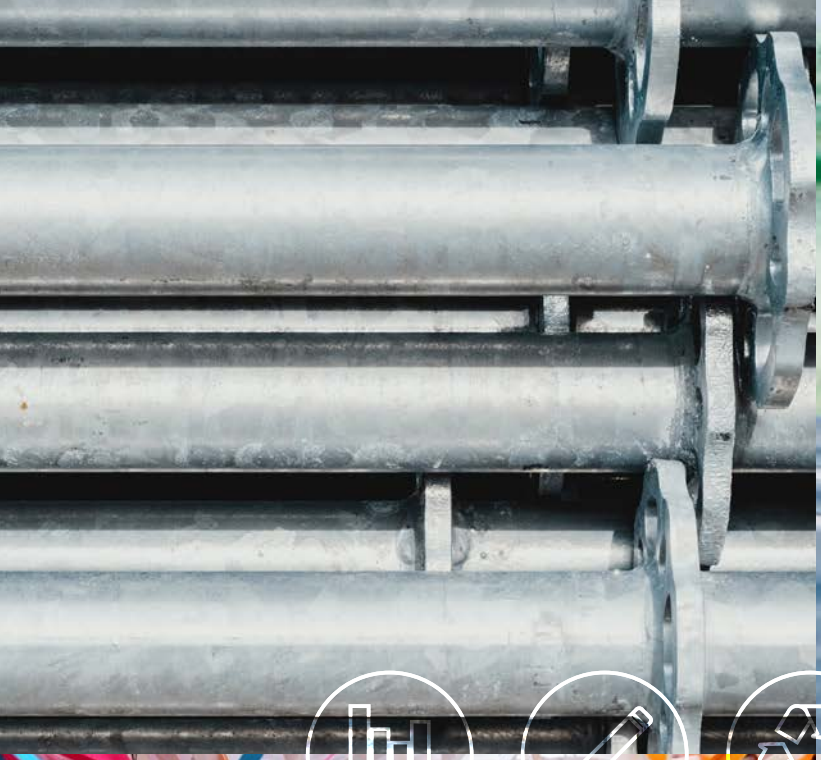
This four-part short course series provides an overview on the technology and best practices of mechanical recycling

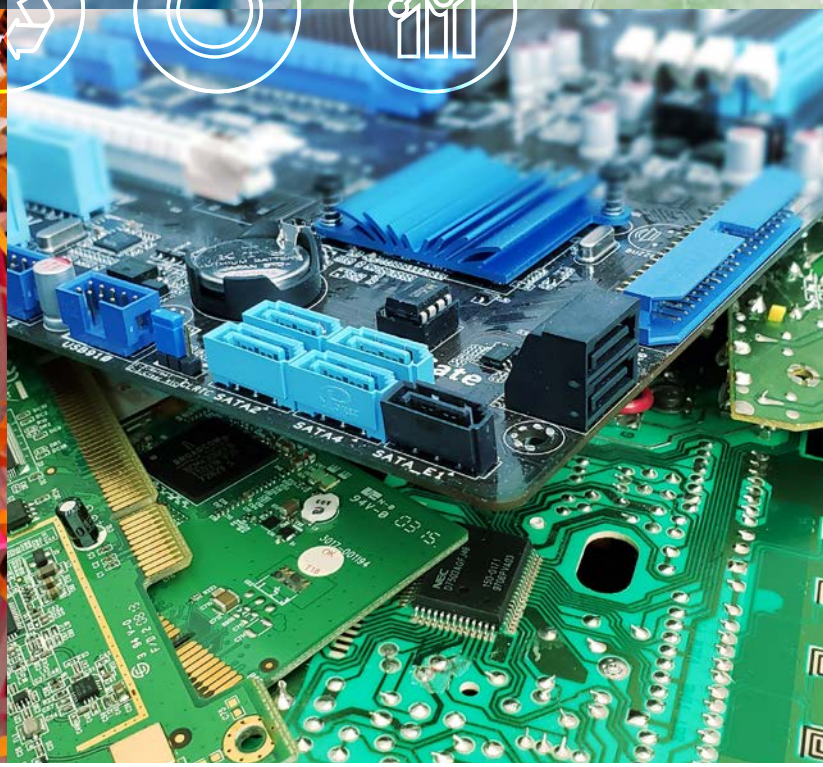
- Participants will also understand the role of mechanical recycling as it relates to the Circular Economy and areas of opportunity for technology advancements

Coming Soon: Emerging Trends in Plastics Recycling Awareness Level Certificate

This five-part series of short courses is intended to provide foundational training in plastics recycling, however, in the context of providing participants an overview of new methods that potentially could transform the industry

- This includes insights into the Circular Economy, chemical recycling, and product design considerations





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