

The global transition from a linear economy to a circular one in plastics packaging is a quest with so many challenges and unexpected journeys, that even Bilbo Baggins would need to muster extra resolve for the mission ahead. Just as JRR Tolkien's chief protagonist in the *Lord of the Rings* trilogy required not just personal bravery, but also the help of a community, to successfully complete his journey, the same is true of the plastics industry, as it endeavours to close the loop on a 'make, use, recycle' strategy that eliminates the need for disposal.

In March, the REMADE (Reducing Embodied-energy And Decreasing Emissions) Institute, based near Rochester in upstate New York, USA, announced \$43 million in technology research aimed at accelerating the country's journey to a circular economy. A public-private partnership established by the US Department of Energy (DoE), and consisting of 117 members from industry, academia, various national laboratories, and trade associations, REMADE selected 24 new projects that it believed would help move the country closer to its energy-conservation and emissions-reduction targets.

It followed that request for proposal (RFP) process with a fifth rollout, valued at around \$50m, that was due to reach full proposal stage by the end of last month.

"To date, we've funded \$65m of research projects, prior to the latest RFP," says senior project manager Ed Daniels. "The funding opportunity is matched by project participants for a 1:1 cost share. Our work focuses on developing new technologies needed to reuse, recycle and remanufacture materials such as metals, fibres, polymers and electronic waste."

Established in 2017, and becoming one of approximately 16 US manufacturing institutes, REMADE developed a technology roadmap with its members that focused on what Daniels calls "five nodes": design for 'Re-X' (remanufacturing, recycling, and/or re-use); manufacturing materials optimisation; remanufacturing and end-of-life re-use; recycling and recovery; and systems analysis and integration.

The fifth element here, systems analysis, involves understanding the flow of materials and evaluating the impact of various pieces of research on energy savings and greenhouse gas emissions reduction. Material trading is, of course, international and so understanding those global flows is pivotal.

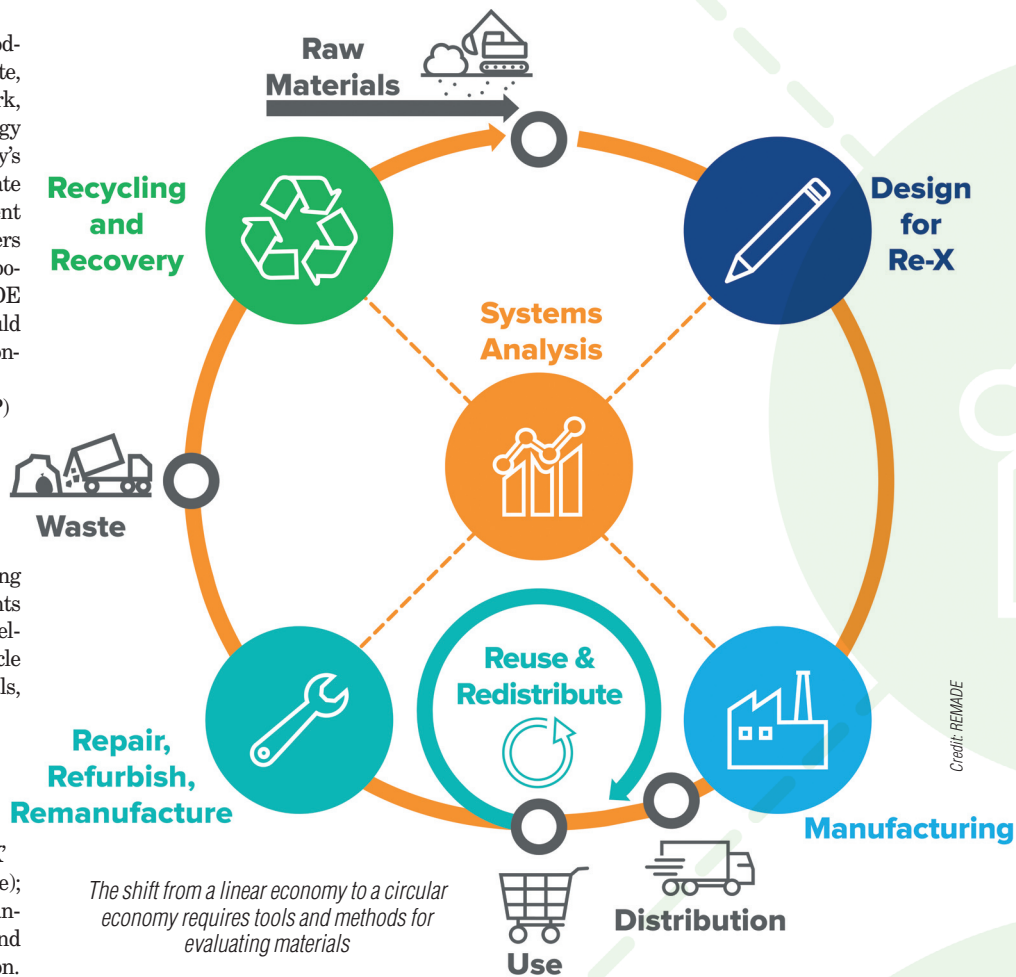
"We update our technology roadmap annually," says Daniels, "as we identify, with member company input, what we'd like to achieve in the future relative to funding. Key R&D areas are identified in each node and then based on the roadmap we release RFPs."

These research projects are open to non-member companies, although they are expected

How it's remade

A public-private partnership is seeking investment-worthy recycling ideas that will help accelerate the USA's journey to a circular economy.

Steven Pacitti speaks to the company about its mission



to become a member if they are chosen for project negotiation. "There is a comprehensive evaluation process, and as we are a private/public partnership, the negotiations can be challenging," he explains. "The performance metrics we establish are very specific. We should be funding projects that collectively could reduce energy use by as much as 1,000 petajoules (PJ) per year, and reduce secondary materials by 40 million tonnes and greenhouse gas emissions by 50m/t. All of these projects are for a duration of two years or less."

The 24 projects unveiled in March are expected to increase the recycling of materials

by as much as 20m/t per year (a nearly 15 per cent increase in all recycled materials in the US) and to save up to 640 PJ of embodied-energy per year, which is the equivalent of conserving 100 million barrels of oil.

According to the US DoE, manufacturing accounts for 25 per cent of US energy consumption at a cost of approximately \$150 billion. REMADE is keen to put a cap on those figures and push them downwards.

"Out of 1,000 PJ, I think polymer recycling has a potential mid-term impact of around 200-300 PJ, and metals maybe 175-200 PJ," he estimates.

Issues being addressed in the current round of projects include plastics recycling in food packaging, which is one of the most pressing sustainability issues in the US. One project is looking at how to capture flexible substrates from materials recovery facilities and recycle them, with a focus on bales of flexibles with less than 10 per cent paper contamination. Another project is seeking to recover polyolefins from multilayer packaging.

The former project is hoping to identify four end-market opportunities for what the partners call an rFlex bale, including roofing panels and extrusion/pelletising applications. There will also be a feasibility study into reintroducing material back into film applications.

"I think it's good to have these goals to go from an application back into the same application, but it's sometimes a big challenge," he adds.

In the US, PET accounts for the highest proportion of recycled packaging materials, while resin codes 3-7 – including PVC, LDPE, PP, PS and others – are catered for by current recycling described as "slim to nothing", so REMADE is actively seeking opportunities across those resins.

"There is a lot of work being done in olefins recycling, and development work for compatibilisers, reactive extrusion of polyolefins, and so on," explains Daniels. "We have nothing going on in PVC right now, but we will entertain proposals in any area of polymer recycling, be it urethanes, nylons or ethylene-vinyl-acetate."

Daniels laughs when I discuss the impressive recycling rates for metal packaging, an industry he knows well from his formative days at Argonne. There, he worked in metals recycling, before using his process and chemical engineering background to develop into polymer recycling and beyond.

"We've been recycling metals for upwards of a century, but if we look back, aluminium recycling had its fits and starts too at the beginning. There was a lot of technology that had to be developed to get to where we are today," he points out. "We are still in the formative stages for polymers, and they're much more complex than metals. The post-consumer stage for plastics is at an early stage."

Although he admits that the inexpensive nature of virgin materials represents a real challenge, Daniels is an optimist and expects these challenges to be resolved. This is not least because so many brands, and subsequently converters, are making firm commitments to reduce their carbon footprint and use more recycled content in their packaging.

But it doesn't end there, and chemical recycling could play a pivotal role, he says. "There is a lot of room for improvement in mechanical recycling, but when you reach the



Ed Daniels says that the post-consumer stage for plastics is at an early stage

limit on that quality, you need to then consider chemical recycling. But even with chemical recycling, you must have good mechanical recycling in front of it, as you can't throw everything into a reactor.

"We do have a couple of projects ongoing that are looking at catalysts and pyrolysis into chemical intermediates."

REMADE is also involved in a project using Trexel's microcellular foaming MuCell technology, which is researching the feasibility of using recycled rPET film-stock (between 4 and 300mm thickness) in three applications: a replacement for milk cartons (laminated multi-material); aseptic bricks; and as a material for continuous thermoforming for food containers.

"We are also investigating other multilayer technologies and how you take them apart and recycle them," adds Daniels. "We have another team looking at some delamination technology. To delaminate and then fractionate is a challenge."

All of REMADE's projects must be documented and made available to its members, while the final report is posted on the Office of Scientific and Technical Information website. Daniels' primary role is to oversee a portfolio of projects.

"In terms of future projects, it's always difficult to predict what people will react to our RFPs with, but there is a lot of space for additional research in polymer recycling," he says. "It is research, so there is no guaranteed success. It's like an investment strategy and so a diversified portfolio is a key focus."

Another key aspect to the research work is education, and REMADE provides training to support the emergence of circular economy technologies.

"Our workforce development programme is an essential part of what we're doing," he

explains. "The labour force needs new skills to work with state-of-the-art recycling technologies."

There is clearly a lot of work to be done. The US landfilled around 27m/t of plastics in 2018, recycling just 3m/t. Although that ratio is slowly improving, there is a long way to go. Nonetheless, Daniels is confident that REMADE's research will move things forward.

"The work we're doing will save energy and reduce carbon emissions, which puts our institute's performance metrics in good alignment with the current Biden administration," he suggests. "Firstly, recycling is the right thing to do, and it encourages the efficient use of materials. But there are also significant business opportunities in that space."

"A lot of work is being done in the US in the area of bio-based materials. At REMADE, we need to try and anticipate what the material challenges of the future will be. To date, we're relatively agnostic about materials, as the market will determine which ones get used. But companies are taking these issues into consideration much more at the design stage now."

"A couple of US states have Extended Producer Responsibility legislation on the books, while a number of organisations have reached agreements to discuss how it should be implemented."

Whatever changes are to come in the packaging materials industry, they will take time to work their way into the system. This should happen in tandem, Daniels argues. "When you focus on developing new technology, you need to be aware of potential future changes in feedstock."

Material-agnostic it might be, but REMADE has not had to make hard decisions when it comes to the projects it commissions, claims Daniels.

"The proposals we have received are aligned with the opportunities we have identified for each materials class," he says. "At the end of the day, I'm a firm believer that most materials are selected for a good reason."

Improving those materials' circular economy credentials can only help in wider efforts to cut emissions and reduce the impact of packaging on the environment. Bilbo Baggins once asked if adventures ever have an end. He supposed not, because someone else always has to carry on the story. Indeed, polymer research will continue for as long as there are polymers, and however they are manufactured. They are indeed 'precious', and their value does not stop once the consumer has made use of the product inside.

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