TECHNOLOGY INNOVATION FOR THE CIRCULAR ECONOMY

Recycling, Remanufacturing, Design, Systems Analysis and Logistics

Edited By

Nabil Nasr

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Preface

The consensus that we need a circular economy is gaining speed. Decision-makers in government and industry increasingly see the immediate value that circularity can bring to the manufacturing sector, while addressing some of today's greatest global challenges. At the same time, academic research continues to investigate the tough technological and logistical questions that need to be answered for a circular economy to become reality.

At the REMADE Institute, my colleagues and I wanted to capture this gathering energy by bringing together the best research and innovation looking to solve circular economy implementations challenges. The result was the first-ever REMADE Circular Economy Tech Summit and Conference, which took place in March 2023 at the National Academy of Sciences building in Washington, D.C.

Attracting over 300 attendees, the scientific research, business models and logistics conference featured nearly 60 presentations of original research, as well as keynotes and plenaries from visionary thought leaders. The conference was held in partnership with the Ellen MacArthur Foundation, one of the most influential advocates for a circular economy at work today, and supported by the U.S. Department of Energy (DOE).

The following book compiles the peer-reviewed papers that were presented over the course of the conference. These materials cover in-depth areas of circular economy design, planning, business models, and enabling technologies.

The REMADE Institute is a public-private partnership, national institute, that focuses on the acceleration of circular economy implementations in the United States. REMADE is one of six U.S. manufacturing institutes that operate under the DOE's Advanced Materials and Manufacturing Technologies Office (*AMMTO*). REMADE is a consortium of 170 members (90 industry, 42 universities, 32 trade associations, and six national labs). It addresses knowledge gaps that, once overcome, can lead to faster adoption of circular economy practices. The 2023 conference included REMADE members, as well as non-members, and included international researchers from many countries including Japan, Germany, France, UK, and Ireland.

First, it is important to understand why circular economy has gained so much attention over the last decade and what role it can play in reducing the environmental footprint of industrial development. The future should be circular, and in the manufacturing economy this means that economic growth will come to depend more on extracting value from existing materials than securing new virgin material supplies. Remanufacturing, refurbishment, reuse, and recycling are processes that need more advancement and expansion to achieve this goal. In addition, our design methods have to evolve to ensure that these processes are effective and economical through design. In many industries, future survival will require transformative redevelopment of business structures to create more inherently regenerative models — an idea that forward-thinking groups like the Ellen MacArthur Foundation are adamantly promoting.

Some of the greatest opportunities for innovation in the circular economy are in remanufacturing, refurbishment, reuse, and recycling. Critical to its growth, however, are developments in product design approaches and the manufacturing business model that are often met with challenges in the current, largely linear economies of today's global manufacturing chains. Beyond the technical and logistical, these processes also meet with both market and policy barriers that stifle its growth across the industrial economy. To combat these challenges, significant investments in technology research, both public and private, highlight the importance of and opportunities for innovation in pursuit of a more resilient, circular economy.

This book consists of 56 chapters in 10 parts covering broad areas of research and applications in the circular economy area. The first four parts explore the system level work related to circular economy approaches, models and advancements including the use of artificial intelligence (AI) and machine learning to guide implementation, as well as design for circularity approaches. Mechanical and chemical recycling technologies follow, highlighting some of the most advanced research in those areas. Next, Innovation in remanufacturing are addressed with descriptions of some of the most advanced work in this field. This is followed by tire remanufacturing and recycling, highlighting innovative technologies in addressing the volume of end-of-use tires. Pathways to net-zero emissions in manufacturing of materials concludes the book, with a focus on industrial decarbonization.

I would like to acknowledge the contribution of the conference Organizing Committee, as well as the Program Committee and its members who reviewed the papers. This book would not have been possible without their contributions. I also would like to acknowledge the following members of the REMADE Institute team (Magdi Azer, Michelle Schlafer, Ed Daniels, Megan Connor Murphy, Steve Remmler, Carrie Degláns, John Kreckel, Jared Ratzel, Michele Gibson, Bonnie Schiffmaker, Sarah Beisheim, Mike Haselkorn) for their support in every aspect of the planning and execution of the conference. Special thanks go to the REMADE Institute CTO, Magdi Azer, who was instrumental in leading and orchestrating the papers' peer reviews and finalization. Additions thanks go to Carrie Degláns from REMADE who assisted in the tracking and organization of submitted papers.

We also highly appreciate the dedicated support and valuable assistance rendered by Martin Scrivener and the Scrivener Publishing team during the publication of this book.