High-Powered Plasma Turns Garbage Into Gas

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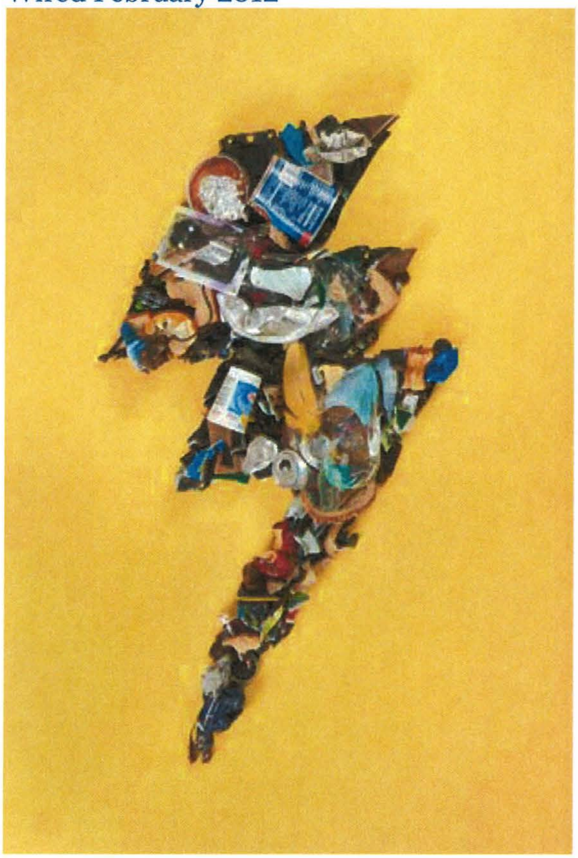

Photo: Kevin Van Aelst

From the highway, one of the biggest landfills in the US doesn't look at all like a dump. It's more like a misplaced mesa. Only when you drive closer to the center of operations at the 700-acre Columbia Ridge Landfill in Arlington, Oregon, does the function of this place become clear. Some 35,000 tons of mostly household trash arrive here weekly by train from Seattle and by truck from Portland.

Dump trucks inch up the gravel road to the top of the heap, where they tip their cargo of dirty diapers, discarded furniture, lemon rinds, spent lightbulbs, Styrofoam peanuts, and all the rest onto a carefully flattened blanket of dirt. At night, more dump trucks spread another layer of dirt over the day's deposits, preventing trash from escaping on the breeze.

But as of November, not all the trash arriving at Columbia Ridge has ended up buried. On the southwest side of the landfill, bus-sized containers of gas connect to ribbons of piping, which run into a building that looks like an airplane hangar with a loading dock. Here, dump trucks also offload refuse. This trash, however, is destined for a special kind of treatment—one that could redefine how we think about trash.

In an era when it's getting more and more confusing to determine where to toss your paper coffee cup—compost? recycle? trash? arrrgh!—and when no one seems to have a viable solution to the

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problem of humanity's ever-expanding rubbish pile, this plant represents a step toward radical simplification. It uses plasma gasification, a technology that turns trash into a fuel without producing emissions. In other words: a guilt-free solution to our waste problems.

Recycling is all well and good. But it hardly addresses the real problem we have with our household waste: We throw two-thirds of it in landfills while somehow managing to feel virtuous that we put last night's empty wine bottle in the recycling bin. Surely we could do better, environmentally and economically.

There is, in fact, value in trash—if you can unlock it. That's what this facility in northern Oregon is designed to do. Run by a startup called S4 Energy Solutions, it's the first commercial plant in the US to use plasma gasification to convert municipal household garbage into gas products like hydrogen and carbon monoxide, which can in turn be burned as fuel or sold to industry for other applications. (Hydrogen, for example, is used to make ammonia and fertilizers.)

Here's how it works: The household waste delivered into this hangar will get shredded, then travel via conveyer to the top of a large tank. From there it falls into a furnace that's heated to 1,500 degrees Fahrenheit and mixes with oxygen and steam. The resulting chemical reaction vaporizes 75 to 85 percent of the waste, transforming it into a blend of gases known as syngas (so called because they can be used to create synthetic natural gas). The syngas is piped out of the system and segregated. The remaining substances, still chemically intact, descend into a second vessel that's roughly the size of a Volkswagen Beetle.

This cauldron makes the one above sound lukewarm by comparison. Inside, two electrodes aimed toward the middle of the vessel create an electric arc that, at 18,000 degrees, is almost as hot as lightning. This intense, sustained energy becomes so hot that it transforms materials into their constituent atomic elements. The reactions take place at more than 2,700 degrees, which means this isn't incineration—this is emission-free molecular deconstruction. (The small amount of waste material that survives falls to the bottom of the chamber, where it's trapped in molten glass that later hardens into inert blocks.)

The seemingly sci-fi transformation occurs because the trash is blasted apart by plasma—the forgotten-stepsister state of matter. Plasma is like gas in that you can't grip or pour it. But because extreme heat ionizes some atoms (adding or subtracting electrons), causing conductivity, it behaves in ways that are distinct from gas.

Dozens of firms are racing to find the right formula to use plasma to blast garbage into gas. Yet despite incremental improvements in the technology, plasma gasification has proved too energy- and capital-intensive for real-world use on everyday trash. If the value of the syngas produced doesn't offset the amount of energy required to power the furnaces and melt the trash, what's the point?

Now S4 cofounder Jeff Surma may have finally solved that problem. (S4, by the way, refers to the fourth state of matter: plasma.) The 52-year-old chemical engineer is convinced that he can transform garbage from something we toss into something we value—and get it to work on a vast scale. He has already made enough advances with the technology to attract millions of dollars in backing from Waste Management, the $12.5 billion trash hauling, recycling, and disposal behemoth, which owns the landfill here in Arlington.

Still, it's a long shot. The US generates about 250 million tons of trash a year. Even with recycling and composting facilities tackling an estimated 85 million tons of refuse per year, it would take thousands of new plants much bigger than this one (and another S4 facility being constructed in McCarran, Nevada) to handle the nation's municipal trash output. That's a lot of plasma.

Photo: Kevin Van Aelst

On a summer afternoon, Surma steps out of his Mercury Mariner, replaces tasselled loafers with work boots, and dons a yellow hard hat. He has a runner's physique and a shock of white hair, and wears wraparound sunglasses. Today he's guiding potential customers from the chemical industry around the Arlington plant, explaining how it all works. Later he confides: "If we're still here in two years, telling you what we *plan* to be doing, you can come back and call bullshit on us."

Here's a short history of how Surma's trash blaster came to be: Fresh out of graduate school at Montana State University in 1985, he was hired by Pacific Northwest National Laboratory, a research facility in Richland, Washington. He was there to work on an especially hideous mess: the Hanford Nuclear Reservation, just down the road. Beginning with the Manhattan Project, the US government cooked most of the plutonium for America's nuclear weapons arsenal at Hanford. With its nine nuclear reactors, giant plutonium processing plants, and buried tanks of radioactive sludge, the site has earned the dubious distinction of being one of the most contaminated nuclear waste sites in the Western Hemisphere.

Surma's first project was to work on so-called joule-heated melters, an experimental method for processing nuclear waste. "We basically fed this muddy slurry into a chamber that was heated with coils," he says, "almost like the coils on an electric stovetop." This chemical process, known as vitrification, immobilizes radioactive materials in an inert form of glass. By and large, the system worked; the team was able to convert waste into more than 30 four-foot-tall canisters of vitrified glass.

But that pricey and delicate process made sense for only the worst materials on the site. Hanford also has huge quantities of more heterogeneous trash, much of which contains low-level radioactivity. "It couldn't go to a landfill," Surma says, but it wasn't suited to vitrification, either. Surma went prowling through the literature for other waste-treatment techniques and was soon reading up on tech known as the plasma torch. In the 1960s, scientists at NASA wanted to learn more about the effect of extreme heat on manned spacecraft reentering the atmosphere. They developed plasma torches to mimic those conditions.

Meanwhile, Surma learned, the practice of using plasma for processing waste had been around for decades, primarily in the metal and chemical industries. Oil refineries, for instance, spend $2,000 a ton to dispose of their toxic sludge with plasma gasification. But few people ever gave the technology much serious consideration for treating everyday garbage because of the high energy costs and because the heterogeneity of municipal solid waste makes it that much harder to efficiently untangle.

Jeff Surma wants to transform garbage from something we toss into something we value.

And then there's the problem of the toxins in heavy metals—materials from busted televisions, microwave ovens, dead batteries, broken thermometers, old paints—which aren't broken down by plasma. If you don't want hazardous leftovers making their way into, say, the water supply, you have to find a way to safely sequester the stuff. Those especially nasty substances, of course, were Surma's specialty.

Around the same time that Surma was looking into all this, a physicist at MIT's Plasma Science and Fusion Center named Dan Cohn was searching for plasma technology's possible environmental applications. He placed a call to Pacific Northwest, asking if anyone at the lab was doing plasma research, and he was connected with Surma. Before long they were brainstorming how to take the technology beyond merely disposing of specialized toxic waste: They wanted to go after the billions of tons of common household trash.

The next step was to pull in a retired engineer from GE named Charles Titus. He was an expert in high-voltage engineering and had become convinced that metal torches, which tend to get damaged by the very heat they deliver, were the wrong technology. It would be better to create plasma with an electric arc strung between two graphite electrodes. (Titus died in 2007.)

But the trio also knew that if they were going to aim for the massive market in municipal solid waste, they needed a clean system with essentially no byproducts. Otherwise, their technology would look like incineration in disguise. One evening in 1994, over a meat-lover's pizza and another round of Sam Adams at a Bertucci's restaurant near MIT, Surma wondered aloud about combining the plasma attack with the vitrification technology he'd mastered at Hanford to handle the nasty leftovers. The concept was captivating, but they would have to find a way to run that kind of machinery without also needing a dedicated hydroelectric dam to power it.

To combine the vitrification and plasma-zapping processes in the same chamber, they needed to keep the molten glass at the bottom of the vessel from cooling down; continuously having to reheat it would interrupt key chemical reactions and could quickly lead to exorbitant energy costs.

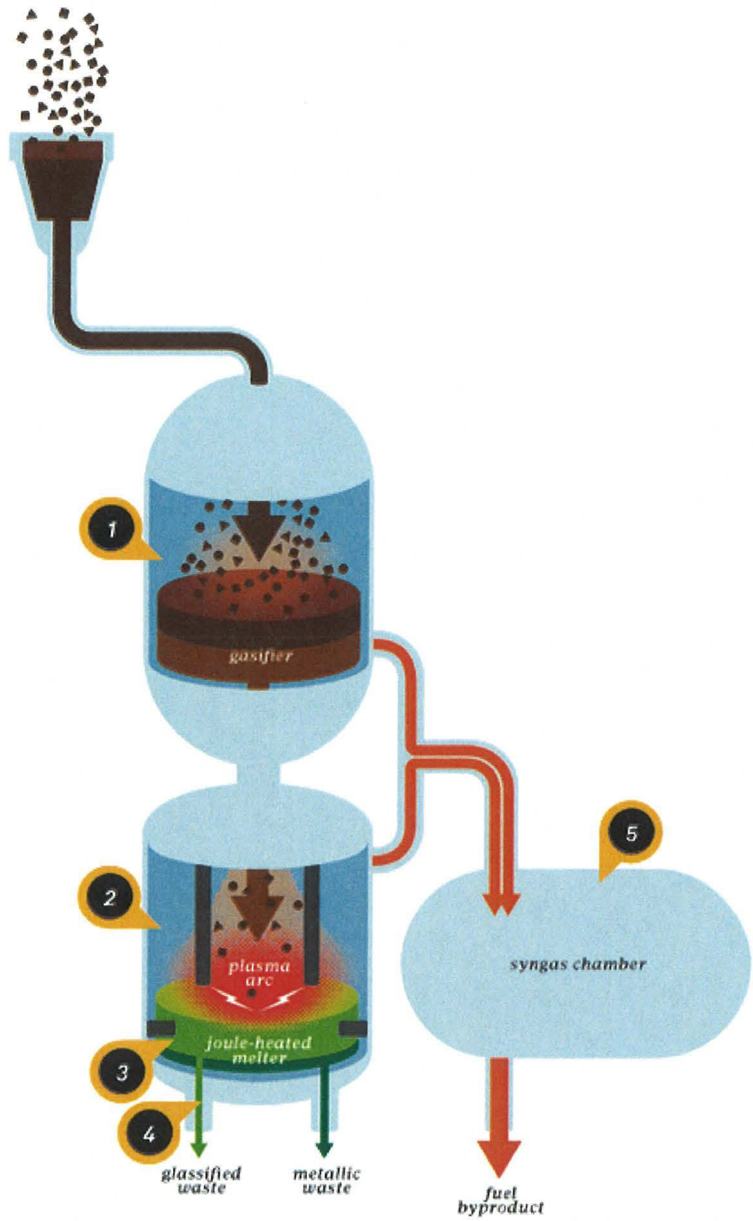
Keep it hot. Sounds straightforward, but it isn't. While the molten soup needs alternating current to maintain steady temperature, the electric arc for the plasma runs on direct current. Titus, the electricity guru, said he could rig the AC/DC combo, and that evening they quickly sketched out details for a system that would enable DC and AC to cohabitate within a plasma gasification furnace jacked up with a melter. This tandem approach, the men realized, promised to provide just enough energy to sustain the plasma and atomize trash, while keeping the glass in a molten state.

"But no more energy than that!" Surma says. The next day they wrote up the details in an invention disclosure, a kind of shortcut for protecting an idea in advance of filing a full patent.

Within a few months, the three scientists felt ready to launch a company. Cohn knew a guy who had made a killing selling his frozen-dinner company to ConAgra and was looking to invest in promising technologies. So one afternoon in 1994, in a dimly lit room with mahogany walls at Manhattan's Chemists' Club, they presented the melter idea to the frozen-dinner guy, who had brought along a venture capitalist friend to offer advice. Surma, Cohn, and Titus got the money, as well as a complementary booklet of coupons for chicken potpies.

How to Blast Trash

The plasma-enhanced melter now operating in Oregon breaks down everyday garbage into its constituent atomic elements. Here's how it works.



1/ Gasification

A conveyer belt delivers shredded trash into a chamber, where it's mixed with oxygen and steam heated to 1,500 degrees Fahrenheit. This process, called gasification, transforms about 80 percent of the waste into a mixture of gases that are piped out of the system.

2/ Plasma Blasting

Material that doesn't succumb to the initial heat enters a specially insulated cauldron. An 18,000-degree electric arc that runs between two electrodes creates a plasma zone in the center of the container. Exposed to this intense heat, almost all the remaining trash gets blasted into its constituent atomic elements. Again, the resulting gases are piped out and sequestered.

3/ Hazmat Capture

At the bottom of the cauldron sits a joule-heated melter, which is like coils on an electric stove and maintains a molten glass bath that traps any hazardous material left over from the plasma process.

4/ Recycling

Swirling in a taffy-like ooze, the molten glass is drawn out of the system. Now inert, it can be converted into low-value materials such as road aggregate. Metals are captured at this point, too, and later recycled into steel.

5/ Fuel Capture

The sequestered gases, known as syngas—mostly carbon monoxide and hydrogen—are cleaned and can be sold and converted to fuels like diesel or ethanol to produce electricity onsite or elsewhere.

Illustration: James Provost

They called their company Integrated Environmental Technologies (eventually InEnTec), and in 1995 Surma took a leave of absence from Pacific Northwest to run it. It was slow going at first. Surma and his team of three engineers didn't finish the prototype melter until 1997. They sold their first commercial units, geared specifically for hazardous waste, in 1999. Early customers included Boeing and Kawasaki, which produce heaps of hazardous waste and have to pay dearly to deal with it. Manufacturers save big money when they don't have to contract with someone else to dispose of their waste, and gleaning useful materials or gases out of a treatment process only adds to overall savings.

But when InEnTec tried to venture into markets beyond the manufacturing and chemical industries, things always went wrong. Surma sold a unit to a company in Hawaii that used it to process medical waste, but that firm ended up folding. Next, he tried to set up a medical waste processing operation in northern California, this time to be run by InEnTec itself. But a group of impassioned citizens stepped in to oppose the project. They didn't—or refused to—understand the science of plasma gasification and the absence of emissions. All they heard was "medical waste treatment plant" (and some version of "right down the street"). After an 18-month struggle, Surma jettisoned the project in 2007. It was a moment of truth. He realized that the business had somehow drifted from the founders' original vision. "It was always our intent, from the very first patent, to go after the municipal solid waste stream," he says. "But customer pull drew us into hazardous- and medical-waste treatment."

Surma decided to retrench—to get back to the goal of processing what he calls the granddaddy of waste streams. Together with InEnTec's chief engineer, Jim Batdorf, he spent three days planted in front of a whiteboard, trying to come up with ways to make it more economically feasible to use the melter on household garbage in all its heterogeneous glory.

The breakthrough alteration they came up with was to stack a conventional gasifier atop the plasma-enhanced melter. The trash undergoes heating and treatment by way of this preliminary gasifier, then moves into the chamber with the plasma zapper and vitrification. It's like partly defrosting a turkey before putting it in the oven. This strategy improves efficiency because it takes less energy for the plasma to blast materials that have already undergone some heating. The leftovers, meanwhile, drop down into the molten soup, which flows in a slow, taffy-like ooze of glass and liquefied metal out the bottom of the system. At the same time, syngas piped out of the plant can be burned as fuel to, in theory, supply all of the power needed to run the melter itself.

The actual plant built by S4—a wholly owned subsidiary of InEnTec—is still so new that it remains to be seen whether the quality and quantity of Surma's syngas matches the predictions and test data gathered so far. "The goal is to take waste and produce a product that is used for energy or for some other process," says Tom Reardon, a vice president with the waste consultancy Gershman, Brickner & Bratton. "They've proven they can produce a syngas. But from it, can they produce the fuel they're supposed to?"

"The easy answer used to be: Store it in a can, put it in a truck, and then send it to a big hole in the ground."

What Surma didn't know back when InEnTec was retooling for municipal trash was that, starting in 2005, executives at Waste Management had quietly dispatched a team of experts and consultants to study plasma gasification. If it looked like a worthy technology, they would invest. After a review that lasted more than two years, they determined that InEnTec was one of the few firms in the world whose technology looked viable. In 2008, Surma found himself on a flight to Houston to give Waste Management executives a presentation about his plasma-enhanced melter.

The company's executives know better than most that we can chuck trash in landfills for only so long. "The easy answer used to be: Store it in a can, put it in a truck, and then send it to a big hole in the ground," says Carl Rush, a senior vice president at Waste Management. "We're moving away from that as a society." Why? People don't like it, it's becoming costlier to transport and bury garbage, and—even in the spacious American West—landfills are gradually butting up against more backyards and inching their way toward local water tables.

Trash-to-fuel technology has in fact been around since the 1970s and involves burning waste to generate electricity. But that method, no matter how fancy your emissions scrubbers, invariably produces a stew of byproducts that need to be disposed of. Consequently, environmentalists—and some in the industry itself—have remained skeptical of trash-to-fuel. Nevertheless, Rush and his team suspected that entrepreneurs might have cracked the problem and began searching for experimental technologies to invest in. Among the more than two dozen companies Waste Management has recently added to its portfolio are a startup with a specialized method for producing compost, a firm that uses gasification to turn biomass into synthetic gas, and a company that converts mixed and contaminated waste plastic into synthetic crude oil.

Not all of these startups will make it, and it's possible that most won't. But Waste Management bosses hope they will help accelerate the transition to an era in which the very idea of garbage itself is garbage—and they want to be positioned to profit when that time comes.

The INENTEC Hydrocarbon Conversion Test Facility is located next door to Richland's tiny airport. Inside the cavernous building stands the first prototype of the plasma- enhanced melter, which is less than a third the size of the unit 85 miles away in Arlington. This is where Surma and his team refine and tune the blasting process in an ongoing series of upgrade experiments, melting materials from everyday trash to asbestos, PCBs, hazardous chemical sludge, and discarded electronic equipment. Data gleaned here will help with tweaks at the plant in Arlington and inform the design and operation of S4's next commercial melters.

Today they're testing a chemical called toluene, one of the most stable organic compounds there is. That makes it a great substance for assessing the melter's proficiency at busting things apart, since being chemically stable means toluene is not easily changed or altered without some kind of big input, such as a blast of superhigh heat.

Staring through a circular window into the furnace, I see the cherry-red glow of the plasma. It looks like a cross between lava and a supernova. (If you could somehow stick your arm in there, it would be instantly vaporized.)

Back in Arlington, I catch up with Waste Management's point person for S4, Joe Vaillancourt. After a tour of the gasification plant, he sits on a desk in the operations room. Plastic still covers the gray carpet, but flatscreen monitors are aglow. "This plant will provide the data to quiet the naysayers," Vaillancourt says. Once it's running at full capacity, it will process 25 tons of waste a day.

He stares out the window for a moment, past the S4 facility to the man-made mountain of garbage behind it. Then he nods toward the consoles, where technicians will monitor the machines and chemical brew that will blast tomorrow's trash to smithereens. "If you don't want landfills, how could you not want this?" he asks.

Contributing editor David Wolman (david@david-wolman.com) *is the author of* The End of Money: Counterfeiters, Preachers, Techies, Dreamers—and the Coming Cashless Society.