GARBOLOGY 101: GETTING A GRIP ON WASTE

Most people choose to ignore it, but managing waste is a pressing and contentious issue

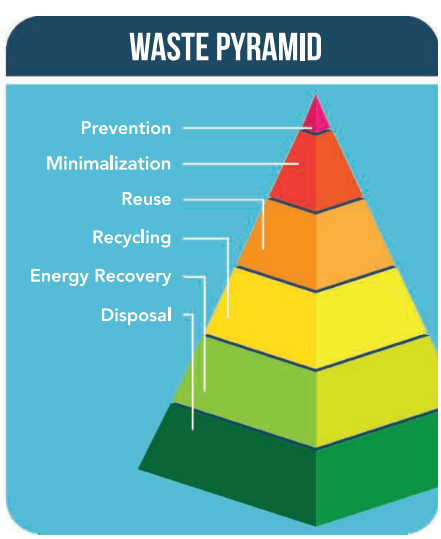
PEOPLE WHO WORK WITH WASTE FOR A living seem to have a special passion for their subject. And they aren't fazed by its complexity. Those traits help explain why Bill Davidson found himself tapping away at his home computer one Sunday morning more than a decade ago.

A consultant "got lost" trying to write a report on waste management in Montgomery County, Maryland, recalls Davidson, now section chief for strategic planning in the county's Division of Solid Waste Services. So the mechanical engineer, who once crunched numbers for the congressional Office of Technology Assessment, decided to try his hand at depicting what happens to all the waste generated each year by those who live, work, and play in these affluent suburbs of nearly 1 million people outside Washington, D.C.

His solution was an elegant flow chart that tracks 15 streams of the county's detritus, which last year totaled 1.34 million tons (see diagram, p. 669). It depicts the ultimate fate of every chicken bone, diaper, cereal box, beer can, plastic bag and bottle, broken toy, mattress, and grass clipping discarded by this racially mixed, highly educated, and relatively environmentally aware suburban community.

Davidson and his colleagues were able to devise such a flow chart because their employer takes waste management seriously. Recycling is mandatory in Montgomery County, for example, and haulers are required to submit reports on what they pick up and where they take it. "We were swimming in data," he says. That's a relative rarity in the world of waste, where reliable statistics are often unavailable.

It may look convoluted, but Davidson's flow chart barely scratches the surface of the complexity, choices, and challenges that modern society faces in managing its waste. For example, it deals with only a slice of the pie known as municipal solid waste (MSW). That's the highly visible trash generated by residents, schools, and businesses and picked up at the curbside or in parking lots. But MSW makes up only a tiny fraction—3% to 5% by weight is a good estimate—of the total waste that humanity generates.



Shaping behavior. Waste professionals hope that humanity will eventually invert this pyramid and make waste reduction—creating little or none—the most popular option.

The United States, for example, produces roughly 12 billion tons of waste each year, of which only 350 million tons are classified as MSW. The rest, sometimes called invisible waste, comes from mining, farming, road building and other construction, and industrial activities. There's also the human waste flushed down toilets and the pollutants dumped into waterways or spewed into the air (see infographics spread, p. 664).

In addition, the diagram only hints at the myriad contentious issues surrounding how waste is collected, processed, and ultimately disposed of in developed nations. Experts have varying views, for instance, on the best way to economically sift recyclables out of the MSW stream, the pros and cons of burning trash to produce electricity, and how to account for the hidden costs to a society of managing waste. Meanwhile, the once-radical idea of generating zero waste has shifted from the streets to the corporate boardrooms, sparking further debate over the extent to which such approaches will actually reduce global demand for important raw materials such as aluminum. The good news: Such discussions are prompting a closer look at what we throw away—and where it ends up.

Bury, burn, and abandon

Trash wasn't always so complicated. "When I give talks on garbage, I start by saying our forefathers created waste with stone chips," says Wilson Hughes, former co-director of the Garbage Project at the University of Arizona in Tucson, which from 1973 to 2001 pioneered the science of garbology under the direction of urban archaeologist William Rathje. "But it didn't become a problem until they settled down and began living in one place. That's when societies had to start thinking about what to do with it."

Sitting around their fires at the end of the day, our ancestors had three choices for handling their waste, Hughes notes: "Bury it, burn it, or leave it on the floor." Fast-forward a dozen millennia, and those three options still exist. The only new wrinkle is recycling. (Of course, the idea of throwing out something that still possessed value might

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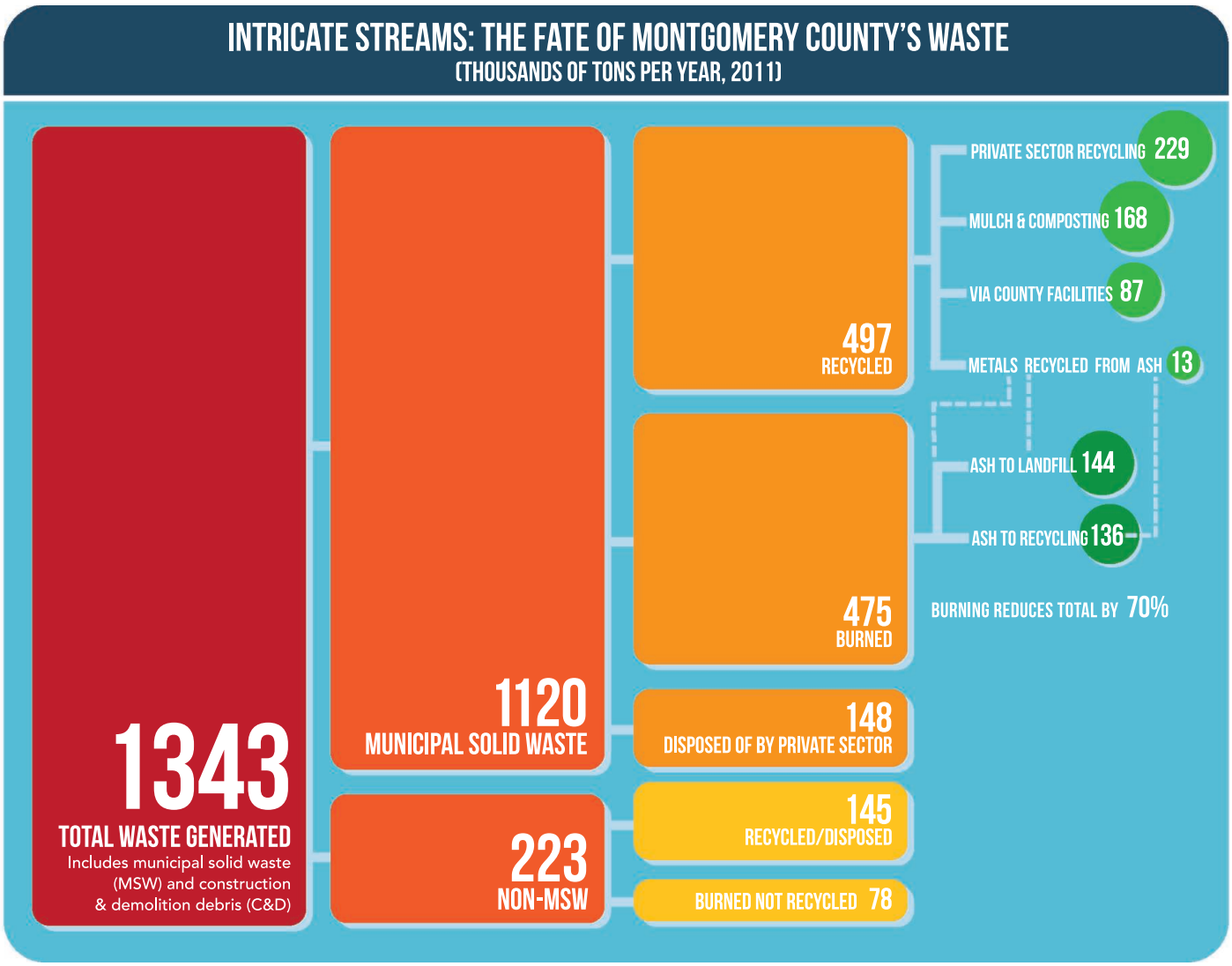

CREDITS: MODIFIED FROM MONTGOMERY COUNTY MATERIAL FLOW DIAGRAM

have seemed bizarre to our resource-starved ancestors, who reused bones, hides, and tools until they wore out.)

The choices a jurisdiction makes about how it handles its waste can have a big impact on its bottom line. "When Montgomery County needs to float a general obligation bond for a new school or road," Davidson says, "it goes to New York to get its bonds rated. And the first question the bond companies ask is, 'Have you got your solid waste act together?' "

Getting that act together can take time, however. Montgomery County, for example, got into the trash business by happenstance in the early 1940s. "Before then, your garbage was picked up by a guy with a truck" who probably took it to a local landfill, Davidson says. "And then World War II happened, the guy got drafted, and a [public] scream went up."

Since then, local officials have developed what is now a comprehensive, integrated system. To start, the county requires residents and businesses to separate their waste into four streams—paper; plastics, metals, and glass; yard waste; and garbage. Private haulers working under county contracts then bring everything to a centrally located, county-owned transfer station and recycling center that also composts the yard waste. The recyclable material is sorted and stored on site, sometimes for months, until an appropriate buyer is found. The garbage is shipped a short distance by rail to an incinerator in Dickerson, Maryland, where it is burned; metals are then removed from the ash and recycled, and the remaining residue winds up in a landfill in central Virginia. The county currently operates no landfills, although it has a permit for a site near the Dickerson plant.

Burning debate

Although waste experts applaud Montgomery County's overall approach, its reliance on incineration is more controversial. Landfills are the most common means of disposal for most of the United States outside the northeastern corridor and are especially popular in regions where land is relatively cheap and available.

Montgomery County's incinerator was built and is operated by Covanta Energy, a New Jersey–based company with dozens of waste-to-energy plants across the United States. It's called a resource-recovery facility because, unlike incinerators of the past, it operates with extensive pollution controls and separates and recycles metals after combustion. The 1800 tons of waste burned each day in its three boilers also generate 52 megawatts of electricity, which is sold to help offset operating costs.

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One of the big advantages of the Dickerson incinerator, Covanta officials say, is that it reduces the amount of waste Montgomery County must send to a landfill. Burning reduces the volume by 90%, they note. The sale of the power also helps offset the costs of the operation.

Environmental groups, however, have long opposed waste-to-energy plants, arguing that they have a negative net impact on the environment. A recent study by the Environmental Integrity Project, a Washington, D.C., nonprofit organization, for example, concluded that the Dickerson incinerator produces more pollution per unit of power than Maryland's four largest coal-fired power plants. The study looked at emissions of carbon dioxide, nitrogen and sulfur oxides, mercury, and lead.

Covanta says its plants shouldn't be compared to coal-fired power stations because producing electricity is not their primary purpose. "Waste-to-energy plants are designed for sustainable waste management, and generating electricity is an added benefit," says James Regan, a corporate communications officer. A more complete life-cycle analysis, he says, would show that waste-to-energy plants actually reduce overall greenhouse gas emissions. They do that by diverting waste from landfills, which generate methane, and by reducing the amount of fossil fuels that must be burned in other plants to generate the same amount of electricity.

Maryland legislators apparently agree. Last year, they put waste-to-energy plants in the same category as wind, water, and solar energy when providing special tax breaks for companies to develop renewable fuels. Most environmentalists oppose that classification, which more than a dozen states have adopted. But it's not just a semantic distinction. Such tax breaks can play a big role in determining whether it's cheaper for a local government to build a waste-to-energy plant or use a landfill.

A beer budget

The economics of waste handling also lie at the heart of another issue that is important to trash professionals: the scale, design, and business model used by recycling operations. Although almost anything can be recycled, experts note, market conditions often determine what is worth recycling.

Montgomery County, for instance, has opted to use public funds to support a midsize recycling system that accepts waste only from its own jurisdiction. It also asks its residents and businesses to help sort recyclables into multiple "streams," promoting the concept heavily to encourage compliance. A primary goal is to hold down the costs to taxpayers without skimping on quality. Or, as Davidson describes his employer's philosophy: "We try to provide champagne service on a beer budget."

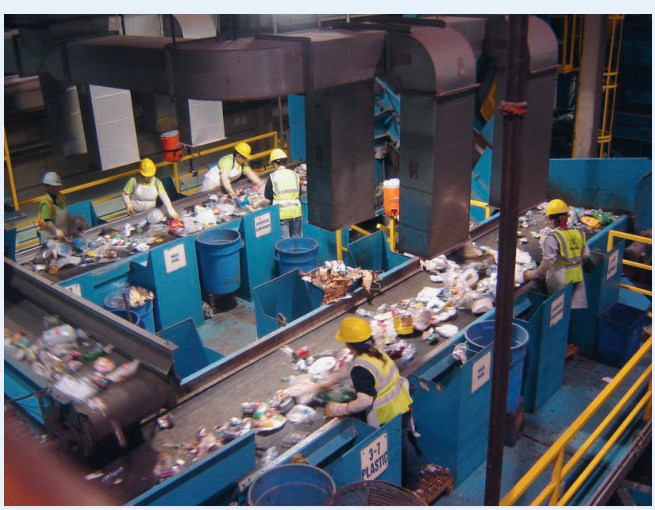
County officials pride themselves on the quality of their separation process, saying that

MODERN-DAY WASTE PICKERS

With 12 tons of trash whizzing past her every hour, Norma Garcia has only a few seconds to spot the diaphanous plastic bags that can foul the machinery at the Montgomery County, Maryland, recycling center where she works as a lead sorter.

But the trim mother of two is good at her job. Within seconds she's plucked another bag from the stream of detritus on the conveyor belt and deftly tossed it into a trash can in the noisy, malodorous—but orderly—three-story concrete building where she's worked for 8 years. Garcia is a traffic cop for waste, directing the recyclable paper, plastic, metal, and glass to its proper destination while barring entry to the plastic bags, medical needles, batteries, pesticides, diapers, and everything else that can't be recycled—and shouldn't be there in the first place.

People have been sifting through trash for as long as society has been producing waste. But compared with those who toil in the steaming, vermin-infested mounds of garbage on the outskirts of Rio de Janeiro or Manila, Garcia and her crew work in relative comfort. They are provided with safety equipment, get regular breaks, earn well above minimum wage, and—although contract workers rather than regular county employees—receive the same health insurance. In fact, the regular hours and indoor venue make working the line a plum assignment and translate into very low employee turnover rates.



Go with the flow. Line sorters at the recycling center.

CREDIT: CARLA BROWN

Still, working with waste brings with it some unavoidable risks. On Garcia's conveyor line, the work screeches to a halt "anytime we see something toxic," she explains through a translator. "We push the button to turn off the line, and people have to leave until they make sure the fumes are gone." The stench is the worst part of the job, she says. "The spoiled milk in a carton … sometimes it's so bad it can make you sick."

Overall, the $2.6 million recycling processing system features some 30 segments of conveyor belt, up to 2 meters wide and totaling nearly 800 meters in length. The belts connect dozens of pieces of special-purpose equipment, from a shaker table that removes broken glass to an eddy current that separates aluminum cans in a process that calls to mind spawning salmon leaping upstream. The 27 sorters are stationed along its entire length, serving as a nearly invisible but essential human element in the process.

A good sorter, Garcia says, must have not only a strong back but also the ability to adapt to the rhythms of the machinery. The workers are constantly in motion—eyes looking far back up the line to spot out-of-place items while their fingers rake the trash that speeds past them. It's not uncommon for workers to lean in the direction of the line even after the machine has been shut down, their bodies and minds propelled by its insistent motion.

Garcia says her job has taught her the importance of separating household garbage from recyclable materials at the curbside, so that the trucks arriving at the facility's tipping floor contain only what the county is able to recycle. But that lesson is lost on her nonsorter friends. "They don't care," she admits. "They say that it's all trash." **–J.D.M.**

a purer product can command a higher resale price. Toward that end, workers on the high-speed conveyor lines at the county's recycing center separate and bale more than a dozen different types of metals and plastics (glass is sorted into four categories but not baled), and the material may be kept for months until the county can find a buyer willing to pay a reasonable price. Montgomery County recycles 44% of its MSW, well above the national average of 24% but short of the county's own target, which it is in the process of raising from 50% to 70%. And what can't be sold must be disposed of.

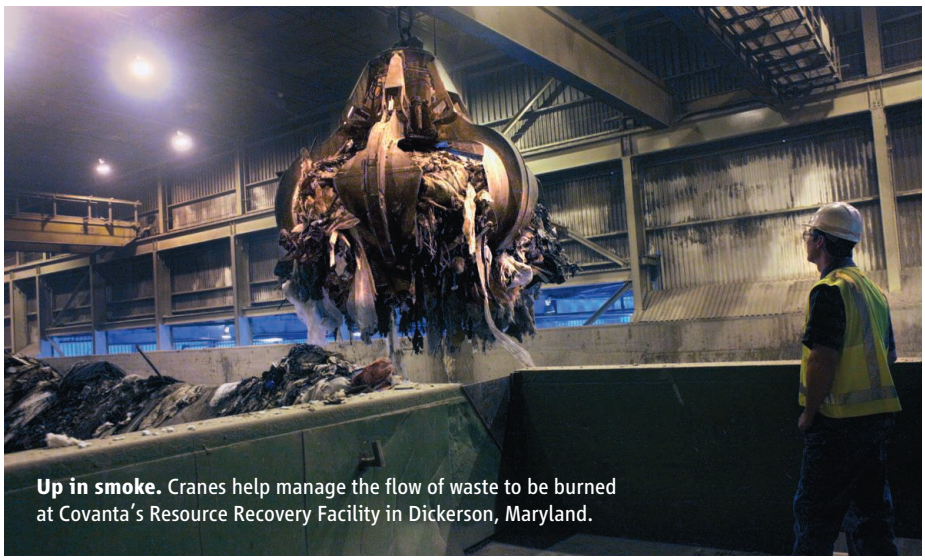
Not far away, however, the behemoth of the trash industry, Waste Management Inc., operates a different model: It pays communities millions of dollars to bring their waste to its regional materials-recovery facility, and it doesn't demand that users sort their recyclables. For the company, economies of scale are the key to profitability.

During the week, a 24-hour stream of trucks arrives at the company's Kit Kat plant, which sits just off a major highway not far from the Baltimore/Washington International Airport. The trucks are delivering unsorted recyclable waste from customers throughout the mid-Atlantic region, including communities that, unlike Montgomery County, lack their own waste-handling facilities.

Kit Kat, which opened in 2007, can sort and process 75 tons of recyclable material an hour. (By comparison, Montgomery County's recycling facility handles 12 tons an hour and operates many fewer hours a week.) In 2010, Kit Kat processed 230,000 tons, 70% of it paper and cardboard.

Waste Management's business model depends on getting the best price possible for those bales of materials from buyers as close as Baltimore or as far away as Beijing. And unlike at a landfill or most transfer stations where the hauler pays a tipping fee to dump its load, Waste Management pays for what comes across its scales. "We do a sort test for each community," explains Jim Marcinko, head of the company's recycling operations for the Delmarva (Delaware, Maryland, and Virginia) area. "We'll analyze a whole day's worth of material. Then we'll deduct our processing fees and send them a big check." For Howard County, where Kit Kat is located, that check totaled $3 million last year.

Waste Management's high-volume approach also gives the company a good reason to invest in potentially game-changing—and lucrative—new technologies. Currently, for example, most waste-to-energy facilities burn plastic to produce steam, which can be used to turn turbines to generate electricity. But that electricity has to compete in the market against relatively cheap sources of power such as coal and natural gas. In contrast, converting the plastic to higher-value transportation fuel could be a bigger moneymaker—if researchers can figure out a practical way to do it. That's why Waste Management is exploring the feasibility of using a high-tech version of pyrolysis, in which waste is heated to 2000°C in the absence of oxygen, to transform plastic into a substance that can be used as liquid transportation fuel.



Up in smoke. Cranes help manage the flow of waste to be burned at Covanta's Resource Recovery Facility in Dickerson, Maryland.

CREDIT: JUANA ARIAS FOR *THE WASHINGTON POST*/GETTY IMAGES

Getting to zero waste

As Montgomery County and other municipalities grapple with the materials that end up in their recycling centers and transfer stations, some waste professionals would like researchers and companies to spend more time thinking about the front end of the waste stream, in other words, reducing how much trash we generate in the first place. That's the concept represented in a widely used "waste hierarchy," issued by the European Union in 2008, which depicts five options for dealing with trash (see graphic, p. 668). In descending order of preference, they are reduce, reuse, recycle, recover, and dispose.

Many in the "zero-waste" movement, in fact, see waste as the product of poor planning. "Waste is just a design flaw," asserts Montgomery County's Davidson. "If materials are created in such a way that they can't be recycled, then they need to be redesigned. And that's what we need to work on."

Garbologist Hughes, who spent a decade managing waste-reduction efforts for the city of Tucson after leaving the university, says the real payoff from the zero-waste movement will be when companies begin "manufacturing things that can be taken apart and recycled. Stuff that has to be dumped won't be made any more."

General Motors (GM), the mammoth global carmaker, is one of many Fortune 500 companies that have embraced the concept of zero waste. In 2008, GM announced a goal of achieving "zero waste to landfill" at half of its 145 plants, a phrase that includes sending some of the company's waste to incinerators but that doesn't count the burial of ash residue. Two years later, it also promised to reduce the total waste generated at its facilities by 10% over the next decade. But what exactly do those targets mean for an automaker?

John Bradburn, an environmental engineer who has spent his entire 34-year career with GM and who now manages its waste-reduction efforts, says it means finding productive uses for material that GM would have previously discarded. That includes making air-inlet panels from recycled bumpers, turning used packaging into sound-absorbing components within vehicles, and converting plastic waste into shipping containers. Bradburn says the initiative extends beyond the factory gates: The air deflectors on the Chevy Volt, GM's electric-gas hybrid car, were once oil-soaked plastic booms used to contain the 2010 *Deepwater Horizon* oil spill in the Gulf of Mexico.

Online
sciencemag.org
Podcast interview with author Jeffrey Mervis (http://scim.ag/pod_6095a).

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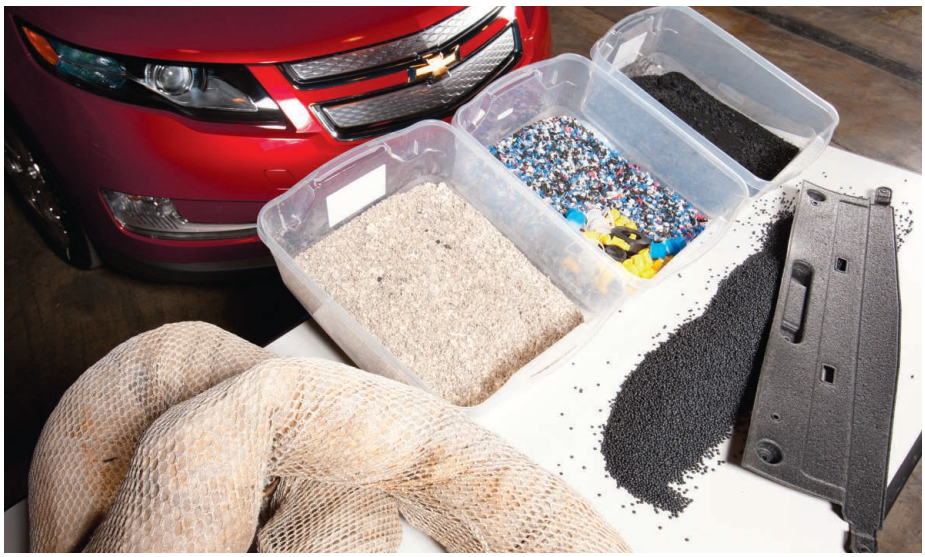
At the same time, GM faces some constraints in reducing waste on the plant floor. "Vehicle parts must come to us in the best possible shape," he says, "and to do that you need robust packaging" that creates additional waste and can be difficult to recycle.

GM says the zero-waste-to-landfill campaign is going smoothly, and an independent auditor recently verified its claims. As of June 2012, GM said 100 facilities—nearly 70%—have already achieved that goal. It hasn't yet reported on progress toward its second goal—to reduce overall waste by 10% in the next decade—but GM says it did cut the amount of waste per vehicle manufactured by 28%, to 304 kilograms, in the 5 years prior to 2010.



Boom times. Booms used to sop up the 2010 *Deepwater Horizon* oil spill have been combined with other plastics and recycled tires to make parts for the Chevy Volt.

Raw facts?

For advocates of sustainability, however, the real question is not what GM or any particular company is doing to reduce its waste. Instead, they want to know whether those steps are helping make significant progress toward a bigger goal: reducing the world's demand for raw materials.

For one particularly valuable material, aluminum, a 2010 forecasting study by the U.S. Geological Survey (USGS) suggests that recycling is having less of an impact than might be expected. The issue involves how much of the projected rise in demand for aluminum—from 46 to 120 million metric tons—can be met with metal from so-called secondary sources, which includes recycled material. That estimate, in turn, rests on some fundamental assumptions about how aluminum is used. The heaviest demand in the next 2 decades will come from developing nations, the USGS report concludes. But those countries will tend to use aluminum mostly to construct long-lasting infrastructure such as buildings, bridges, and power lines.

As a consequence, the aluminum probably won't be available for reuse for many decades, according to the report. In contrast, advanced economies tend to use aluminum in products with shorter lives, such as cars, trucks, and jets. Although most of that aluminum will be recycled, it won't be enough to meet the global demand.

Based on that analysis, the USGS report concludes that "the proportion of aluminum generated from old scrap may decrease" between now and 2025. The industry disagrees, saying that there will be 50% more recycled metal available over the next 2 decades than the USGS has projected.

The dispute demonstrates just how hard it can be to measure the extent to which recycling helps conserve Earth's resources. Some waste-management scholars worry that recycling has become a feel-good activity that diverts the public—and government agencies—from the need to find the most effective strategies to reduce waste and limit the nonsustainable extraction of raw materials.

A new book by Samantha MacBride, an adjunct professor at Columbia University's School of International and Public Affairs, argues that the primary burden of reducing waste should fall on the shoulders of manufacturers rather than on the public. "Recycling only affects 80 million tons of MSW a year [in the United States]," she notes. "It's really only the tip of the iceberg." Even so, the title of her book makes clear that she hasn't abandoned all hope: *Recycling Reconsidered: The Present Failure and Future Promise of Environmental Action in the United States*.

Making the case for changing how the world perceives and handles waste, however, will require solid statistics. Without them, "trash talk" is too often simply that: uninformed opinions. But in the United States, at least, long-ago political decisions about how to regulate waste are limiting the flow of data.

In particular, twice within a decade Congress amended a potentially powerful tool to manage materials flow: the 1976 Resource Conservation and Recovery Act. The changes limited the U.S. Environmental Protection Agency's ability to monitor and regulate large chunks of the U.S. waste stream. As a result, it now has responsibility for just two of the smaller pieces of the pie: municipal and hazardous waste.

The outcome was predictable, says Sue Briggum, a longtime observer of federal environmental policy as vice president for federal public affairs at Waste Management. "If you only measure hazardous and municipal waste, that's what will get managed and that's what will get recycled. And what you don't measure becomes invisible."

Last year, EPA put out a notice asking for comments on whether it should expand the definition of MSW and look more broadly at what's called "sustainable materials management." Sensing a business opportunity, Waste Management told EPA that it welcomed the invitation to shift the discussion from "how to dispose of waste safely" to "the safe recovery of used materials." But observers say federal legislators have little appetite for increasing the agency's regulatory powers and, specifically, the scope of the law.

USGS, meanwhile, has proposed wiping out the small team of analysts who produce the federal government's only comprehensive and authoritative studies on materials flows, including the report on aluminum. Agency officials admit that the $5 million cut to the team's parent office, part of a broader belt-tightening for 2013, "would reduce its ability to assist other federal agencies who rely on timely, accurate, and unbiased mineral resource data for decision making."

In other words, eliminating the effort would make the government less able to manage its material resources wisely. Now that sounds like a real waste.

–JEFFREY MERVIS