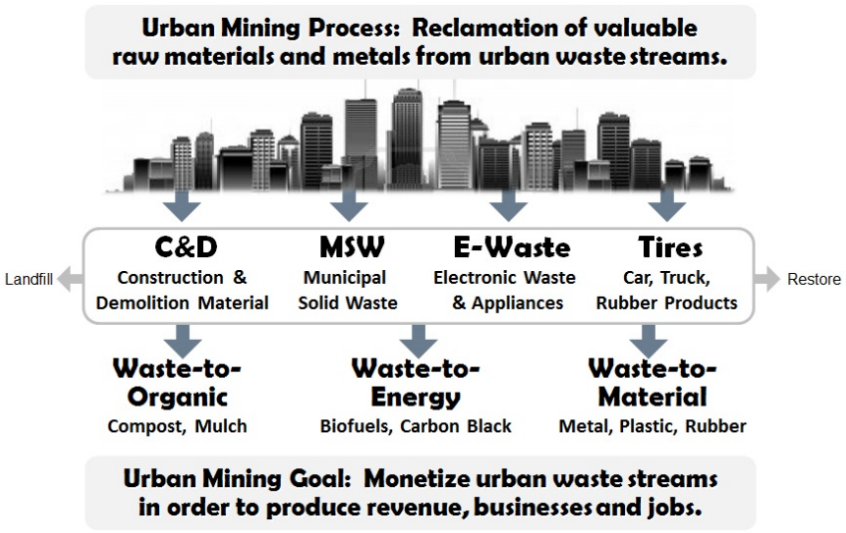
Advanced Technology
Material Recovery Facilities (MRFs)

www.eCyclingUSA.com
By: Chuck Vollmer
2 August 2015



One of the Jobenomics strategic initiatives involves urban mining. Urban mining is defined as a process of reclaiming raw materials and metals from municipal waste streams including construction and demolition material (C&D), municipal solid waste (MSW), electronic waste (e-waste) and tires. These waste streams contain combustible and non-combustible materials. Combustibles are carbon-based matter that has caloric value that can be converted to marketable products via waste-to-organic and energy via waste-to-energy technologies. Non-combustible elements can be reclaimed via waste-to-material technology. Material recovery or reclamation is accomplished via a material recovery facility, or MRF, pronounced "murf".

Every U.S. community should consider urban mining to (1) reclaim valuable raw materials and metals, (2) reduce landfilling and exporting of toxic waste, (3) mitigate environmental pollution associated with traditional surface and subsurface mining operations, and (4) produce revenue for local business and job creation.

American urban mining is decades behind Europe and China in terms of advanced technology material recovery systems. Of the 3,000+ U.S. recycling companies, the vast majority use manual processes to strip out high value metals and discard the remaining materials in landfills. In many cases, ozone-depleting refrigerants and foams are not handled properly. As a result, Jobenomics started eCyclingUSA LLC[1] to help local communities design and implement turnkey advanced technology material recovery facilities that can safely, cleanly and efficiently monetize high-value waste streams in order to create the revenue necessary to mass-produce new small businesses, which in turn, creates thousands of new inner city jobs. Urban mining also has many indirect benefits including reducing transportation costs, mitigating the effects landfilling toxic substances, and producing substantial environmental savings over traditional mining methods. According the EPA, urban mining uses 75% less energy, emits 86% less polluted air and leaches 76% less polluted water into the ground than traditional surface and subsurface mining operations.

In 2014, China became the leading urban mining nation by establishing a number of major ($1 billion level) urban mining centers with advanced technology MRFs that reclaim raw materials, metals and minerals from every conceivable type of manufactured item or system that contains reclaimable raw materials and metals. The Chinese put a premium on processing electronic waste that contains precious metals (gold, platinum, silver, palladium, etc.), common metals (copper, iron, tin, lead, zinc, titanium, etc.) and high-value plastics

[1] eCyclingUSA, www.eCyclingUSA.com, note: the author of this report is also the CEO of eCyclingUSA

(e.g., ABS). A ton of motherboards (printed circuit boards)/CPUs (central processing units) contain over $1,000,000 worth of precious metals—much of which can be reclaimed.

The material recovery industry is generally referred to as the "scrap" industry. According to the Institute of Scrap Recycling Industries [2], the scrap recycling industry employs 137,970 Americans—the vast majority of whom recycle scrap manually. Jobenomics believes that this employment number is a very conservative number compared to its ultimate potential if government renewable energy standards mandated recycling goals to include both organic and non-organic (scrap) fractions. As discussed later in more detail, government mandates are important to provide a reliable and consistent source of feedstock for processing operations and investment.

Scrap goes far beyond MSW and includes electronic waste, consumer products, appliances, scientific and medical equipment, furniture, utensils, hardware, equipment, containers, rubber products, tires, cars, trucks, planes, trains, ships, bridges, ports, piers, stadiums, buildings, as well as any other unused, obsolete or discarded product or material. E-waste also includes peripherals. Personal computer e-waste peripherals include printers, monitors, keyboards, mice, etc. E-waste associated with demolished buildings includes wiring, lamps, HVAC systems, water heaters, ducting, lighting, refrigerators, stoves, dishwashers, etc. Natural disasters, like Hurricane Sandy, generate massive amounts of e-waste that could be processed to generate funds for reconstruction.

Compared to organic MSW material, scrap has (1) much higher monetary value, (2) much greater contribution to mitigation of GHG emissions and energy conservation of virgin metals and minerals, and (3) much higher employment potential if affordable advanced technology MRFs were located in several hundred US communities.

In Europe where waste processing is mandated, MRFs usually operate at full capacity (3 shifts per day) using feedstock generated by as little as 300,000 people. The US has a population of over 320,000,000 that could mathematically support 1,000 such MRFs. As compared to the rest of the world, Americans cast off significantly more scrap items than the rest of the world.

The World Bank[3] calculates that Americans cast off 5.7 pounds of MSW per capita per year, versus 4.4 in Europe (average of Germany, UK and France), 3.8 pounds in Japan, 2.2 pounds in China and Brazil, and 0.7 pounds in India. By 2025, Americans are projected to decrease MSW generation by 11%, Europeans and Japanese are projected to remain at the same level, and developing countries to increase substantially: India 106%, China 68% and Brazil 55%. Given the developing world's growing middle-class, waste will be as big an economic and employment opportunity as it is an environmental hazard.

Germany, the Netherlands, Sweden, Belgium Austria and Denmark have largely phased out landfilling[4] in order to meet the EU's 2008 Waste Framework Directive requires recycling of at least 50% of household waste by 2020. Compliance with this mandate by these countries have led to the development of average advanced technology MRFs to process, segregate and reclaim valuable raw materials.

---

[2] Institute of Scrap Recycling Industries, Inc. (ISRI), Economic Impact Study U.S.-Based Scrap Recycling Industry (2013), http://www.isri.org/docs/default-source/recycling-analysis-(reports-studies)/economic-impact-study-u-s-based-scrap-recycling-industry-2013.pdf?sfvrsn=8

[3] The World Bank, What a Waste: A Global Review of Solid Waste Management, Annex J, MSW Generation by Country, http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTURBANDEVELOPMENT/0,,contentMDK:23172887~pagePK:210058~piPK:210062~theSitePK:337178,00.html

[4] EurActiv, Landfills continue to rule despite EU recycling target, http://www.euractiv.com/sustainability/landfills-continue-rule-despite-news-518229

The average equipment cost of an average advanced technology MRF is between $10M and $20M as compared to the $200M average for a waste-to-energy plant that converts MSW to electricity, compost, char or synthetic gases/oils. At full capacity, MRFs employ up to 200 direct and 300 indirect/induced personnel. 1,000 advanced technology MRFs could therefore employ 500,000 Americans. In the near term, 100 MRFs are clearly achievable producing 50,000 jobs and providing a revenue stream for cash-starved municipalities.

The highest value scrap is electronic waste, or Waste Electrical and Electronic Equipment, WEEE, which is the nomenclature of the European Commission. The US EPA uses a narrow definition of e-waste that includes computer-related devices, televisions, hard copy devices and mobile devices. Europe's WEEE definition is much broader and covers any end-of-life electrical and electronic equipment that has a plug or battery.

E-waste contains precious metals and other highly valuable materials. Metal deposits in e-waste are up to 30 to 50 times richer than ore extracted from mines. For example, one ton of gold ore yields about 5 grams of gold, but one ton of phone circuitry yields about 150 grams, 30 times as much[5]. A ton of cellphones (6,000 units) yields approximately $15,000 in precious metals. Computers and servers are also a source for precious metals. Due to the advent of cloud computing and mobile devices, about 400 million US personal computers are in use and ready for end-of-life management. An average PC weighs 20 pounds, so 400 million PCs represents 8 billion pounds of feedstock. It is probably safe to say that every PC has three times its weight in peripherals, generating a total of 32 billion pounds, or 16 million tons of feedstock—enough to keep 530 five-ton per hour MRFs operating three shifts (20 hours for 300 days per year).

E-waste also includes hazardous (toxic, corrosive, flammable or reactive) substances that are a risk human health and to the environment. According to the International Environmental Technology Center[6], 50 million tons of e-waste is produced globally each year, of which, only 15% to 20% is recycled and the rest is landfilled or incinerated. Most of toxic heavy metals in landfills are from e-waste—the US ratio is 70%—that include substances like lead, mercury, cadmium and beryllium, as well as hazardous chemicals and polluting plastics.

According to the EPA, e-waste is the fastest growing waste stream in America, but only 25% is collected for recycling[7] with the remainder landfilled. Of the recycled 25%, it is estimated that four-fifths are exported to foreign recyclers (many in third world countries often with child laborers working in toxic e-waste dumps) and one-fifth is recycled domestically in the US. The EPA admits that reliable data on exports is not available.

The pictures to the right were taken by a Jobenomics team member during a recent visit to a Chinese urban mining center. These pictures show Chinese workers removing discarded US printed circuit boards (PCBs) and central processing units (CPS) from 40-foot containers (stacked seven containers high and many containers wide) that were recently shipped from California.

PCBs and CPUs are highly valuable and should be processed in America as opposed to exporting. Using advanced technology MRFs similar to ones that are operational across China and Europe, every American community (city, country or region) with populations greater than 300,000 could be earning $30 million per year by processing its indigenous e-waste as well as creating up to 500 direct and indirect jobs.

---

[5] The Diplomat, The Potential of Urban Mining, http://thediplomat.com/2013/11/the-potential-of-urban-mining/
[6] UNEP, International Environmental Technology Center, Policy Brief on E-waste: What, When and How, http://www.unep.org/ietc/Portals/136/Other%20documents/PolicyBriefs/13052013_E-Waste%20Policy%20brief.pdf
[7] EPA, General Information on E-Waste, http://www.epa.gov/osw/conserve/materials/ecycling/faq.htm#recycled

From an environmental perspective, the good news is that China is shutting down its notorious toxic e-waste dumps, limiting e-waste imports to only pre-possessed items and developing state-of-the-art urban mining centers that process the full range of organic and non-organic materials. These actions will make a significant energy conservation contribution to the climate change equation as well as significantly reducing environmental disruption and pollution associated with surface and sub-surface mining.

According to the US EPA, developing nations will soon be discarding more e-waste than the developed word. In the last two decades, China has increased computer usage from 10 million computer users in 1997 to over 400 million internet users today. China is the largest producer of electronic equipment. According to the International Business Times[8], in 2011, China produced 90% of the world's personal computers, 80% of all air conditioners, 80% of all energy-saving lamps, 74% of all solar cells and 70.6% of all mobile phones. Given the relatively short life-spans of consumer electronics, wonder China putting urban mining in high gear.

On a more sinister note, a Senate Armed Services Committee[9] report stated that "much of the material used to make counterfeit electronic parts is electronic waste, or e-waste, shipped from the United States and the rest of the world to China." While national security is a major concern, these counterfeits find their way into products across a wide range of American industries, including telecommunications, healthcare, transportation, and consumer electronics. Consequently, e-waste end-of-life management impacts not only energy conservation, economics, environment and employment issues, but security as well.

Over the last several years, Jobenomics conducted dozens of meetings with US mayors regarding how to monetize e-waste streams and use the revenue for jobs creation. Virtually all of the city managers (mayors, city councils, solid waste managers) were unaware that they were foregoing such a lucrative source of revenue. City managers were very interested in how Europeans were monetizing their waste streams and Jobenomics/eCyclingUSA's efforts to bring advanced technology MRFs to America.

Over 100 state-of-the-art e-waste MRFs are in operation in Europe. Advanced technology MRFs can shred electronics and appliances to the pellet or powder level, and then collate the raw materials by type (copper, aluminum, iron and plastics) and color. A typical system can process an appliance as large as a refrigerator in one minute in a closed environment to prevent any leakage, like CFCs, into the environment. US designed equipment can accommodate e-waste as large as two-door refrigerators (American refrigerators are larger than European). These large capacity machines can also accommodate similar sized equipment like computer racks, medical equipment and vending machines. The US is in the process of transitioning from coin-operated vending machines to high-tech machines that accept credit cards and mobile payments, and feature digital screens, video cameras, and smartphone charging stations. As many as 5 million American vending machines are now obsolete and ready for e-waste end-of-life management.

---

[8] International Business Times, China Manufacturing: 10 Things The Chinese Make More Of Than Anyone Else In The World [Infographic], August 2013, http://www.ibtimes.com/china-manufacturing-10-things-chinese-make-more-anyone-else-world-infographic-1369727

[9] Electronics TakeBack Coalition, Commentary: E-Waste Export Policy Key to Stopping Electronics Counterfeits and Protecting Military Readiness, 26 September 2014, http://www.electronicstakeback.com/2014/09/29/commentary-e-waste-export-policy-key-to-stopping-electronics-counterfeits-and-protecting-military-readiness/

Many city managers were unaware that their policies encouraged exporting their electronic waste overseas. Many solid waste managers acknowledged that they use companies to handpick high-value electronic waste items for shipment overseas using the same 40 foot containers (now empty) that brought foreign electronics into the US. These solid waste managers and their bosses were pleased that they received payment for these handpicked items up to $10 per ton. They were not so pleased when they were informed that advanced technology MRFs can generate revenues up to $1,165 per ton.

Turnkey advanced technology e-waste MRFs can be operational within a year, profitable during the first year, and debt free (pay-back investors) within two years thereafter. The two major investment issues involve the availability of feedstock, which could largely be solved by government mandates, and commodity prices, which have recently dropped by around 25% but are expected to increase to all-time highs. As the world's growing middle class demands more electrically-powered gadgets and the Internet-of-Things connects more electronics to things than people, commodity prices are likely to rise.

Typical Plant

eCYCLING USA

Large plant (10 ton/hour)
- ≈ $20 million
- ≈ 40,000 square foot facility
- ≈ 10 to 15 acres of land

Small plant (3-5 ton/hour)
- ≈ $10 million
- ≈ 15,000 square foot facility
- ≈ 3 to 10 acres of land

10 months to build and install.

$ Value of e-Waste Raw Materials

For Rough Estimating Only

Feedstock: Computers, Consumer Electronics, Small and Large Applicances

Metal/Material	% of Feedstock	$s per Metric Ton*	$/Ton (2204 pounds)	Total $/Year (10 ton/hour x 22 hour/day x 300 days/year)
Iron/Steel (Fe)	15%	$ 260	$ 39.00	$ 2,574,000
Copper (Cu)	5%	$ 5,223	$ 261.17	$ 17,237,484
Aluminum (Al)	20%	$ 1,565	$ 312.97	$ 20,655,888
ABS Plastics	10%	$ 1,984	$ 198.36	$ 13,091,760
Other Plastics/Foam	40%	$ 683	$ 273.30	$ 18,037,536
Telephones/Printers/Fax	3%	$ 602	$ 18.05	$ 1,191,350
Electric Motors	2%	$ 2,226	$ 44.52	$ 2,938,373
Computer Components**	5%	$ 3,938	$ 196.89	$ 12,995,026
Source: Jobenomics, eCyclingUSA	100%	$ 16,481	$ 1,344	**$ 88,721,417** Revenue***
				$ 30,238,000 Cost of goods sold****
				$ 5,780,000 Operating expenses****
				$ 52,703,417 Net Income
				59% EBITDA

*Scrap prices as of 23 July 2015

**Manual disassemby of unprocessed computer components

***Does not include grants, tax incentives, carbon credits or tipping fees

****10 ton/hour plant operating 3 shifts per day for 300 days per year

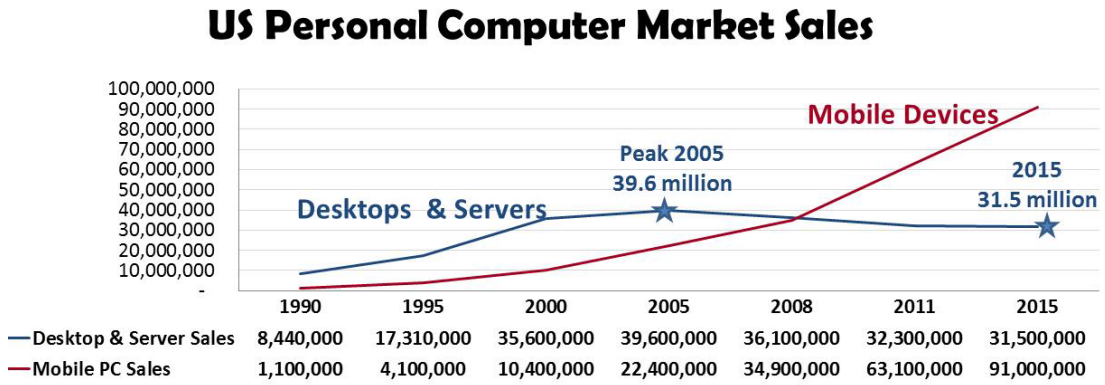
**Unprocessed Computer Components	% of Feedstock	$s per Pound*	$/Ton (2204 pounds)
Central Processing Units	1%	$ 30.00	$ 661.20
Memory Chips	1%	$ 12.00	$ 264.48
Cell Phones	3%	$ 4.04	$ 267.12
Laptops	20%	$ 0.50	$ 220.40
Hard Drives	20%	$ 0.91	$ 401.13
Mother Boards	15%	$ 3.00	$ 991.80
Medium Grade Boards	10%	$ 0.90	$ 198.36
Low Grade Boards/Wiring	5%	$ 0.19	$ 20.94
Power Supplies	10%	$ 3.84	$ 846.34
Misc	15%	$ 0.20	$ 66.12
Source: Jobenomics, eCyclingUSA	100%	$ 55.58	**$ 3,938**

With a $25 million, 10 ton/hour, advanced technology e-waste MRF, a medium-sized city could generate up to $88 million annual revenue with $53 million annual profits after the first year of operation[10]. Average payback period for an advanced technology e-waste MRF is typically less than three years, which is significantly shorter than most renewable energy technologies.

A basic understanding of the revenue and profit calculation is important to understanding why e-waste reclamation should such a highly lucrative business enterprise. The calculation is based on a feedstock mix of computers, consumer electronics, and small and large appliances. Metal and material content figures are generally well established by the scrap industry. The dollar value for metals, plastics, glass and PCBs are updated daily on multiple e-commerce websites, such as Scrap Register[11], Scrap Monster[12] and Alibaba[13]—the world's largest e-commerce site that is owned and operated by the Chinese, the largest commodity-buyers in the world. As calculated above, the value per metric ton of the feedstock mix is $1,344. On a yearly basis, a 10 tons/hour MRF, operating 20 hours a day for 330 days per year, would produce $88,712,417 worth of revenue. After expenses, it would yield approximately an EBIDTA of 59%, or $52,703,417 per year. Note: this calculation does not include tipping fees, grants, tax abatements, or carbon credits which would enhance revenue and profitability. It also does not include advanced computer component processing systems that are in development. For example, #2 Insulated Wire (common small appliance wires) sells for $1.01 per pound, but would yield $2.51 if processed for the pure copper, a 149% increase.

It is important to note that the commodity prices listed on the chart represent clean or highly pure fractions, which can be sustainably achieved by MRFs that have advanced technologies, such as optical sorters and infrared scanners. Commodity prices are highly sensitive to purity—the higher the purity, the higher the profit. For example, 99% pure copper sells close to the spot price of copper of $5,223 per ton, whereas as 80% pure copper (called dirty copper that contains other heavy metals like brass) only reaps around $3,000 per ton.

There are also ways to increase profitability by increasing the amount of items that contain precious metals (computers, servers and cellphones) in the mix. As of February 2015, e-waste components sold as high as $26.00 per pound. This is a partial price list: CPU processors $30.00/pound, memory chips $12.00/pound, cell phones $4.04/pound, motherboards $3.00/pound, hard drives $0.90/pound, medium grade printed circuit boards @ $0.88/pound, and low grade printed circuit boards $0.19/pound. An average personal computer has 6 pounds of these high value components.



[10] These figures are calculated on scrap prices as of 23 July 2015 based on a feedstock mix containing a reasonably high content of precious and high-value common metals. Lower quality or insufficient supplies of feedstock will result in lower revenues and profits.

[11] Scrap Register, http://www.scrapregister.com/scrap-prices/united-states/260

[12] Scrap Monster, http://www.scrapmonster.com/scrap-prices

[13] Alibaba, http://www.alibaba.com/Metallurgy-Chemicals-Rubber_Plastics_m6

With the advent of cloud computing and mobile devices, some people believe the era of the personal computer is over in the United States. While personal computer sales are down from its peak of 39,600,000 in 2005, PC sales have stabilized at approximately 31, 500,000 per year. On the other hand, mobile device sales have exploded as shown to 91,000,000 in 2015. Mobile devices are sources of high-value e-waste materials and precious metals. When one considers the concept of the "Internet of Everything", the CISCO motto, forecasters believe that both PCs (servers and desktops) and mobile devices (smartphones, pads and tablets) sales will continue to increase in the foreseeable future. Moreover, if every day items are embedded with printed circuit boards to make them smarter and "Internet of Everything" compatible, the e-waste stream will not only get bigger but more valuable.

In 2014, approximately 350 million computers were sold globally, of which 137 million were PCs. Worldwide, 2 billion PCs are currently in operation will be soon ready for end-of-life management[14]. By 2018, PC production will drop 12% to 121 million. On the other hand, 1.2 billion smartphones and 1.1 billion tablets, phabets (a smartphone having a screen which is between the size of a typical smartphone and a tablet) and other portables are projected for production, up from near-zero in 2012[15]. Until Americans stop exporting or landfilling 95% of this e-waste, it will miss out on a huge economic and employment opportunity. If US policy-makers would enact some form of e-waste mandates, these mandates would generate sufficient investor interest to construct advanced technology e-waste MRFs across America. Due to urban mining properties compared to virgin mining (traditional surface and subsurface mining operations), the material recovery industry offers a potential energy conservation contribution that is unmatched by any other single technology.

[14] Worldometers, Forrester Research, http://www.worldometers.info/computers/
[15] International Data Corporation Worldwide Quarterly Smart Connected Device Tracker, 3 September 2014, http://www.idc.com/getdoc.jsp?containerId=prUS25077914