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The Economic Potential of E-Waste Recycling in Minnesota

A Pilot Study

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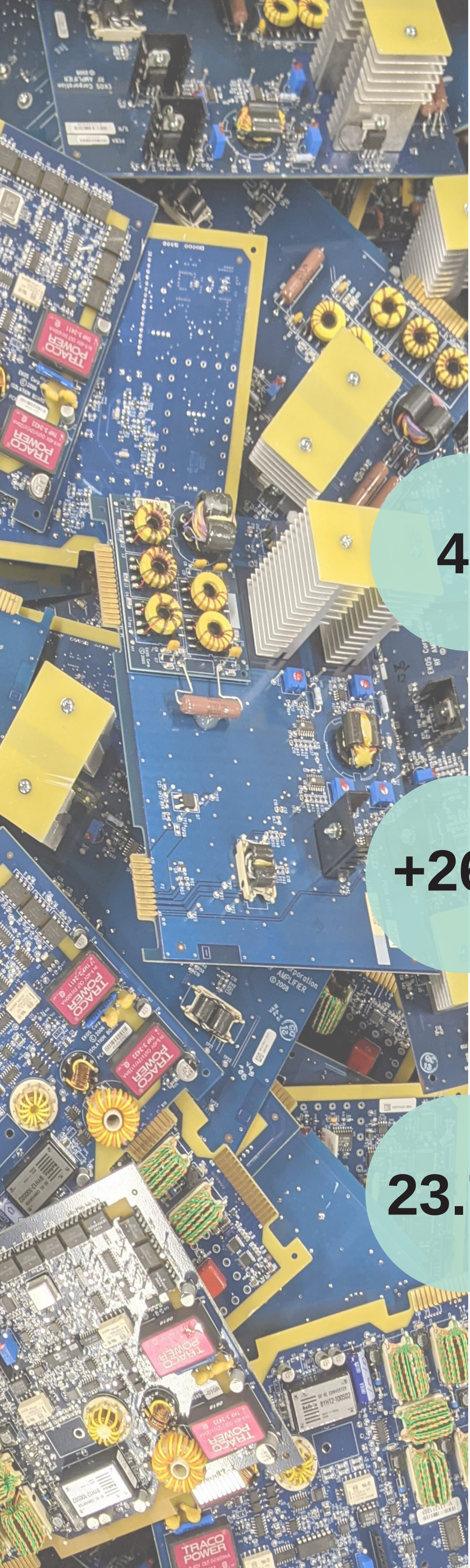


E-waste by the numbers...

46

pounds per person

The U.S. currently generates about 46 pounds of e-waste per capita annually.[1]

+266

million pounds annually

Over 266 million pounds of e-waste is available for recycling in Minnesota every year.

23.7%

of e-waste captured

Minnesota only captures 23.7% of e-waste for recycling; much of the remainder gets into traditional waste streams. [12,17]

Background

Electronic waste is the fastest growing waste stream in the world, and it is full of valuable metals.[1] Although some traditional e-waste streams such as cathode-ray tube (CRT) TVs and VCR and DVD devices are declining, new electronic devices are coming onto the market more rapidly and will maintain an increasing e-waste stream.[2-13] E-waste, also referred to as WEEE (waste electrical and electronic equipment), is growing at an annual rate of 3-5% globally. [4,13-16] E-waste includes information technology equipment, communications equipment, as well as household appliances. The US currently generates about 46 pounds of e-waste per capita annually [(P.72),1,3] Minnesota only captures 23.7% of e-waste for recycling; much of the remainder gets into traditional waste streams.[12,17]

Landfilling or incinerating e-waste causes significant pollution and health problems. For example, 70% of the heavy metals (i.e., lead, mercury) present in landfills come from e-waste.[18] Heavy metals cause a myriad of health effects, such as neurodegenerative effects, which are especially severe in children.[19-23] Throwing away electronics also wastes valuable material. By weight, metals account for 60% of the material composition of e-waste. The metals found in e-waste include copper, nickel, palladium, iron, lead, tin, aluminum, and zinc, among others.[14,24-25] Metals are infinitely recyclable.[26] The avoided toxicity and high quality of recycled products makes recycling e-waste a win-win proposition for environmental and human health.

E-waste is also a promising source for metals that are facing increasing demand due to the transition to renewable energy. The International Energy Agency estimates that in order to reach net zero emissions by 2050, metal demand will increase 6-fold compared to 2022 levels.[27] Legislation such as the Inflation Reduction Act provides billions of dollars for electrification, energy storage, and wind and solar power, and finding responsible sources of metals to service these technologies is a national priority.[28] This study provides insight into the potential for e-waste to meet this demand by estimating the total weight of sixty-eight elements available for recycling within Minnesota's e-waste stream.

The authors of this study came together from industry, environmental activism, and academia. Repowered is a non-profit e-waste recycling and refurbishing company and one of the largest collectors in the state of Minnesota. Iron Range Partnership for Sustainability is an organization based in Virginia, Minnesota, whose mission is to facilitate collaboration toward a sustainable and thriving Iron Range. Dr. Roopali Phadke, a professor from Macalester College, has conducted research on recovery and sustainable use of precious metals. The group approached the subject matter with the lens of sustainable job creation for Northern Minnesota, and to that end, envisions this work as a pilot study that will lead the way to further research and investment in Minnesota's e-waste recycling capacity.

At a 100% recycling rate, Minnesota's e-waste stream could supply enough copper for 155,000 EVs per year.[73]

Study
Methodology

Using peer reviewed research, reports, and local data on e-waste, this study documents the elemental content in fourteen categories of e-waste. The research used in this study ranges predominantly from 2017 to 2022, with two studies each in the years 2011 to 2015 and one study from 2002.

01

Categorizing e-waste: An e-waste recycling facility based in St. Paul, MN provided data on e-waste category types and the proportion of each category by weight in a typical e-waste stream (see Figure 1). Data on white goods (I.e., refrigerators, washing machines etc.), which typically make up about 50% of e-waste, was added to the facility data based on the findings of Ongondo (2011).[29]

Figure 1: Categorization of materials mix from a sample e-waste collection facility

50.0%	3,013,619 lbs - White Goods (refrigerators, washing machines, etc.)
12.5%	755,705 lbs - IT and Personal Display
8.0%	483,855 lbs - Printers
6.5%	391,017 lbs - PCB & Memory Boards
5.7%	342,067 lbs - Scrap Metals
3.2%	190,831 lbs - Consumer Electronics
3.0%	181,685 lbs - Small Household Appliances
2.8%	166,277 lbs - Waste & Plastic
2.4%	143,820 lbs - Laptops, Notebooks, Tablets
1.9%	111,949 lbs - IT and Networking
1.9%	111,804 lbs - Low Grade Scrap
1.4%	83,508 lbs - Batteries
0.6%	34,280 lbs - Miscellaneous
0.3%	15,729 lbs - Lighting
	6,026,147 lbs

Study
Methodology *continued...*

02 **Literature review:** A comprehensive literature review was conducted to yield the proportion and weight of sixty-eight elements present in each e-waste category. For example, Buechler (2020) provided data on the breakout of fifty-six different elements in ten categories of e-waste. Data from ten similar studies were aggregated to understand the elemental composition of each e-waste category. There are many variations of batteries in the e-waste stream. For batteries, specific studies that established element content were used along with one manufacturer's data sheet.[24, 30-46]

03 **Minnesota:** The population data used is the projected population for the state of Minnesota in 2023 (reference results section).[47] The per capita e-waste generation in the US provides the basis for calculating the total weight of e-waste available for recycling in the state of Minnesota.[1]

04 **Calculation of value:** Where current market value data was available, the value of each element as of January 2023, was multiplied by the respective portion of the total weight and was used to calculate the total annual value of e-waste in Minnesota.[48-71]

05 **Jobs:** According to the Coalition for American Electronics Recycling Jobs report, e-waste collection, demanufacturing, shredding and information technology asset collection/refurbishing activities generate one full time job for each 172,000 pounds of e-waste processed.[20, 72, 75] This does not include any jobs involved in a final materials recovery process.

Findings

At a 100% e-waste recycling rate in Minnesota, the following amount of "Top 10 Elements" made available (by weight in pounds) would be:

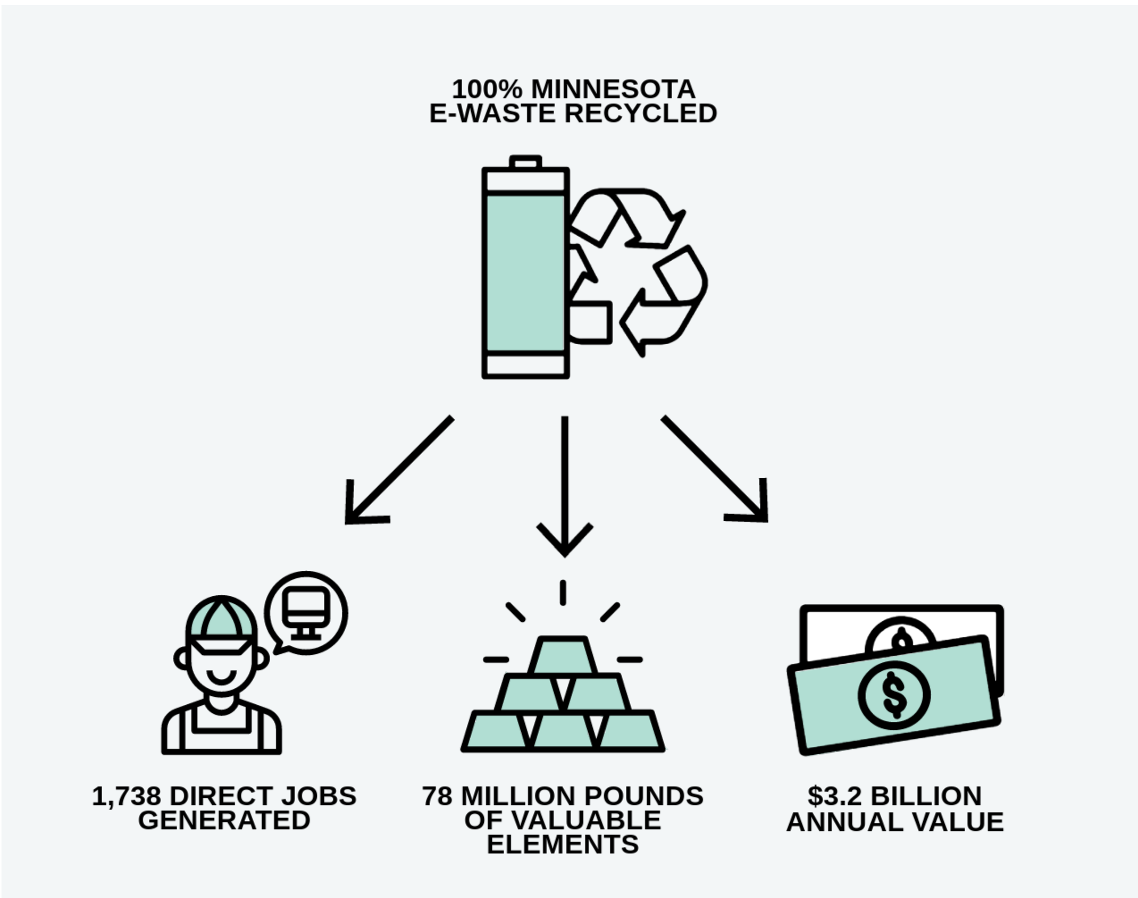
Figure 2: MN 2023 Total e-Waste Top 10 by WEIGHT		
Element	**Weight (lbs)**	**Percent**
Iron	**31,948,426**	40.6%
Copper	**25,350,177**	32.2%
Tin	**7,575,259**	9.6%
Aluminium	**6,669,743**	8.5%
Lead	**2,596,846**	3.3%
Zinc	**1,966,195**	2.5%
Barium	**564,601**	0.7%
Nickel	**309,746**	0.4%
Sulfur	**283,289**	0.4%
Manganese	**216,608**	0.3%
58 Other Elements	**1,141,272**	1.5%
Total Weight	78,622,162	100.0%

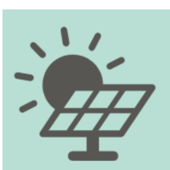
The value (in USD) of the "Top 10 Elements" at a 100% e-waste recycling rate in Minnesota would be:

Figure 3: MN 2023 Total e-Waste Top 10 by VALUE		
Element	**Value US $**	**Percent**
Palladium	**1,519,264,623**	47.8%
Platinum	**1,036,326,242**	32.6%
Gold	**343,116,072**	10.8%
Copper	**107,432,898**	3.4%
Tin	**100,940,322**	3.2%
Lithium	**14,287,284**	0.4%
Iron	**11,725,072**	0.4%
Aluminium	**7,997,629**	0.3%
Silver	**5,940,166**	0.2%
Ruthenium	**5,806,676**	0.2%
58 Other Elements	**28,335,108**	0.9%
Total Value	**3,181,172,092**	100.0%

RESULTS

Over 266 million pounds of e-waste is available for recycling in Minnesota every year, including 78 million pounds of the sixty-eight valuable elements identified in this study. Based on the aforementioned market prices, the total estimated value of the sixty-eight elements in a single year's worth of e-waste generated in Minnesota is $3.2 billion. The projected job creation, if 100% of e-waste in Minnesota were to be captured for recycling or refurbishment (not including the final step of material recovery), is 1,738 direct jobs, and a total of 3,345 new jobs. Figure 2 gives a breakout of the top ten elements by weight, and Figure 3 gives the top ten elements by value.





441,000 solar panels

At a 100% recycling rate, Minnesota would have enough silver to produce 441,000 solar panels per year from its e-waste.[46]

155,000 EVs

At a 100% recycling rate, Minnesota's e-waste stream could supply enough copper for 155,000 EVs per year.[73]

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