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The REMADE Institute—a Manufacturing USA Institute co-funded by the U.S. Department of Energy (DOE)—was established to enable early-stage applied research and development of technologies to reduce embodied energy and carbon emissions associated with industrial-scale manufacturing. Recognizing that direct engagement with industry stakeholders is critical to setting the Institute’s technology priorities and to help define REMADE’s research priorities, the Institute partnered with Nexight Group, a technical and management consultancy specializing in technology roadmapping, to assist in building this roadmap.

The development of the 2018 REMADE Technology Roadmap was informed by a variety of stakeholder inputs from academia, industry, trade associations, and government through online surveys, and subject matter expert workshops.

To more effectively highlight how REMADE intends to develop the workforce needed to research, develop, and commercialize new REMADE technologies and solutions widely across U.S. industry, and to highlight the centrality of EWD to REMADE’s mission, the activities originally found in the 2018 roadmap have consolidated into this stand-alone workforce development roadmap that is divided into the following sections:

► Introduction

This section provides an overview of the REMADE Institute and its mission, goals, and performance metrics. It also introduces the nodes (focus areas) for the Institute. Finally, REMADE’s multi-phased workforce development strategy and the three-tiered structure for organizing and delivering training products are briefly introduced.

► REMADE Workforce Development Roadmap

This chapter describes the focus of the node’s work, the desired future state, the technical and economic challenges currently faced, and the knowledge gaps that must be addressed to overcome those challenges. The findings are based on input collected from the technology roadmapping workshop, the REMADE Workforce Profile, feedback collected through Industry Member interviews, and opportunities identified while preparing the REMADE curriculum catalog. Finally, the chapter closes with identification of a set of research activities and milestones for workforce development that are needed to achieve REMADE’s mission.
► REMADE Workforce Development Goals and Vision

Having presented the workforce development activities, the final section of the roadmap presents the broader REMADE Workforce Development Goals and Vision.

► Appendix

The appendix consists of a single section that summarizes the process used to conduct the Industry and Trade Association workforce development Interviews. It also summarizes some of the key findings from the interviews.
Introduction

Background and Mission

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 launched in January 2017.

In partnership with industry, academia, trade associations, and national laboratories, REMADE will enable early-stage applied research and development of technologies that could dramatically reduce the embodied energy and carbon emissions associated with industrial-scale materials production and processing. 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).

Technical Focus Areas

The current state of materials manufacturing technologies, tools, methods, and processes presents challenges to achieving the level of Re-X envisioned as the future state of the manufacturing industry. Current products are generally not designed with Re-X in mind, and manufacturing processes are not optimized for in-plant scrap reuse or the use of lower embodied-energy alternative feedstocks. At product end-of-life, there is a lack of reliable tools for assessing product condition and the potential for Re-X. Current methods for collecting, characterizing, sorting, separating, cleaning, and reprocessing materials can also make Re-X efforts too energy-intensive and cost-prohibitive.
To achieve its mission and overcome these challenges, the REMADE Institute has organized its activities around five 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.

The nodes will pursue research activities focused on overcoming challenges in the following areas:

- **Design for Re-X**: Design tools to improve material utilization and reuse at End-of-Life (EOL)
- **Manufacturing Materials Optimization**: Technology to reduce in-process losses, reuse scrap, and use secondary feedstock in manufacturing
- **Re制造 & EOL Reuse**: Efficient, cost-effective technology for cleaning, component restoration, condition assessment, and reverse logistics
- **Recycling and Recovery**: Rapid gathering, ID, sorting, separation, contaminant removal, reprocessing and disposal
- **Systems Analysis and Integration**: Data collection, standardization, metrics, and tools for understanding material flow

**What is Re-X?**

Re-X is shorthand for recovery, reuse, remanufacturing, and recycling.

However, while not specifically called out in the above definition, sub-processes such as disassembly, sorting, inspection, cleaning, and collection should also be considered when considering Re-X within the manufacturing industry.

To support the transition to a more circular economy through design, recycling, reuse, remanufacturing, and systems improvements, industry needs a workforce educated and trained in the technologies, processes, and analysis methods critical to design, decision making, and implementation. However, current education and training materials and programs are geared for traditional manufacturing considerations and don’t often provide for the needs and requirements of the circular economy.

**REMADE Workforce Profile Study**

Following the release of the 2018 roadmap, REMADE partnered with the Economic and Workforce Development Center at Monroe Community College in Rochester, New York 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, which was applied to each of the five REMADE focus areas (nodes), was to develop a foundational understanding of the REMADE-aligned workforce that could inform where training opportunities for the incumbent workforce should focus. Among the key findings from that study are the following:
• Employment opportunities for engineers and scientists in REMADE-relevant industries largely favor specialized skill sets:
  o For engineers, the ability to apply multiple technological platforms to improve product development and performance is essential.
  o For technicians, skills related to repair, predictive/preventive 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.

Multi-phased EWD Strategy

One recommendation from the REMADE Workforce Profile was for the Institute to use a combination of surveys and or focus groups to refine the specific skills and competencies that REMADE’s EWD efforts should target. In response, REMADE executed a multi-phased strategy to identify the EWD challenges industry currently faces and guide development of training products throughout 2019 and beyond. The key elements of that strategy are as follows:

► Industry Interviews

REMADE conducted in-depth interviews with 11 industry members and trade organizations to identify incumbent workforce development gaps and receive feedback on how REMADE can help industry address its training challenges.

► Curriculum Catalog

REMADE also catalogued existing workforce development programs being offered by REMADE-relevant trade organizations, certifying agencies, and university partners. This catalog provides a critical baseline that will enable REMADE to address workforce training gaps without duplicating existing offerings.

► Technology Development

The technology REMADE and its Members develop in the course of their research projects represents new knowledge that can be disseminated when projects have ended. As research teams develop new tools, they can train REMADE Members to leverage these new capabilities in their own operations.
Three-Tiered Training Structure

Having identified the engineers and technicians within the incumbent workforce as the intended audience and based on the industry workforce development gaps that were identified, the Institute created a three level Tiered Certificate Pathway for organizing and delivering training products. This Tiered Certificate Pathway, and the conceptual goal and modality through which training will be delivered is shown on the next page.

REMADE Tiered Certificate Pathway for Organizing and Delivering Training

**REMADE Professional Certificate**

- **Conceptual Goal:** A combination of Short Course Workshops (Modules) that are stacked and aligned to achieve a formal certificate from the REMADE Institute. A certificate level is intended to indicate an assessed level of mastery of topics. Catalog of workshop offerings will be developed over time through in-house expertise, project calls, and RFP’s.

- **Modality:** Face to face and online formats.

**Short Course Workshops (Module) Level**

- **Conceptual Goal:** Teaches more in-depth understanding of single or multiple concepts, technologies and practices designed for the incumbent workforce. Average Length: standalone short courses running in length of 3-4 hours to multiple days.

- **Modality:** Face to face and online formats.

**Overview and Awareness Level**

- **Conceptual Goal:** Brief in its depth with a focus on providing basic awareness and overview of a given best practice, technology or sharing industry updates. Average Length: 1 hour.

- **Modality:** Offered in a variety of formats including live streamed webinar, recorded video presentation, face to face presentation at conferences.
Workforce Development
The **Workforce Development** portion of this Roadmap identifies activities that will develop the workforce needed to support design for Re-X, recycling, and remanufacturing. Activities include prioritizing topics and target audiences (including production line technicians and scientific and engineering staff) for training content, understanding preferred formats and durations for training content, and developing education and training materials needed to teach key skills. The activities focus on propagating these education and training materials into industry and academia to produce the workforce and the industrial cultures that will sustain and expand Re-X. Importantly, REMADE’s approach focuses on **filling gaps in existing training** through the creation and piloting of training content rather than repeating available training. Further, REMADE will prioritize **reaching the incumbent workforce** in the near term while educational content for the future workforce is being developed for longer-term impact.

**Development of the REMADE Curriculum Catalog**

To help identify gaps that require REMADE workforce development activities, REMADE built a catalog of existing workforce training offerings relevant to Re-X, documenting 1,244 relevant training opportunities offered by 29 trade organizations. This catalog is available on REMADE’s website and will inform specific content development priorities.

**Desired Future State of Industry**

To build the current and future workforce needed for Re-X, REMADE must work with its partners in industry and academia to achieve the following future state characteristics:

- An established system for the education of new workers and retraining of existing manufacturing workers for the needs of the circular economy, delivered through hands-on, in-person classroom, and online through courses, course modules, job training aids, and other training mechanisms used by industry.

- Developed curricula for education and training for Re-X which is customizable and has been implemented in relevant manufacturing companies and promoted to academic institutions (including community colleges, technical schools, and institutions offering undergraduate and graduate degrees).

- Re-X concepts and needs have been incorporated into continuing education benefits including professional development qualifications.

- Industry has developed and maintains an understanding for Re-X skills, technologies, and cutting-edge developments to keep the workforce up to date.

- The concepts of Re-X have been promoted across industry and are integrated into sustainability, risk management, and business investment decision making.

- Industry, trade organizations, academia, and consumers are aware of the importance and implications of Re-X and these stakeholder groups cooperate to support Re-X’s development and implementation.
Technical and Economic Challenges and Associated Knowledge Gaps

To realize the desired future state of Re-X Workforce Development, the manufacturing industry must work to overcome the following challenges and address the associated knowledge gaps, which are listed below each challenge.

1. **The current systems and resources for transitioning existing workers from current manufacturing jobs into Re-X jobs is insufficient**
   - Processes and systems to pass knowledge and skills from current workforce to those transitioning into the Re-X workforce are underdeveloped
   - Employers cannot easily assess workers’ knowledge and skills pertaining to Re-X due to lack of established certification programs that verify skills
   - Today’s manufacturing workforce is aging, providing growing urgency to this need

2. **Re-X concepts and base knowledge/skills are not well integrated into education and training programs**
   - Education in base manufacturing skills is diminishing, creating a gap for manufacturing training across all levels of education, including trade schools, community colleges, and universities

3. **Educational and training content specific to Re-X concepts is only sparsely available today**
   - It is difficult for industry to keep up to date on emerging Re-X technologies, opportunities, and trends; workforce development content specific to Re-X that can be customized for insertion to company training programs does not yet exist

4. **Limited understanding of Re-X business practices and potential value discourages industry from adopting the structural changes needed to fully incorporate circular economy approaches**
   - Information and case studies about Re-X business practices, including a definition of sustainability and assessments of integrated supply chains, is not widely available
   - Holistic product design cannot easily account for upstream and downstream factors along integrated supply chains due to this lack of information
   - Cost-benefit analyses and design tradeoff analyses that account for end-of-life management and other circularity factors are limited by this lack of information, hindering consideration of Re-X into risk management decision-making

5. **Communication between Re-X stakeholders and the rest of the manufacturing industry is limited**
   - The emerging workforce is unaware of the opportunities and career possibilities in Re-X, leading to limited talent entering the industry
   - Because the Re-X industry is broad and fragmented, it is difficult for those working in it to connect, leverage knowledge, and build individual and collective skills
• Links between researchers developing new Re-X relevant technologies and manufacturers who might benefit from those technologies to realize operational improvements are ad hoc or lacking today; as a result, industry misses opportunities and researchers risk pursuing research that is not addressing industry-relevant challenges

Workforce Development Research Priorities

Addressing these challenges will require coordinated efforts to develop, deliver, and distribute education and workforce development offerings. The following table outlines key Workforce Development research activities for REMADE to pursue over the next 10 years, focusing initially on the first five. This table also outlines how each of the activities fits in REMADE’s Tiered Certificate Pathway. Because REMADE is an industry-member driven Institute, many of the near-term activities are appropriately focused on improving knowledge and skills among the incumbent workforce. Educational efforts designed to train the future workforce are also important in the near term but are unlikely to have significant impact across the industry as REMADE translates project results into training modules that can be disseminated more broadly.

Legend

OVER & AWARE – Overview and Awareness training
SHORT COURSE – Short Course Workshop Modules
PROF CERTS – Tiered Certificate Pathway

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>OVER &amp; AWARE</th>
<th>SHORT COURSE</th>
<th>PROF CERTS</th>
<th>TIMELINE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conduct a U.S. labor market analysis to identify the occupations and competencies for engineers and technicians that are relevant to REMADE</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>2023</td>
</tr>
<tr>
<td>Conduct a stakeholder analysis with REMADE Members, trade associations, to identify gaps in EWD curriculum/content related to REMADE technologies where REMADE should focus its EWD efforts</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>2019</td>
</tr>
<tr>
<td>Develop a curriculum catalog that describes existing training offered by trade organizations certifying agencies, and universities to</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>2018</td>
</tr>
<tr>
<td>Develop a deliver one-hour webinars that introduce REMADE-relevant topics such as plastic, metal, and paper recycling and Design for Re-X</td>
<td>+</td>
<td>+</td>
<td>2019 - 2022</td>
<td></td>
</tr>
<tr>
<td>Deliver one-hour overview and awareness webinars that introduce REMADE projects and the results being obtained to a broader audience.</td>
<td>+</td>
<td>2020 - 2022</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Develop short-course modules related to recycling as part of Tiered Certificate Pathway</td>
<td>+</td>
<td>+</td>
<td>2020 - 2022</td>
<td></td>
</tr>
</tbody>
</table>
and deliver them online, at conferences, and/or trade shows

| Develop short course modules focused on basic remanufacturing processes (e.g., cleaning, repair, condition assessment) to support workforce development outreach | + | + |  |
| Develop short course modules focused on preparing the future workforce to utilize design for Re-X approaches based on feedback collected from industry at a Design for Re-X workshop | + | + |  |
| Develop short course modules focused on utilizing secondary feedstocks in manufacturing and deliver them online, at conferences and/or trade shows | + | + |  |
| Develop and deliver webinars that train REMADE members how to use new tools that are developed as part of REMADE projects. | + | + |  |
| Incorporate project results in incumbent worker training content and in undergraduate- and graduate-level courses (e.g., modules on reducing embodied energy during materials manufacturing and materials selection) | + | + |  |
| Develop an online repository that houses REMADE training content | + | + |  |
| Compile existing data on cleaning processes to develop training materials and disseminate best practices to industry | + | + |  |
| Gather existing data on repair processes, develop training materials, and disseminate best practices | + | + |  |
REMADE Workforce Development Goals and Vision
Consistent with the workforce development activities presented in the previous section, the REMADE Workforce Development Goals and Vision provides the overarching strategy that will guide REMADE’s EWD efforts over the next several years.

IDENTIFY EXISTING GAPS AND OPPORTUNITIES (2018-2019)
► Complete Workforce Profile Report
► Conduct industry interviews to identify training gaps within incumbent workforce.
► Survey and catalog current training offerings at REMADE-relevant trade organizations, certifying organizations, and academic member institutions.

CREATE AND PILOT CONTENT (2019-2020)
► Develop and expand training content consistent with the Tiered Certificate Pathway hierarchy.
► Launch Professional Certificate Programs for incumbent workforce that indicates mastery of topics within Institute technology focus areas.
► Offer single topic Short Course workshops designed for the incumbent workforce.
► Present Overview and Awareness training that aligns to the Short Course and Professional Certificate Programs.
► Identify strategic partnerships to maximize distribution of REMADE workforce development content. Opportunities include, but are not limited to, the following:
  • Short course workshops at conferences and/or individual companies
  • Conference panels and speaking engagements
  • Promotion of REMADE workforce content on partner social media platforms

BROADEN AND AMPLIFY DEVELOPED CONTENT (2020-2021)
► Increase number of REMADE Overview and Awareness and Short Course training offerings.
► Increase number of training offerings available through the REMADE Professional Certificate Program.
► Integrate workforce development offerings in conjunction with the deployment of REMADE-relevant technology.
► Create a virtual repository of REMADE workforce development products.
► Strengthen strategic partnerships that can increase access to REMADE training opportunities.

SUPPORTING ACTIVITIES
► Strengthen workforce development through REMADE project participation.
► Leverage the Manufacturing Extension Partnership to increase awareness of and access to REMADE training opportunities, especially among small-to-medium sized enterprises.
► Participate in National Manufacturing Day to inform and encourage students to pursue careers in sustainable manufacturing.
► Launch a REMADE internship program in partnership with Industry Members.
Appendix A

Industry and Trade Association EWD Interviews

To determine whether the workforce development activities presented in the 2018 Roadmap represented the needs of its members and to gain a better understanding of training gaps, REMADE held a series of interviews with its industrial and trade association members during fall 2018 and winter 2019. The interviews not only informed the Roadmap update, they also helped REMADE refine the Tiered Certificate Pathway structure REMADE will use to organize and deliver training products.

To initiate the process, all REMADE industry and trade association members were invited to participate in the interviews. In collaboration with the Nexight Group, REMADE developed a series of questions that were provided to all interviewees in advance of the meeting. These questions were as follows:

1) What are the main categories of workers in your organization?

2) What skills and experience do you look for in your hires? How do these skills and experience vary by worker category?
   i) Do you consider past training and/or certifications during the hiring process?

3) How are new hires trained for their job function?

4) What kind of professional development or ongoing training do you offer employees?

5) What skills gaps do you have today in your workforce (segment them by worker level)? As you think about new areas, recycling for example, remanufacturing, as you think about these three areas and maybe also design for future work.
   i) When considering recycling technologies, does your workforce require additional training resources in
      (1) Collection technologies
      (2) Separation technologies
      (3) Conversion technologies
      (4) Other?

   ii) When considering manufacturing material consumption, does your workforce require additional training resources addressing:
      (1) In-process material waste technologies
      (2) Process and production yield improvement approaches
      (3) Technologies for managing trace contaminants
      (4) Other?
When considering remanufacturing technologies, does your workforce require additional training resources addressing:

(1) Condition assessment
(2) Design for remanufacturing
(3) Cleaning technologies
(4) Core visibility/availability
(5) Component restoration technologies
(6) Other?

6) What is your preferred delivery method and for workforce training? Does this vary by skillset or worker category?

7) REMADE is interested in developing workforce training resources that fill gaps and align with REMADE’s technology focus. How can REMADE workforce development help you?

Eleven organizations participated in the interviews. Collectively, they provided feedback on a diverse set of EWD needs for the following REMADE-relevant industries: plastic and e-waste recycling, security-driven electronics and lifecycle management, agriculture, construction, and industrial heavy equipment producers and remanufacturers, automobile parts manufacturers and remanufacturers, power distribution equipment and services, consumer packaging goods, research and education organizations focused on waste management. Specific topics grouped into themes, that were identified and subsequently incorporated into the Workforce Development Roadmap are listed below. The numbers associated with each topic indicate the number of industry Members who identified a topic as important.

**Technology**
- New technologies that can increase recycling and conversion of materials at end-of-life (3)
- Proper methods of disassembly for remanufacturers – how to avoid damage during disassembly.
- Collection technologies (2), separation technologies, and monitoring/routing technologies
- Cleaning technologies for remanufacturers
- Challenges associated with utilizing secondary feedstocks and best practices for overcoming them (2)
- Economics/value proposition for recycling (2)
- Use of virtual reality for recyclers
- Engineering-level course for remanufacturing
- Plastic recycling modules that can be provided to universities to increase student awareness of recycling technologies (2)

**Design for Re-X**
- Design guidelines to help designers understand how to increase circularity - including packaging design, design for recycling (4)
- Design for remanufacturing awareness and tools (2)

**Delivery**
- Centralized platform where recyclers can build peer networks and influence others to recycle.
• Methods to transfer knowledge from skilled workers about to retire to younger employees.
• On-site/In-person training, including hands-on training - preferred by more experienced production employees (6)
• Consultant-led training
• Online training – preferred by new entrants into the workforce (6)
• Awareness training to expose employees to basic content before offering detailed training.