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# Reversing Production

*Researchers develop system to recover and reuse electronic wastes.*

**An estimated 12 million tons of electronic waste may soon be jamming American landfills. Rising concern has prompted a Georgia Tech study to create a "reverse production" system that designs infrastructure to recover and reuse every material contained within e-wastes. Professors Jane Ammons and Matthew Realff, center, are conducting the study in cooperation with Chuck Boelkins of the Georgia Department of Natural Resources.**

by RENEE TWOMBLY

Some historians have theorized that the demise of the Roman Empire could be partly attributed to the gradual poisoning of its citizens. They believe lead leached from so many sources — from tableware to water pipes — that Romans eventually succumbed to chronic heavy metal toxicity.

Now, many governments around the world are worried that their citizens might become modern-day Romans because of the heaps of trashed electronics clogging landfills.

Such "e-waste" — discarded computers, televisions, cell phones,

audio equipment and batteries — leach lead and other substances that eventually can seep into groundwater supplies. Just one color computer monitor or television can contain up to eight pounds of lead. An estimated 12 million tons of e-waste may soon be jamming American landfills, according to the U.S. Environmental Protection Agency.

Concern has reached such a level that some European countries are forcing manufacturers to take back discarded electronics, and in the United States, California and Massachusetts have banned their disposal in municipal solid waste landfills. But what then?

A study under way at the Georgia Institute of Technology — in cooperation with the Pollution Prevention Assistance Division of the Georgia Department of Natural Resources (DNR) and the National Science Foundation — may offer a model for other states and nations.

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It is a "reverse production" system that designs infrastructure to recover and reuse every material contained within e-wastes — metals such as lead, copper, aluminum and gold, and various plastics, glass and wire. Such "closed loop" manufacturing and recovery offers a win-win situation for everyone — less of the Earth will be mined for raw materials, and groundwater will be protected, researchers explain.

But this simple concept requires a lot of brand new thinking, says Jane Ammons, a professor in the School of Industrial and Systems Engineering and a governor-appointed member of the Georgia Computer Equipment Disposal and Recycling Council. She and colleague Matthew Realff, an associate professor in the School of Chemical Engineering, are devising methods to plan reverse production systems that will collect e-trash, tear apart devices ("de-manufacture it") and use the components and materials again — all while making the process economically viable.

Though this system is being designed for Georgia, its application elsewhere has sparked interest nationally and internationally, the researchers say. Officials in Taiwan and Belgium have consulted with the researchers, as have several multi-national electronics and logistics firms. Also, the researchers' work on carpet recycling was used in testimony to Congress and helped in developing an industry coalition that has the goal of diverting 25 percent of carpet from landfills by 2012.

The project is building on other research that Ammons and Realff are conducting. Their fundamental work in reverse production systems has been repeatedly funded by the National Science Foundation. Ammons' related research is funded by the National Science Foundation (NSF) as one of four ADVANCE chaired professors at Georgia Tech. ADVANCE is a program to improve the career success of women faculty in science and engineering, and the chaired professors are serving as mentors for younger women faculty in their schools. Also, Ammons and Realff are applying their findings from other studies to the e-waste project. For example, they have modeled the regional and national infrastructure necessary for cost-effective and environmentally beneficial collection and recycling of carpet to extract nylon fiber, caprolactam monomer and other products.

"It's a matter of seeing a waste as a resource," Ammons says.

Key to their approach is the ongoing development of a mathematical model to predict the economic success of recovery efforts. Modeling is necessary given the uncertainty inherent in a host of variables — quantities, locations, types and conditions of old parts, and numerous aspects of transportation (distance, costs of fuel, labor, insurance, etc.). Ammons and Realff have involved experts, many of them from Georgia recycling and salvaging businesses, to probe the complicated interplay between manufacturing, de-manufacturing and logistics.

"Strong leverage comes from our new mathematical models," Ammons says. "They allow us to ask really good questions while designing the infrastructure for these systems."

Realff's expertise is the design and operation of processes that recover the maximum amount possible of useable product from e-waste. He has devised ways to separate metals, as well as different qualities of plastic from crushed, ground-up components. Realff and his students measure density and surface properties in novel ways. For example, they measure how far pieces fly off a conveyer belt and how well air bubbles stick to them. This information enables more accurate representations of recycling tasks to be incorporated into the strategic models and the synthesis of lower-cost alternatives, Realff explains.

"For chemical engineers, this is a challenging problem that has not been widely studied," he says. "It's exciting. We are creating a new architecture for separation systems." From this work, new industries and an infrastructure can be created to recover value not only from e-waste, but also from automobiles and other durable goods, Realff adds.

The reverse production systems research project has also delivered a wonderful learning opportunity for Ammons' and Realff's students, who come from many countries to study at Georgia Tech. Many of these students are planning to take the methodology back home to help plan recycling and recovery systems in their countries.

Now into the second and final year of the Georgia project, Ammons, Realff and their students are tweaking and testing their mathematical model (which for some problems has required computers to determine more than 300,000 variables) by testing hundreds of "what-if" scenarios. The researchers are continuing their collaboration under a new grant from the National Science Foundation; it will help broaden their model to other reverse production system problems.

Meanwhile, the DNR is eagerly awaiting the final results of the study.

"This work is tremendously important. E-waste poses potential serious environmental problems if it continues to go into landfills," says Chuck Boelkins, a DNR resource recovery specialist. The Georgia recovery system "may become a national model. It could be key to the future of responsible environmental management."

■ For more information, contact Jane Ammons, School of Industrial and Systems Engineering, Georgia Tech, Atlanta, GA 30332-0205. (Telephone: 404-894-2364) (E-mail: jane.ammons@isye.gatech.edu); or Matthew Realff, School of Chemical Engineering, Georgia Tech, Atlanta, GA 30332-0100. (Telephone: 404-894-1834) (E-mail: matthew.realff@che.gatech.edu)

*Renee Twombly is an Alabama-based freelance writer.*

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