Impact Report 2019

Advancing the Nation in Sustainable Manufacturing

Accelerating the Transition to a Circular Economy

- Recycling & Recovery
- Remanufacturing & End-of Life Reuse
- Manufacturing Materials Optimization
- Design for Recovery, Reuse, Remanufacturing & Recycling (Re-X)
- Systems Analysis & Integration

About the REMADE INSTITUTE

The Sustainable Manufacturing Innovation Alliance was selected by the U.S. Department of Energy to lead its new Reducing EMbodied-energy And Decreasing Emissions (REMADE) Institute. This national coalition of leading universities and companies is forging new clean energy initiatives deemed critical in keeping U.S. manufacturing competitive.

The mission of the REMADE Institute is to enable the early stage applied research and development of key industrial platform technologies that could dramatically reduce the embodied energy and carbon emissions associated with industrial-scale materials production and processing.

By focusing our efforts on addressing knowledge gaps that will eliminate and/or mitigate the technical and economic barriers that prevent greater material recycling, recovery, remanufacturing and reuse, the REMADE Institute seeks to motivate the subsequent industry investments required to transform innovative Institute technologies into scalable, cost-effective, state-of-the art domestic manufacturing capabilities that will drive U.S. manufacturing competitiveness well into the 21st century.

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REMADE Performance Goals

30%
reduction of primary feedstock consumption and increase secondary feedstock by 30%

20%
reduction in GHG associated with a 10x reduction in primary material feedstock

30%
reduction of energy demand for secondary feedstock processing by 30%

25%
improvements in embodied energy efficiency

CROSS INDUSTRY REUSE
enable cross-industry reuse of recycled feedstock

COST PARITY
achieve cost parity for secondary materials

A Message from the Chief Executive Officer

The REMADE Institute is in its second year of operation. We are leading the development of technology solutions that will foster a circular economy in the United States.

Our research portfolio continues to expand, and now includes thirty technology projects that will reduce the energy and environmental burden of domestic manufacturing while improving manufacturing cost-competitiveness through increased materials recycling and remanufacturing. Our current portfolio will conserve more than 300 PJ of embodied energy (the equivalent of 50 million barrels of oil each year) and reduce greenhouse gas emissions by more than 10 million metric tons per year (the equivalent of the annual emissions of about 5 million cars.) While those are of significant value to industry, the economy, and the environment, a major advantage of our work is to advance the knowledgeof the U.S. industry and increase its competitiveness and readiness for the challenges of the future. And this is only the beginning.

Our success is a direct result of the support and commitment of our partners. The Institute is comprised of more than eighty industry, academic, national lab, and trade association partners who are working together to solve the challenges across the product life cycle from design and materials optimization to remanufacturing and recycling that limit the efficiency and competitiveness of U.S. manufacturing. More than half of our industry members are small and medium sized businesses. Our larger members include organizations such as Nike, Caterpillar, Unilever, and Michelin. The manufacturing diversity of our industry partners and trade associations that represents an even broader sector of U.S. industry, coupled with the talent of our academic and national lab partners ensure the continued success of the Institute in solving the key challenges to domestic manufacturing sustainability and the achievement of a circular economy.

Another significant part of the Institute's mission is developing a 21st century workforce with REMADE relevant skills. The Institute completed a national labor market study documenting the occupations, skills, and competencies required to successfully deploy REMADE technologies. With input from industry, a three-tiered certificate strategy was developed and the first of many workshops was conducted. Content will continue to expand, and workforce development is included in the latest REMADE RFP.

As our industry faces its many challenges, REMADE will continue to lead and advance the transition to a circular economy. Through collaboration with industry leaders and academic innovators we will continue to succeed in the development of technology solutions for sustainable manufacturing in the United States.

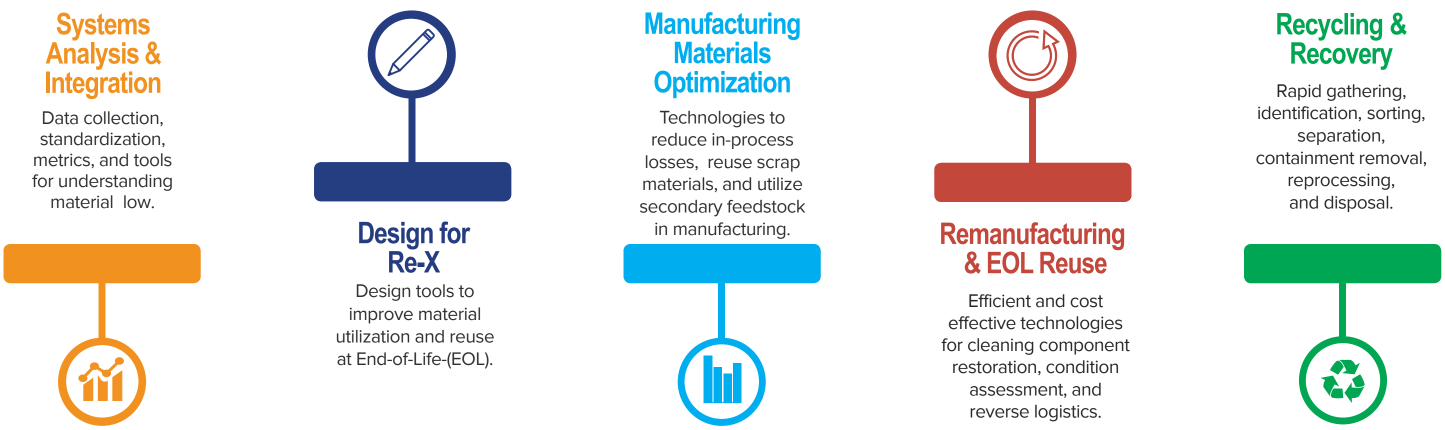
A special thanks to all our consortium partners, the U.S. Department of Energy, and New York Empire State Development.

Chief Executive Officer
REMADE Institute

Technology Focus Areas

To achieve its mission, the REMADE Institute is organized around five focus areas, or nodes.

Four nodes align to the material lifecycle stages: Design for Re-X, Manufacturing Materials Optimization, Remanufacturing & End-of-life Reuse, and Recycling & Recovery; the fifth node, Systems Analysis & Integration, addresses systems-level issues that are broader in scope than any one particular node and have the potential to impact all the nodes.



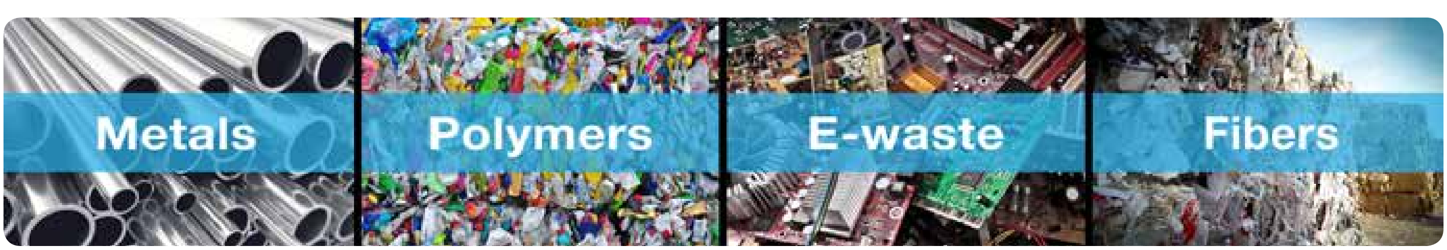
Materials and Energy Conservation, the Cornerstones of a Circular Economy are Critical Drivers

Today, manufacturing accounts for 25 percent of U.S. energy consumption. With improvements in materials production and processing, the United States could significantly increase manufacturing energy efficiency, which could also yield substantial economic savings. To help realize these opportunities, the REMADE Institute—a $140 million Manufacturing USA Institute co-funded by the U.S. Department of Energy—was established in May 2017.

The primary goal of REMADE is to develop technology solutions that will:

1. reduce energy emissions through a reduction in primary material consumption and an increase in secondary feedstock use in energy-intensive industries,
2. achieve feedstock “better than cost and energy parity” for key secondary materials, and
3. promote widespread application of new enabling technologies to be broadly deployed across multiple industries

The REMADE Institute is particularly focused on increasing the recovery, reuse, remanufacturing, and recycling (collectively referred to as Re-X) of metals, fibers, polymers, and electronic waste (e-waste).



Institute Highlights

TECHNOLOGY

$14M invested in technology projects (to date) and **plans to invest another $25M** this year

2 Request for Proposals (RFPs) released with 2 RFPs planned for the next 12 months.

Impact Analysis Calculator created to estimate the material efficiency and embodied energy benefits of Institute Projects

Industry-focused Technology Roadmap addresses the research priorities across the 5 nodes and 14 thrust areas.

EXPECTED IMPACT

Annual savings in embodied energy **equivalent to 50million* barrels of oil** each year.

10million* metric tons per year greenhouse gas emissions reduced – the equivalent annual emissions of 5 million cars.

The Institute expects to **exceed performance goals** within the first five years of the Institute.

*This is the anticipated impact of the 30 Institute projects selected to date, which being on page 5.

COLLABORATION

80 members and growing

Engaged in **over 30 national events** such as Circularity 19, National Academy of Sciences Roundtable, EPA America Recycles, Ellen MacArthur Foundation Acceleration Workshop, and the World Re-manufacturing Conference

Hosted 7 workshops at member sites Nike, John Deere, Michelin, University of Wisconsin Milwaukee, University of Miami, Virginia Tech, and Rochester Institute of Technology

WORKFORCE

3-Tiered Certificate strategy developed, and content delivery started.

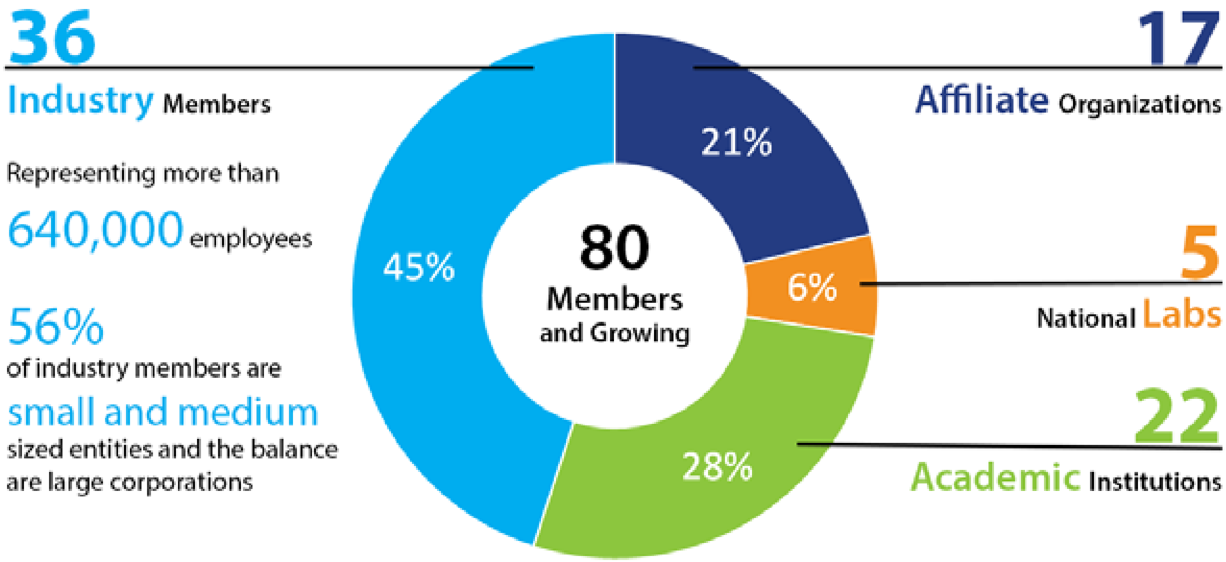
Over **1,200 relevant training opportunities** compiled and posted on the REMADE website.

10 webinars hosted with research innovators and industry leaders

National labor analysis completed, identifying REMADE relevant occupations, skills, and competencies required of the current workforce

Our Members

With 36 industry members representing 640,000 employees, 22 academic institutions, 17 trade/non-profit/affiliate organizations, and 5 national labs, the REMADE Institute is well positioned to develop and deliver innovative solutions that will transform the U.S. manufacturing ecosystem.



REMADE Institute Projects

The REMADE Institute currently has 30 public-private partnership projects that will develop technology solutions to cost-effectively increase the recovery, reuse, recycle and remanufacture of materials such as metals, fibers, polymers, and electronic waste.

Recycling & Recovery Projects

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

This project seeks to adapt relatively low-cost and low-energy leaching technologies to directly recover copper and precious metals from e-waste. This approach will enable the recovery of these metals from the mixed metals and plastics streams from e-waste and also enable recovery of the plastics. This technology could replace energy-intensive pyrometallurgical processes such as high-temperature smelting that might otherwise be used to recover metals, but due to the high-temperature the plastics are consumed.

Utilizing these less energy-intensive and lower-cost technologies will provide the economic incentive to dramatically increase e-waste recycling by as much as 20%. The potential energy and emissions reduction are estimated at 21PJ per year and 1.2 million MT of CO2eq per year.

New Approaches to Improve Deinking Flotation to Increase the Availability of High-Quality, Low-Cost Recycle Paper Fibers *- Virginia Tech and Thiele Kaolin*

This project addresses paper fiber recycling needs. The paper industry in the U.S. replaces more than half of its fiber needs with secondary resources recovered from post-consumer paper and paper products. This project will help 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.

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

This project seeks to improve the recycling efficiency of recovered rubber materials from used tires back into new tires, by increasing the addition of micronized rubber powder (MRP) from used tires in the production of composite polymer materials (CPM) which is used in the production of new tires. CPM is a blend of MRP and virgin rubber. Increasing the use of MRP for new tires significantly reduces greenhouse gas emissions versus other tire recycling processes such as tire burning in cement kilns, crumb or reclaimed rubber manufacturing. While MRP is an attractive cost-effective option for recycling of tires, its incorporation into new tire compounds is limited to ensure that those compounds have properties equivalent to virgin polymers.

This project will develop an understanding of the properties of MRP as a function of the MRP feedstock (used tires) and processing conditions for the production of MRP. This would enable the development of specifications for sorting of used tires and grinding of the tires MRP, together with the associated formulations and tire constructions that will allow higher incorporation of MRP back into new tires without degradation in tire performance, including reliability, durability and rolling resistance. The estimated energy savings for this project are 21PJ per year.

Reinforced Recycled Polymer Composites *- Oklahoma State University, Niagara Bottling LLC, and Shaw Industries*

This project seeks to increase recycling of bottles and carpeting materials by combining both materials into desirable composite materials (such as repairable plastic pallets and acoustic panels) of a combined value significantly greater than each separately. Increasing the value of the recycled materials will motivate collection, recovery, and recycle rates.

The project also provides the opportunity and motivation for the recyclers to introduce new technologies for recycling, including and especially that for the secondary material streams such as PET and carpet, making recycled plastic more economically attractive.

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

This project seeks to demonstrate the potential of solvent-based extraction process to recover plastics mixed metals and plastics electronic waste (e-waste) for cross-industry reuse. Following extraction of the plastics, the mixed-stream would be primarily metals. The plastics would be recovered from the process solvent using an anti-solvent. If successful, this project will significantly increase the recycling rates of e-waste and the recovery of plastics and metals from this source material. The potential energy savings and emission reduction from this project are estimated at 16PJ per year and 334,000 MT of CO2eq. per year.

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

Cost-effective technologies for the in-melt removal and/or neutralization of trace contaminants in metals is critical for secondary feedstocks to achieve cost parity with primary feedstocks. This exploratory project will experimentally evaluate the addition of “scoping” elements in molten aluminum to neutralize trace contaminants that would otherwise constrain the recycling of aluminum.

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

Increasing the utility of steel scrap through innovation in sorting and impurity removal will increase the use of secondary feedstock and achieve cost parity for secondary materials for steel products. This study will investigate: 1) physical methods such as optical sorting to upgrade scrap steel and 2) chemical or metallurgical treatment methods to remove or neutralize the effect of impurities in molten steel.

Determining Material, Environmental and Economic Efficiency of Sorting and Recycling Mixed Flexible Packaging and Plastic Wrap *- American Chemistry Council (ACC), Resource Recycling Systems (RRS), and Idaho National Laboratory (INL)*

This project will further develop technology to recover flexible plastic film from a material recovery facility (MRF). Market opportunities for the recovered film will be examined and the resulting economic and environmental impacts will be evaluated. The technology to be 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.

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

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

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

Alternative process technologies will be experimentally evaluated to upgrade carbon black recovered from end-of-life tires to meet carbon black market quality specifications. Approximately 3.87 Mt of waste tires accrue every year in the United States. If all these tires were processed to recover the carbon black, about 1.1 Mt of carbon black could be recovered to use as a secondary feedstock.

Scalable High Shear Catalyzed Depolymerization of Multilayer Plastic Packaging *- University of Massachusetts-Lowell, Michigan State, Unilever, American Chemistry Council (ACC), and National Renewable Energy Laboratory (NREL)*

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 will investigate catalytic depolymerization as a cost-effective approach to process these films into higher value products suitable for use in a variety of applications.

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

This project aims to evaluate the impact of single stream recycling (SSR) on paper contamination in recovery operations and explore emerging recovery processes for minimizing fiber contamination.

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

This project focuses on the improving the separation of non-ferrous scrap metals from other non-ferrous metals using electrodynamic sorting (EDX) at high throughput and with greater purity and yield.

Systems Analysis and Integration Projects

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

This project will model and test the U.S. fiber recycling industry – specifically for paper and paperboard – to improve its long-term profitability and increase its environmental benefits.

The project will provide a virtual testbed that will explore resilience to volatility in scrap quantities, quality, markets, and prices, and consider changes to current and future recycling capacities and technologies in order to increase domestic fiber recycling by 15% or more.

Identifying strategies to maximize benefit of fiber recovery through systems quantification *- Massachusetts Institute of Technology (MIT), The American Forest & Paper Association (AF&PA), WestRock, and Graphic Packaging*

This project will analyze the system-wide economic and environmental implications of changes in the recovery of fibers. The project will use 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.

A goal of this project is for REMADE members to more accurately determine the energy and emissions benefits associated with paper and paperboard recovery.

Systems Analysis for PET and Olefin Polymers in a Global Circular Economy *- Michigan Technological University, American Chemistry Council (ACC), and Idaho National Laboratory (INL)*

This exploratory project will develop a framework for systems analysis of PET and polyolefins in the context of a circular economy. These polymeric materials are currently recycled at low rates in the U.S., but are among the largest volumes of polymeric materials that are recyclable. The objective of this project is to develop a framework that will enable analyses of factors such as new recovery technologies that might enhance the recovery and recycle of polymers including polyolefins and PET.

Mapping the Material Base for REMADE *- Yale University, Unilever, International Zinc Association, and Massachusetts Institute of Technology (MIT)*

This project will develop a materials flow baseline for REMADE materials (metals, fibers, polymers, and e-waste) to support measurement of the impact of future technology improvements through REMADE projects. A harmonized and validated set of data for metals, fibers, polymers and e-waste will be developed within a consistent framework that allows comparisons of material efficiencies across REMADE materials at all life-cycle stages.

Design for Recovery, Reuse, Remanufacturing & Recycling (Re-X) Projects

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

This project will create 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.

The novelty of this tool lies in its ability to incorporate real-world load/component health data that has been acquired by condition monitoring systems in the field into early-stage design assessment using random variable models. This approach enables data-informed design for Re-X.

Design for Remanufacturing *- Rochester Institute of Technology (RIT), Caterpillar, Inc., and Remanufacturing Industries Council (RIC)*

This project is focused on working directly with remanufacturing industry leaders to create a set of pragmatic "design for remanufacturing" rules that would allow design engineers to integrate remanufacturing considerations in their component and part designs and pave the way for integration of these design rules across various engineering tools and CAD platforms currently in use to enable improvement in component and part manufacturability.

These design rules will be verified on existing parts and CAD file(s) provided by the industrial partner to identify potential changes to improve the part manufacturability. Integration of manufacturability into the design paradigm is expected to enable an increase in remanufacturing contributing to an annual energy saving of about 50 PJ and an annual emission reduction of 3.6 million MT of CO2-eq.

Development of an Industrially Relevant RE-SOLAR Design Framework *- University of Pittsburgh, University of California-Irvine, National Renewable Energy Laboratory (NREL), and First Solar*

Solar modules are creating a major surge in e-waste because inadequate attention is focused on designing for recycling or reuse. This project provides a design framework of high-efficiency modules that can be economically recycled, recovered, remanufactured, and/or reused.

Manufacturing Materials Optimization Projects

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

This project lays out an approach to develop a new process for recycling aerospace (AA7075) aluminum scrap into a high strength castable aluminum alloy. The project will focus on developing approaches to overcome the technical challenges (such as hot tearing and micro segregation) which limit industry's ability to process and use up to 35,000 metric tons of aluminum scrap. The expected energy benefits are estimated at 6.5 PJ per year with an emissions reduction of about 370,000 metric tons per year.

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

This project will examine ways to better utilize ground tire rubber from recycled tires and use the particles in asphalt pavement. Ground tire rubber is currently being used as an asphalt modifier, however because of the difference in density with asphalt it suffers from inadequate storage stability, rendering it an un-preferred material in asphalt paving.

Iowa State University has developed a technology that matches ground rubber tire density with asphalt (and enables the substitution of SBS elastomers that are otherwise used in asphalt) with simple compounding techniques, producing a asphalt product that meets storage stability specifications that would be more acceptable to the paving industry. The energy savings opportunity from this technology is estimated at 4.2 PJ per year.

Increasing Melt Efficiency and Secondary Alloy Usage in Aluminum Die Casting *- Ohio State University, Alcoa USA Corporation, and North American Die Casting Association (NADCA)*

The aluminum casting industry uses limited quantities of secondary alloys because of their poor quality (i.e. high concentrations of residual contaminants such as iron). In this project thermodynamic and kinetic models coupled with experimental validation and testing will be used to develop holistic contaminant control techniques including alloy, flux and refractory chemistries to increase melt efficiencies with higher levels of secondary materials use.

Remanufacturing & End-of Life Reuse Projects

High Speed Laser Cladding for Hard Surface Replacement *- Rochester Institute of Technology (RIT), Caterpillar, Inc., and Synergy Additive Manufacturing*

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 reduce the cost of applying the layers that will enable use of this technology in remanufacturing.

The new approach to cladding will result in increasing the reuse rate in engine remanufacturing from 70% to 95%, reducing annual embodied energy and emissions by 1.3 PJ and 44,000 metric tons, respectively.

In-situ Nondestructive Evaluation of In-flight Particle Dynamics and Intrinsic Properties for Thermal Spray Repairs *- Iowa State University (ISU) and John Deere*

The quality of coated surfaces from thermal spray repairs is determined by the particles impacting the surface. A better understanding of in-flight particle dynamics will enable improved success rates for repairs in the remanufacturing industry.

Remaining Life Determination *- Rochester Institute of Technology (RIT), University of Illinois at Urbana-Champaign, and Caterpillar, Inc.*

Non-destructive methods to measure accumulated mechanical damage (i.e., fatigue) prior to failure do not exist. Research will focus on methods to reliably detect features associated with early stage fatigue damage to predict the remaining useful life of the part.

Non-Destructive In-process Assessment of Thermal Spray Repairs *- Rochester Institute of Technology (RIT), University of Pittsburgh, ITAMCO, and Caterpillar, Inc.*

Thermal spray process inspection is currently lot-based which can result in the rejection of entire lots of parts due to process variation. This project will focus on development of non-destructive in-process evaluation of thermal spray to minimize reject rates of good parts.

Quantitative Non-Destructive Evaluation of Fatigue Damage Based on Multi-Sensor Fusion *- University of Illinois at Urbana-Champaign and Penn State University*

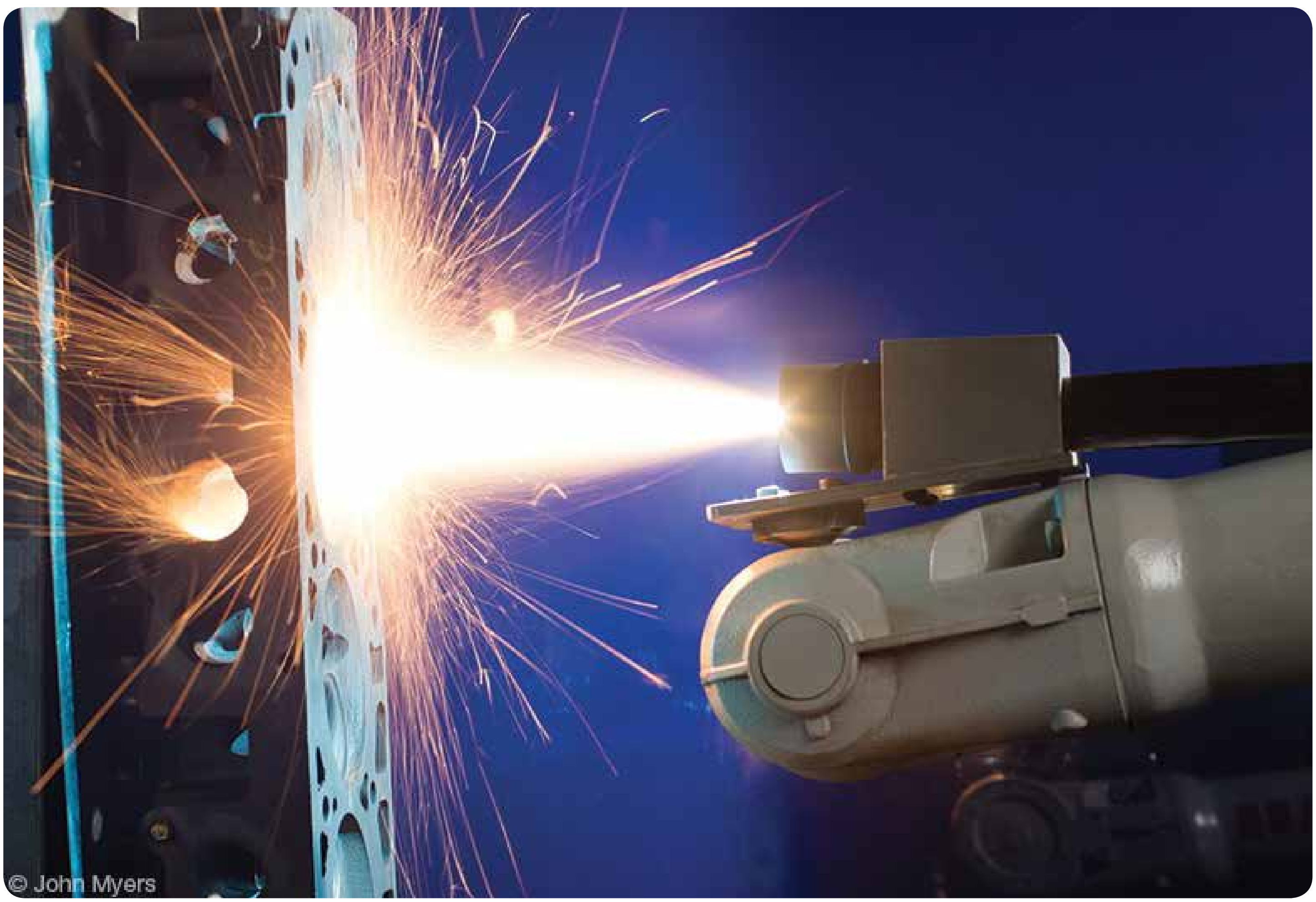
Current single-sensor non-destructive fatigue damage evaluation techniques have limited accuracy in predicting actual fatigue damage and the remaining useful life of a recovered part. The integration of multiple sensors which respond differently to fatigue damage has the potential of increasing the predictive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

Epoxy/Silicon Potting Material Removal for Greater Recovery of Circuit Boards *- Rochester Institute of Technology (RIT), Caterpillar, Inc., and CoreCentric Solutions*

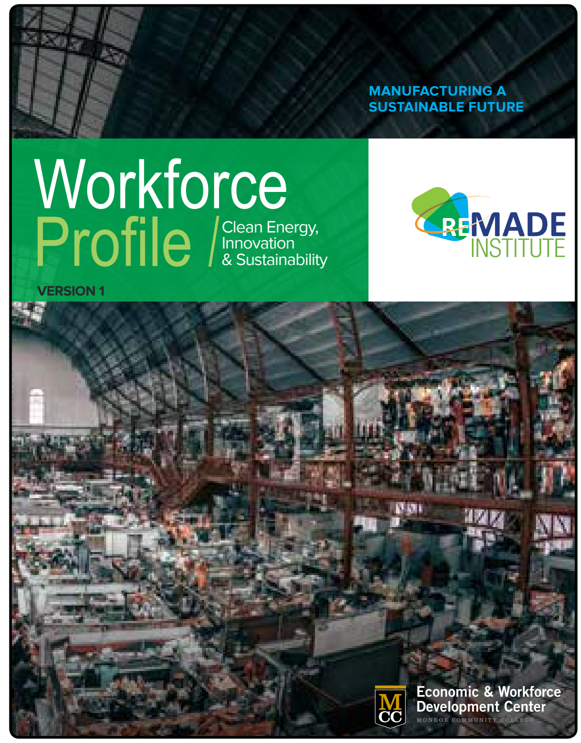
More cost-effective technologies are needed to remove coating or potting materials from circuit boards to enable repair and reuse. Two alternative technologies, laser ablation and micro-media blasting, will be tested and evaluated to quantify cost-effectiveness relative to industry specified cost targets.

Condition Assessment of Used Electronics - *Rochester Institute of Technology (RIT), Caterpillar, Inc., and CoreCentric Solutions*

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 will be examined to determine their feasibility for use in the remanufacturing industry.



Preparing the American Workforce



Workforce Profile

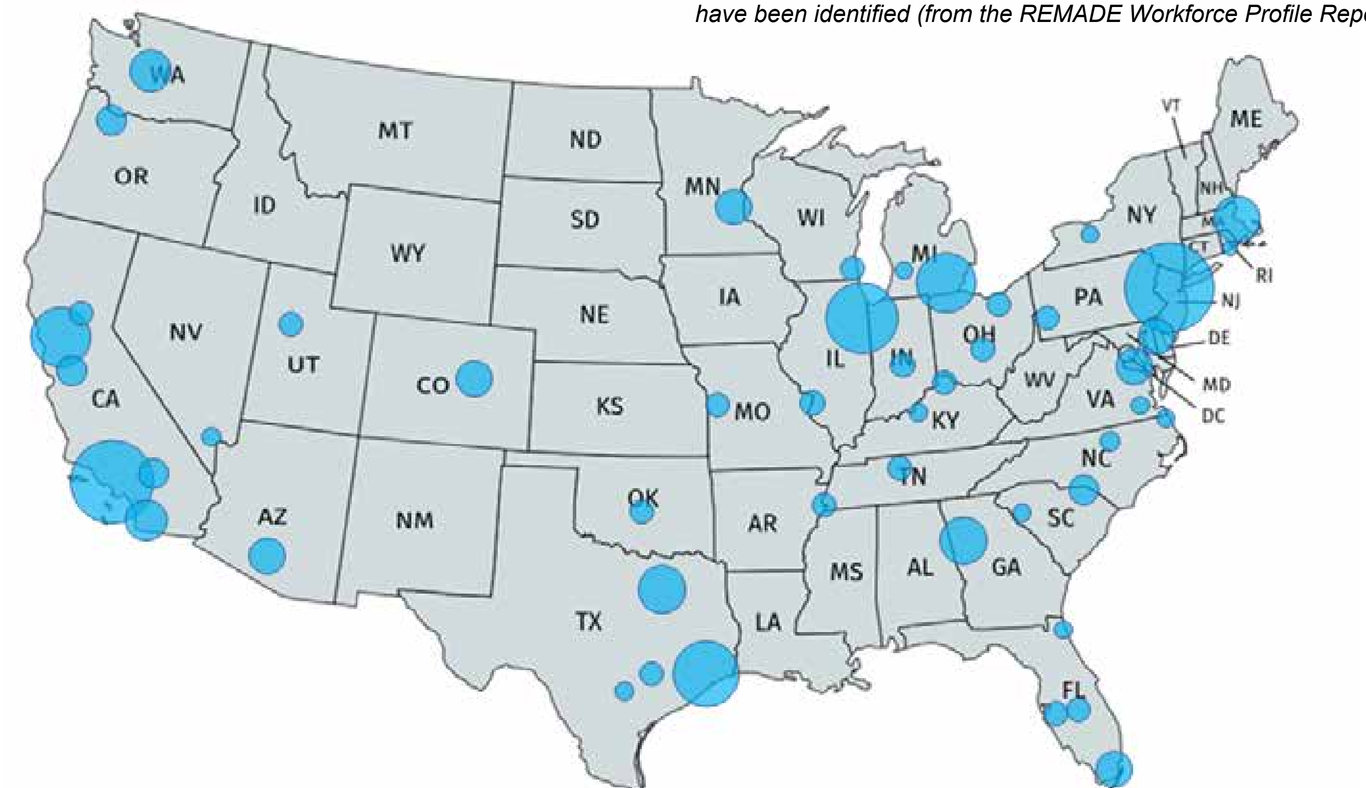
REMADE partnered with the Economic & Workforce Development Center at Monroe Community College in Rochester, NY to conduct a workforce profile study that organized and defined the REMADE-relevant workforce into two levels: engineers and technicians.

The goal of that study was to develop a foundation understanding of the REMADE-aligned workforce that could inform where training opportunitites for the incumbent workforce should focus. Among the key findings from that study, it was identified that employment opportunitites for engineers and scientists in REMADE-relevant industries largely favor specialized skill sets:

- For engineers, the ability to apply multiple technological platforms to improve product development and performance is essential.
- For technicians, skills related to repair, predictive/preventative maintenance, machinery, hand tools, and welding are required.

Additional details regarding the methodology that was used and the results of that were obtained can be found in the REMADE Workforce Profile located on the Institute's website.

Regions where concentrations of REMADE workforce have been identified (from the REMADE Workforce Profile Report)



Roadmap & Tiered Certificate

Tiered Certificate Pathway

Having identified engineers and technicians within the incumbent workforce as the intended audience, REMADE created a three-level tiered certificate pathway for organizing and delivering training products.

Through REMADE's training structure, industry will have access to a full suite of coursework stacked to enable the creation of a formal REMADE Certificate Program.

REMADE Educational Webinar Series

Over the last year REMADE delivered an extensive webinar series including areas of remanufacturing, recycling, and system analysis. Members can access all of the webinars on the REMADE website at www.remadeinstitute.org

Education and Workforce Development Roadmap

In the summer of 2019, REMADE released its first Education and Workforce Development Roadmap that highlights REMADE's multi-phased workforce development strategy, three-tiered structure for delivering training and future goals and vision.

The Institute created a standalone roadmap to highlight the centrality of EWD to REMADE's Mission.

Accelerating the Transition to a Circular Economy

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The REMADE Institute is a proud member of

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