Part IV:
Quantifying the Benefits of WEEE Recycling

Using Life Cycle Assessment (LCA)

The objective of LCA is to inform decision making by identifying changes at every stage of a product's life cycle that can reduce its environmental impact and overall cost. The result is a full-cost accounting of the true impact that diversion programs, such as WEEE, can have in terms of the environmental and human health savings to society.

The life cycle of a product comprises several phases, including production, distribution, consumption, and end-of-life management, as well as the upstream and downstream processes associated with production (e.g., the extraction of raw materials) and disposal (e.g., the collection, processing, hauling, and disposal or recycling). LCA illustrates the importance of fully accounting for the broad range of environmental impacts of a product throughout its life cycle, rather than focusing on a single impact, such as climate change. Environmental impacts can be defined as all things that affect the environment, including extractions from the environment (e.g., ores, crude oil) and emissions to the same (e.g., waste, carbon dioxide, methane).

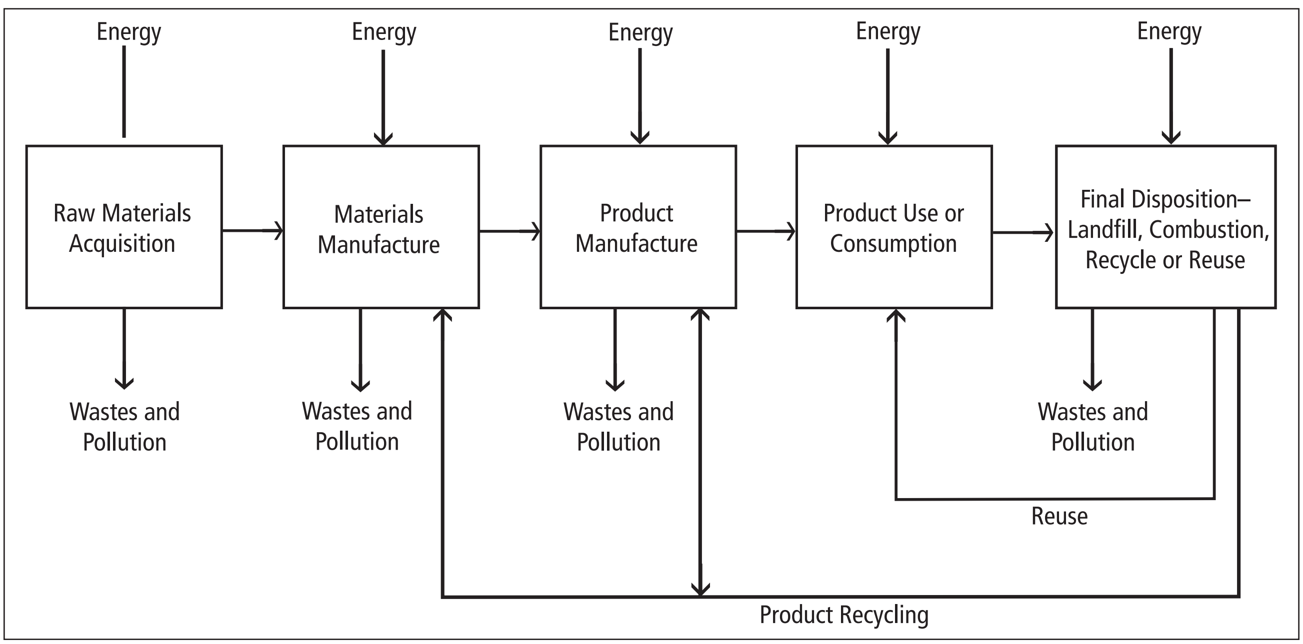
Benefits of Reusing and Recycling WEEE

The environmental benefits from WEEE diversion programs are drawn from the associated benefits of recycling, which include the environmental impacts of recycling (collection, processing, hauling), the avoided environmental impacts of raw material acquisition and manufacturing, attained when recyclables are used instead of virgin resources, as well as the avoided impact of waste disposal (landfill). Recycling WEEE products diminishes most or all of the inputs needed to manufacture the replacement product from virgin materials. Avoiding these "upstream" processes significantly reduces energy usage, associated greenhouse gas (GHG) emissions, and other pollutant emissions as well. Recycling desktop and laptop computers, for instance, has conserved approximately 86 and 89 gigajoules (GJ) of energy per tonne respectively, whereas recycling computer peripherals and printing devices conserves only 69 GJ per tonne.

Categorizing Pollution

As noted earlier, waste diversion programs are traditionally evaluated based on the weight (tonnage) or volume of materials diverted. Unfortunately, neither of

Figure 3: Typical product life cycle



these parameters are indicators of the environmental impacts these materials have when they are diverted or disposed. For instance, they provide no information on the amount of pollution avoided by reusing or recycling a product instead of manufacturing a new one with virgin material. This circumstance makes it difficult for lay people and, more importantly, decision makers to see the benefits of diversion in terms of its real effect on human health and the environment.

To remedy this problem, Sound Resource Management's MEBCalc™ (Measuring the Environmental Benefits Calculator) provides a new set of measurement parameters that are much more meaningful in terms of environmental impact. The calculator measures the environmental benefits of diversion in terms of seven categories of pollutants, each of which is related to a distinct set of environmental impacts.

These categories and some of the pollutants that cause the environmental effects measured are as follows:

1) **Climate change** (measured as carbon dioxide equivalents (C02e)—characterizes the potential increase in greenhouse effects as a result of human-caused emissions. CO2 from fossil fuel combustion is the largest source of greenhouse gases (GHGs).

2) **Human respiratory health** (measured as particulate matter ≤ 2.5 microns equivalents)—characterizes potential human health impacts from anthropogenic releases of coarse particles, fine particles, and particular precursors that are known to exacerbate respiratory conditions such as asthma or lead to more serious respiratory symptoms and diseases.

3) **Human toxicity** (measured as toluene equivalents)—characterizes potential human health impacts from releases of chemicals and heavy metal pollutants that are toxic to humans, including 2,4-D, benzene, DDT, formaldehyde, permethrin, toluene, chromium, copper, lead, mercury, silver, and zinc.

4) **Human carcinogens** (measured as benzene equivalents) – characterizes potential human health impacts from releases of chemicals and heavy metal pollutants that cause cancer in humans, including 2,4-D, benzene, DDT, formaldehyde, kepone, permethrin, chromium, and lead.

5) **Eutrophication** (measured as nitrogen equivalents)—characterizes the potential environmental impacts from adding mineral nutrients, such as nitrogen and phosphorous, to soil or water. These impacts can include shifts in the number of species in ecosystems, reduced ecological diversity, and increased algal production and the associated effects on fish and other species.

6) **Acidification** (measured as sulfur dioxide equivalents)—characterizes the potential environmental effects from anthropogenic releases of acidifying compounds, primarily from the burning of fossil fuels and biomass, which affect vegetation, soil, buildings, animals, and humans.

7) **Ecosystem toxicity** (measured as 2,4-D equivalents)—characterizes the potential for chemicals and heavy metals released into the environment to have a negative impact on terrestrial and aquatic ecosystems, including wildlife.

Monetizing Pollution

Each pollutant has a different effect on the environment and human health, so comparing the impacts of various pollutants is difficult. In order to make pollution data easier to understand and analyze, MEBCalc™ applies monetary values (in this case Canadian dollars) to each pollutant category based on either the estimated real financial costs to society in terms of environmental harm and human health impact or the actual market value of the pollutant's emissions established through trading schemes such as auctions for the US EPA's sulfur dioxide emissions permits under the Clean Air Act provisions for controlling acid rain.

Table 4: Avoided environmental impact value per tonne

CLIMATE CHANGE	HUMAN RESPIRATORY HEALTH	HUMAN TOXICITY	HUMAN CARCINOGENS	EUTROPHICATION	ACIDIFICATION	ECOSYSTEM TOXICITY
eCO_2	ePM2.5	eToluene	eBenzene	eN	eSO2	e2,4-D
$50	$13,779	$162	$4,175	$6	$668	$4,519

Net Environmental Impact (tonnes) X Monetized Value ($/tonne) = Net Environmental Benefit

After the pollution impact is measured for each category for each recycled or reused material, a monetary value is assigned to the pollution benefit reduction associated with reuse and recycling. Reuse and recycling are credited for saving energy and virgin material resources. The credit is based on avoided energy costs and their environmental effects, as well as avoided pollution from primary resource extraction, manufacturing, and related transportation.

Monetization provides decision makers with a quantitative tool for evaluating the trade-offs among the seven types of environmental effects to see where the greatest benefits can be gained through recycling or reuse. It also allows us to compare the environmental benefits to the financial costs of the various waste management options.

To calculate the dollar value of the environmental and human health benefits of diversion, MEBCalc multiplies the avoided pollution amount for each material diverted by its monetized value, as shown in Table 3. The net benefit is the monetized value of the avoided human health and environmental impact caused by pollution.

Understanding the Benefits of Recycling WEEE

To determine the environmental impact of WEEE recycling programs across Canada, actual WEEE tonnage diverted in a year is used as an input to MEBCalc. A study was conducted on the environmental benefits of Ontario's WEEE diversion program in 2007, and it was found that, on a per tonne basis, recycling desktop computers contributed the greatest environmental benefit at more than $975 per tonne, accounting for approximately 51% of the total. Recycling monitors was next at 29%, and printers were at 9%, with televisions in last place but still providing environmental benefits of $229 per tonne. Based on program targets, it is anticipated that TV recycling will account for an increasingly greater share of the environmental benefit as the WEEE recycling program matures. The economic value of the environmental benefits of recycling different types of WEEE is shown in Figure 4.

From a pollution perspective, the greatest benefits are reductions of toxics to humans that would have been released to the environment if the recycled WEEE products had instead been landfilled and virgin resources were used to produce the products manufactured, rather than materials recycled from discarded WEEE. The economic benefits are drawn from the benefits associated with avoided potential human health costs. Savings in GHG emissions and in emissions that cause respiratory illnesses come in second and third, respectively. Figure 5 shows MEBCalc's valuation for the public health and ecological benefits from recycling WEEE for each impact category.

The results of this analysis emphasize the need to collect greater amounts of WEEE for recycling, with a particular emphasis on those products that produce the greatest environmental benefits because of their diversion.

Figure 4: Environmental benefit of recycling WEEE per tonne (monetized into Canadian $ for Ontario 2007)

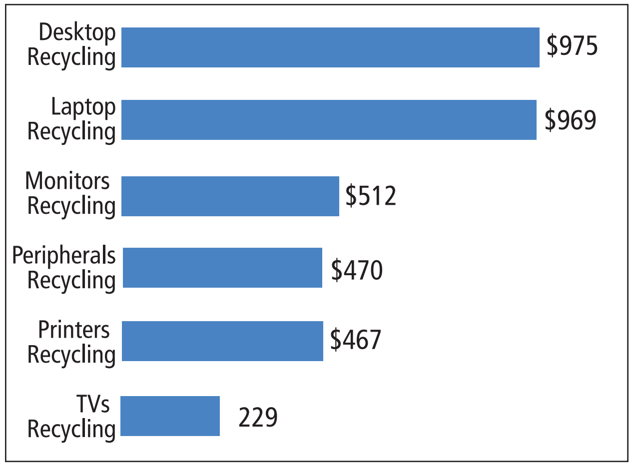
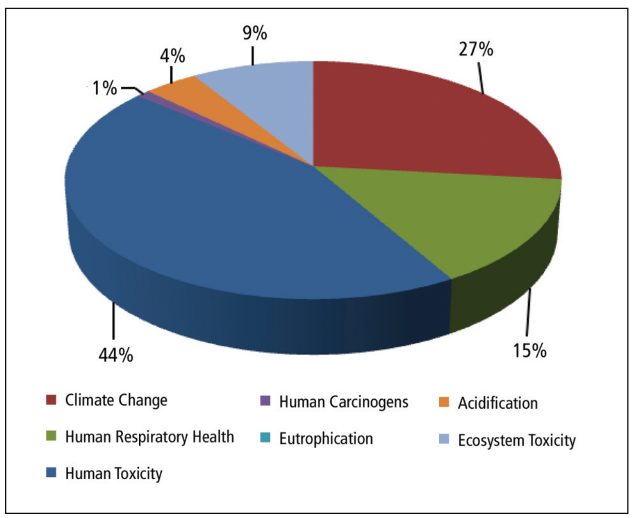


Figure 5: Share of pollution reduction benefit from recycling WEEE (per tonne)



Monetizing the Benefits of Reusing WEEE Discards

Though recycling WEEE has a significant impact in terms of avoiding the pollution that would have been generated if new electronic products had been created from virgin resources, WEEE reuse provides environmental benefits that are orders of magnitude larger than the benefits from WEEE recycling. These greater benefits result because the environmental impacts of reuse involve mainly refurbishing, which has a fraction of the effect on the environment that manufacturing new electronic products has (see Table 5). The importance of reuse over recycling is also explained by the fact that the recycling of electronic equipment under presently available technologies involves reducing a complex piece of equipment to shards of metal, plastic, and glass. While these materials are recyclable, the integral value they had prior to shredding is a large multiple of the value of the shards.

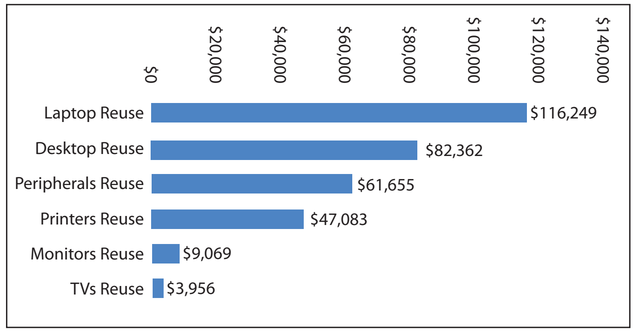
Table 5: Refurbishing energy and emission impact as a proportion of new product impact

TVs Recycling	20%
Printers Recycling	10%
Peripherals Recycling	1%
Monitors Recycling	5%
Laptop Recycling	10%
Desktop Recycling	10%

Measuring the environmental impact of WEEE reuse requires comparing the environmental impact of not having to manufacture new products as well as the impacts associated with raw material extraction for all the component metal, glass, and plastic materials that make up electronic equipment. It is estimated that processing WEEE products for reuse has a significantly lower energy impact than processing the same material for recycling, given that there is no shredding or grinding of material.

Reusing desktop and laptop computers, for instance, has an avoided energy impact of 587 and 1,234 GJ per tonne respectively, and provides the greatest environmental benefit per tonne. Reuse of computer peripherals and printing devices also have substantial benefits as a result of the avoided production of new products, but these benefits are smaller. The economic value of the environmental benefits of reusing different types of WEEE is shown in Figure 6.

Figure 6: Environmental benefit of reusing WEEE per tonne (monetized into Canadian $)



Although these energy savings are real, it is important to take into account the energy impacts of refurbishing activities and of the manufacture of replacement parts. It is also important to consider the additional usage of electricity that may result because of the continuance in the marketplace of older computers or television sets that are less energy efficient. These energy and environmental impacts will offset some portion of the upstream benefits of reusing WEEE products. If the energy inefficiencies of older products are substantial compared to those of new products, reuse could result in increased energy and environmental impacts.

In terms of particular types of environmental benefit, avoidance of emissions contributing to human toxicity, climate change, and ecosystems toxicity account for most of the environmental benefits gained from reusing WEEE products. Avoided human toxicity is by far the most important, accounting for 69% to 83% of the total environmental benefits for the six WEEE product categories collected in Ontario in 2007.

These data further emphasize the need to set up collection systems that prioritize reuse and repair over recycling in nearly all cases.