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Hitting the Books: Future humans may mine rare earth metals from today's landfills

It might wind up being more cost effective than mailing our old phones in for recycling.

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Traditionally, gold hasn't been good for a whole lot beyond being pretty — it was too soft to hold an edge and too heavy to use in construction — but these days it often serves as a vital electronics component which, along with a select number of other rare earth metals, enables the modern world to operate. But before we can use these elements to fabricate the electronic gadgets, do-dads and contrivances that we rely on, they have to be pull from deep within the planet, and therein lies the problem.

As futurist Byron Reese and entrepreneur Scott Hoffman explain in their new book, Wasted, mining rare earths is a resource and energy intensive endeavor akin to "extract[ing] a tablespoon of pepper that has been randomly spread through a pound of salt." It is far from our only imprudent and thriftless economic activity. Throughout the book, Reese and Huffman explore humanity's wasteful ways, providing insights into these massively complex issues and offering actionable next steps towards a larger solution.

Smartphones provide ample fodder for those interested in waste in all its permutations. The newest and best models are launched at press events that rival Hollywood movie premieres; they cost a bundle, and people ooh and ahh over the latest, or fastest, or biggest, or smallest version—

depending on what's fashionable at any given moment. Wait a few years, though, and you can't even give them away. They sit in drawers gathering dust.

What does the life cycle of a smartphone look like? How does it go from hero to zero—and how much of the process of creating these ubiquitous devices is lost to waste?

Like humans, smartphones begin and end as dust. To build one of these modern marvels, we start with the elements from the periodic table. In the case of your phone, it requires a lot of them. Sixty, in fact—which is more than can be found in your body.

Elements are substances that cannot be broken down into any simpler substance. Gold and carbon are just gold and carbon—unlike, say, bronze, which is a mixture of copper and tin. There are 118 elements, of which 83 are both stable and non-radioactive.

Some of these elements are the so-called rare earth elements, which have become essential to our modern world. Despite the name, however, rare earth elements aren't actually rare. In fact, they're quite common. They're hard to obtain because their deposits aren't concentrated and they're difficult to mine and refine.

The most commonly used ones aren't all that expensive, despite how difficult it is to extract them. An ounce of lanthanum or cerium or samarium will set you back less than a quarter. Even the more expensive, heavy rare earth elements are still affordable—certainly compared to an element like plutonium (which, if you could even figure out a way to buy it, would cost you more than $100,000 an ounce).

In addition, the worldwide market for rare earths is rather small. The value of all the rare earth elements mined in a year is barely as much as the value of all of the copper mined in two weeks or the aluminum mined in a month.

So why are they such a big deal? Because they do very specific things in electronics and, for the most part, they have no substitutes. Think of baking a cake. It may call for three cups of flour and a tablespoon of baking powder. If you are short a tablespoon of flour, no big deal, but if you leave out the tablespoon of baking powder, well, you don't have a cake. Baking powder isn't expensive and it isn't rare, but it's essential to baking.

Rare earths have amazing powers. They make things glow brighter. They magnetize objects. They can be mixed with metals to make vastly stronger alloys. The kinds of products they enhance are critical; many are essential for modern living.

And our smartphones need most of them.

However, the process of mining and refining rare earths isn't easy and takes a long time. It's a nearly alchemical process involving acids, ovens, and proprietary processes. Imagine trying to extract a tablespoon of pepper that has been randomly spread through a pound of salt. That's the basic purity we're talking about with rare earth ore. And some of the processes take up to two years to run.

In addition to rare earths, a smartphone requires a number of other elements. By weight, the most common is aluminum. By value, it's gold. The rest of the elements all come together in their own idiosyncratic way from every corner and crevice of the planet.

Of course, they all have to be mined, a process that undergirds much of our modern world. Every person in a modern industrial economy like the United States, every single day of their lives, requires on average 20 pounds of sand, 15 pounds of coal, 3 gallons of petroleum, 1 pound of iron ore, 1 pound of salt, and 0.5 pounds of phosphate (which is used mostly in the fertilizers that grow the food we eat).

And that's nowhere near everything. According to the Minerals Education Coalition, in all, 100 pounds of ore must be extracted from the earth every day of every year for your entire life to support your modern lifestyle. And that's just in the United States.

Yet in the grand scheme of things, mining doesn't use much land, and what it does use can often be reclaimed. That's the good news. The bad news is that the amount of resources consumed doing all that mining, from water to fuel, is enormous, as is the resource consumption associated with all of the processing that must be done.

How much waste is there in mining? In a sense, it's all waste. In a world without waste, ingots of refined elements would be conveniently strewn about the surface of the earth in great abundance, ready to be picked up and used. But, of course, they aren't.

You can see part of the effective waste factor in their prices. Take gold, for instance. What do you think it would cost to buy a gold mine with 1 million ounces of proven gold reserves? First-order thinking might suggest that the value of that mine would be the price of gold—about $1,400 an ounce—times the number of ounces in that mine, so…$1.4 billion.

But in reality, because gold is so difficult to mine, you could buy the mine for a mere $50 million. That's right—gold mines are generally valued at $50 per ounce of gold in them.

If gold sells for $1,400 an ounce, purified, and the gold mine is only valued at $50 an ounce, then it's easy to see that the $1,350 difference isn't the value of the gold but the waste inherent in extracting and refining it.

But even that $50 an ounce is waste. The mine is worth $50 an ounce only because significant amounts of labor and risk went into determining that it was in fact a proven source of gold. In a world without waste we never would have had to expend the capital and take that risk to make the assessment. Not every hole gold miners dig has “pay dirt” in it.

The value of all the gold in a random 100-acre tract of land is essentially…zero. Gold is, in fact, worthless, in the sense that the minuscule flecks of gold that may or may not be in your backyard aren’t worth anything. You can’t go to the bank and borrow money against the gold mining rights of your backyard.

In addition to the waste implicit in the price of the elements, there is the human toll as well. Many mines are inherently hazardous to both people and the environment. Child labor and even forced labor are used around the world. Can the human cost be eliminated or at least mitigated? Can’t those who manufacture goods like our smartphones do something about these issues? Yes, but it’s not as simple as that, since the supply chains that bring these elements together touch untold millions of people.

Imagine a small village in the developing world. It may have a mine that has no miners as employees. Instead, anyone can come to the mine, chip out ore, bring it to the surface, and be paid for its weight. That ore is sold by the truckload to an intermediary that sells it by the trainload to a refinery in a distant city that buys from scores of producers. The chemicals needed to refine the ore are likewise made in distant facilities that have their own supply chains across a dozen countries.

The elements produced from the ore are made into components which are then shipped to another facility where a different step in the manufacturing process occurs. Those unfinished goods are aggregated at a different place in perhaps a different part of the world to have another step in the manufacturing process performed on them.

If you are in the business of building millions upon millions of smartphones, the number of people and places involved dwarfs the imagination. You simply cannot effectively police every step of the process to make sure best practices are always used.

What you can do, however, is require those you do business with directly to follow certain guidelines, and require that they require their suppliers to do the same, all the way down the supply chain. Abuses are inevitable because there is almost always money to be made in the abuse business. But responsible manufacturers do surprise inspections of their suppliers, who are required to do likewise to theirs.

Could a smartphone be made that uses only ethically sourced materials built in a sustainable way? As it happens, Bas van Abel set out to do just that when he founded Fairphone. The goal was to make a phone with a long-lasting design, completely modular so that it can be easily repaired and upgraded, built under good working conditions out of materials that were sourced from sustainable and safe environments. Oh, and the phone needed to be easily recyclable.

Clearly, the idea had merit. Fairphone began as a crowdsourcing project and sold twenty-five thousand units before production even started. To date, the company has sold well over a hundred thousand phones and is even “mining” resources from old, discarded phones.

To its credit, Fairphone isn’t just taking the easy path to building a “fair” phone. The easy path would be to deal only with well-regulated developed nations—by, for instance, purchasing materials from Australian mines instead of those in the Congo, where conditions are much murkier. Instead, Fairphone goes into the areas that are the most challenging and works with producers to improve conditions.

But even this practice is far from perfect. Van Abel admits, “The problem with that is you work with mines where there might be child labor. You work with mines where the working conditions are still not super-duper.” He warns, however, that a more heavy-handed approach would end up backfiring. “If you go into a policing mode and tell them all what to do, they’ll just show you what you want to see.”

Even with the best of intentions, which van Abel clearly has, it’s difficult to fully execute his vision.

The waste—both in materials and human costs—is significant just to collect the materials of our smartphones. To go into the waste involved in manufacturing would occupy an entire book, so in the interest of brevity, let’s assume the new phone gets made and is delivered into the hands of an eager consumer.

Now let’s jump forward in time a few years. That fancy new smartphone we meticulously built has reached the end of its useful life, at least as far as the person who bought it is concerned. What happens to the phone then?

Surely, given the enormous cost, difficulty, and waste involved in mining all of the elements used in the phone, the valuable material in the device can be quickly and efficiently recycled, right?

Not quite.

Why aren’t smartphones recycled as much as, say, aluminum cans? At first glance, phones would seem to be ready-made for recycling; they are little containers of all kinds of conveniently ordered precious metals, all in one package. Throwing one out in the trash seems the epitome of waste, akin to a cartoon fat cat lighting a cigar with a hundred-dollar bill.

But this is where the challenge lies. You’ve probably heard the statistic that the value of all of the chemicals in the human body is something like $1.92. On a theoretical level, that makes sense to most; after all, we’re made of relatively common stuff—carbon, hydrogen, oxygen, calcium, et cetera. Our smartphones, on the other hand, contain aluminum, gold, lithium, and all sorts of other materials.

But here's the bad news—the raw materials in your cellphone are worth even less than the raw materials in your body. Only about half as much, actually.

Let's look at the gold in a phone, which makes up half of the scrap value of the whole device. Worldwide, the average yield of primary gold production (that is, gold that originates in a mine) is 1 gram of gold per ton of ore. A gram is the weight of a paperclip. One ton of ore is about the size of a mini-fridge, the kind you might see in a college dorm room.

The kind of phone you think about recycling—say, an iPhone 6—weighs about 5 ounces. That means there are about 6,400 iPhones in a ton. According to metallurgist David Michaud of 911Metallurgy Corp., an iPhone 6 has 0.014 grams of gold in it. So our ton of iPhones contains about 90 grams of gold. So far, so good. The density of gold in an iPhone compares very favorably to what we might find in nature—90 grams of gold in a ton of iPhones versus 1 gram of gold in a ton of ore.

It's safe to say that if a gold prospector down in a mine were to come across a vein of pure iPhone, it would be cause for great celebration. Alas, the mother lode of iPhones is rarely found in nature.

The 3 ounces of gold you get from your ton of iPhones is worth $4,200 at $1,400 an ounce. This works out to about 65¢ a phone.

Here's the catch: The problem with recycling iPhones is not dissimilar to the problem with mining rare earths—they're distributed widely. Since melting down your iPhone at home isn't a current option, we'd have to figure out a way to get that device to a smelter for less than 65¢. You could hardly mail one for that much, let alone figure out a way to buy the unwanted iPhones.

But there's still hope, since there are other substances of value in the phone, such as copper and nickel. To get the amount of metals found in a 5-ounce iPhone from primary production would require about 2 pounds of each respective ore. At current prices, the nickel in the phone is worth about 3¢, and the copper 5¢. The iPhone 6 contains about 31 grams of aluminum as well. This metal is worth about $1,500 a ton, which makes the aluminum in the iPhone worth about a nickel. Beyond gold, copper, and nickel, as the saying goes, the juice simply isn't worth the squeeze. Other metals in the phone are used in such minute quantities that it's more efficient to mine high-grade ore than to extract from the low-grade "ore" of the phone.

So…65¢ for the gold, and 13¢ for the other metals. It's difficult to make the numbers work.

Apple, however, is a bit more optimistic. In 2017, Apple launched a war against waste, hoping to one day be able to make its products from 100 percent recycled materials rather than using any primary production metals, and going so far as to launch a pilot program to build robots that can disassemble iPhones and other devices. Spoiler alert: They're not very close to achieving this goal.

The vast majority of discarded devices are still operational. So instead of shredding and melting down the phones or disassembling them with robots, what about reusing them?

Functional recycling happens to a certain point already. As previously noted, an early adopter who buys a $1,000 smartphone every two years generally doesn't toss it in the trash when deciding to buy a new phone. That phone is probably still worth at least $100, an amount most people don't cavalierly ignore. There are a number of ways that phone finds itself in the hands of a new owner.

But several years after it has been reused, passed along, and gone through a second or third lifecycle, the phone's value is down even more, perhaps to just $5 or $10. At this point, it isn't worth the trouble of selling the phone (transaction costs are a form of waste), but it still has enough value for someone to feel bad about chucking it in the trash.

Thus, it's likely to end up in the landfill known as the hall closet, or the ubiquitous junk drawer. Credible estimates suggest there are more than two billion cellphones stored unused in people's homes.

At the very end of its life cycle, no matter what happens, the phone is essentially worthless. What happens?

Marc Leff, President and Co-founder of GRC Wireless, might enter the picture. His company buys all cellphones, regardless of condition. You ship it and they send you a check. They pay different prices for each phone, from a dime for an old flip phone up to $400 for the latest and greatest phones made.

We caught up with **Leff** and chatted with him about the ins and outs of his business, which he seems to regard as both a livelihood and a mission. The phones that arrive in large numbers every day are divided into two roughly equal groups. The first group is phones that still work and can be sold in secondary markets. As **Leff** tells us, the goal is to get five or six life cycles out of a phone across its useful life, which is fifteen years. In fifteen years, the finest and best smartphones of today will likely be worth nothing to anyone in the world. And this half of his business is the lucrative part.

The other half of the phones, the ones that **Marc** pays as little as a dime for, are largely a money-losing or break-even proposition. They are subdivided into two groups. The first are disassembled for parts, usually in less-developed countries. These are the phones old enough to not have much value themselves but which are still widely used somewhere. There is no supply chain for parts for these older phones, so the folks who disassemble them are providing a useful service and making a living doing it, ultimately reducing the waste that would occur with a phone that is perfectly fine except for, say, a broken pin on the charging port.

The final group, the old phones that are barely worth a dime, are sent off to smelters to have the "easy" metals, such as gold and aluminum, stripped from them.

Eventually, no matter how many life cycles you get from a phone, someday it will be worthless. And when that happens, unless there is major technological change that allows for recycling at home, phones won't get recycled, since it isn't even worth the postage to send them to someone (except perhaps a container-load at a time).

It's a paradox. On its own, one phone is essentially worthless. But in a given year, the world makes 1.5 billion smartphones and, sooner or later, those phones will have to be dealt with. In aggregate, now we are talking 22 tons of gold, and proportional amounts of all the rest of the raw materials. And this is just one single category of device, and a small one at that. Add in all the computer screens, TVs, laptops, and printers, and by one estimate, as far as gold is concerned, 10 percent of all new production could be replaced by recycling.

How do we keep this waste from occurring? The problem may seem intractable, but what if there's an easy answer?

There's an economics concept called "internalizing externalities." This practice charges the external costs of an action to the person or entity inflicting them. For instance, if Company X pollutes a river, then the damage done to the environment should be assigned a value, and whatever that value is should be levied in the form of tax on that company. Doing so forces the company to take into account the total impact of its actions, not just the ones it pays for directly. This method of taxation is also arguably the only form of assessment that can improve upon the theoretical efficiency of a free market.

If we can determine that a cellphone in a landfill inflicts $10 in damage to the environment, then we can enact a deposit system. When you buy a phone, you pay an extra $10 for it, up front. When the useful life of that phone is up, whoever owns it has two choices: They can toss it into the landfill, inflicting $10 in damage, or they can turn it in and get the $10 deposit back. Several states do this with beverage bottles: You pay a dime extra when you buy the drink, and someone gets a dime for returning the empty bottle. That's the same idea here.

If the societal cost of a cellphone in a landfill were zero, then the whole system would be reasonably waste-free. If a phone costs $1,000 today and fifteen years later it's worth a dime, 99.99 percent of the value of the phone was consumed. In a perfect world, if you could magically wave a wand and separate the phone into its core elements, they're only worth a dollar. Even if our $1,000 phone ends up being worth $1 and we throw it away, then we've still gotten virtually all of the value out of the phone.

But the societal cost of a cellphone in a landfill isn't zero. So what is it? We don't actually know, but we do know that smartphones are made of some pretty toxic stuff. There's arsenic in many of them, as well as lead and mercury. Less well known, but just about as toxic, are cadmium, chlorine, bromine, and lithium. The trend, however, is to use less of these substances. Apple touts in its iPhone

X Environmental Report that the device features “arsenic-free display glass” and is mercury-free, PVC-free, beryllium-free, and free of brominated flame retardants.

In a sense, losing sleep over smartphones going into landfills misses a much larger problem. The combined weight of every phone manufactured last year is about 250,000 tons, but the amount of electronic waste the world produces each year is about 50 million tons. That means that if you took every phone made this year and dumped them straight into a landfill, the resulting increase in the world’s electronic waste would be a rounding error.

That 50 million tons of electronic waste works out to about 15 pounds a person. However, if you live in the developed world, you threw out more than twice that. You have to throw out a lot of phones to equal the weight of that microwave oven that got trashed. Your phone may have a tiny bit of lead in it, but that big TV sitting in your garage has at least 6 pounds of it.

In the United States, electronic waste accounts for just 2 percent of landfill volume, but that 2 percent accounts for 70 percent of all of the toxic substances in landfills. With recycling rates of electronic waste hovering around 20 percent, this is a problem that will only get worse.

Will we ever reach a point where it makes sense to mine landfills for the gold in them? Perhaps. The best assumption we can make suggests there are about 2 grams of gold per ton of landfill detritus—twice what typical primary production might yield. But the landfill ore is far more toxic than gold ore, so it may not make sense.

For those of you with a well-developed sense of the macabre, perhaps you’re wondering about the ore content of cemeteries. If you were to mine the top 6 feet of a cemetery, the yield would be about 0.25 gram of gold per ton of dirt, given reasonable assumptions about what percentage of people are buried with their jewelry, medical devices, or gold teeth. Luckily for the dead, that is pretty low-quality ore.