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# Methodology to Calculate Net Environmental Impacts of Refurbishing Various Products

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## Contents

## Project background

Anthesis has estimated environmental and financial savings associated with eBay consumer to consumer (C2C) and business to consumer (B2C) sales of used and refurbished products for a number of years. In 2023, the methodology for estimating the net environmental impacts of refurbishing was refined and applied to a series of products within the mobile tech, computing and home goods categories.

Avoided carbon emissions and avoided waste (landfill and incineration) were calculated for this study. This document describes the sources of external data, the calculations carried out, and the assumptions made for this case study.

## Key concepts

### Environmental impact categories

Carbon or greenhouse gas (GHG) emissions and waste are important environmental metrics that are relevant to the majority of products, can be easily communicated and are increasingly becoming requested by customers. These two environmental impact categories were calculated for this assessment.

### Impacts of displaced products

Through use of pre-owned and refurbished products, the cradle-to-gate life cycle environmental burdens of a new product are avoided. There is an environmental benefit from the reuse of a product because the extraction of raw materials, production, processing and upstream transport of the equivalent new product are no longer required. Similarly, the displaced product will not go to a waste stream because it was not manufactured, therefore avoiding landfill or incineration.

### New product displacement rate (DR)

New product displacement rate describes the proportion of reused product purchases that replace or displace the purchase of a new product. This parameter recognizes that some reused products are additional purchases that would not have been bought as new products – for example the purchase of a used laptop would probably displace the purchase of a new laptop, but a used garment might be purchased in addition to a new garment.

### Lifetime (New = LT, Reused/Refurbished = LT')

Re-using a second-hand product gives the product extra life (LT'), but a refurbished item may have shorter life than a new item (LT)– so more than one refurbished item would be needed to replace the full lifespan of a new item.

### Overall displacement rate (DR x LT'/LT)

Overall displacement rate is a combination of the new product displacement rate and the additional life. These two parameters are multiplied together to give the overall displacement rate.

### Net impacts of refurbishing

There are impacts associated with the refurbishing of a product including energy use in the refurbishing process, process efficiencies (some of the items going through the refurbishing process will go to end-of-life because they cannot be sufficiently refurbished for use) and manufacturing of replacement parts.

In addition, refurbishing can lead to net environmental impacts or net environmental savings if there are differences in transportation modes and distances to the user compared to shipping a new device.

Finally, the use of the displaced product is not avoided because the extended life of pre-owned products generates the same use-phase impact as new products would have generated. That said, refurbished products might use more electricity than new models.

## Environmental impacts of products and parts

eBay provided a list of products to assess as part of this case study. For each of these products, Anthesis identified a life cycle assessment (LCA) to calculate the carbon footprint of this product. Because the carbon footprint of a product category can vary widely, carbon footprints were expressed on an intensity basis. Anthesis also worked with eBay and eBay sellers to identify parts of each product that were likely to be replaced in the refurbishing process. The LCAs identified were also used to determine the carbon footprints of individual parts. Data sources are summarized in Table 1.

Table 1. Data sources for carbon footprint information

| Product Category | Product | Potential Replacement Parts |
|---|---|---|
| Mobile Tech | Smartphones | Battery, LCD, bakplate, camera, speakers |
| | Tablet | Battery, outside casing, screen |
| | Smartwatch | USB cable, strap, shell, PWB, battery |
| | Drone | Frame, propeller, camera, motor, battery |
| Computing | Laptop | Motherboard, screen, casing and keyboard, battery |
| | Monitor | Screen, motherboard |
| | Desktop | Hard drive, RAM, motherboard |
| Home Goods | Vacuum | Floor brush and furniture tool, flexible hose, hose collar, extension tube |
| | Chainsaw | Blade, chain, other steel parts |
| | Air Fryer | Basket |

Sources of carbon footprint information:
- Ecoinvent 3.8
- Ma et al. (2018)
- Neuberger (2017)
- Gallego-Schmid et al. (2016)
- Carvalho et al. (2017)

## Assumptions

For all devices, three scenarios were computed: an average case, a best case and a worst case:

- Average case: attempts to represent average conditions;
- Best case: puts most parameters at their best-case values while trying to remain realistic;
- Worst case: puts most parameters at their worst-case values, often by applying eBay Recommerce assumptions that are mostly suitable to reuse (not refurbished). The worst-case scenario is also typically used to investigate the potential implications of the refurbished device not being as energy-efficient in the use phase as newer models.

Assumptions made are summarized in the next sections.

### Additional life (LT'/LT)

The lifetime of refurbished devices is likely to be closer to that of new devices than that of products that are solely reused. For this case study, relative lifetimes were informed from sellers' interviews and the eBay Recommerce Methodology for reused product (see Table 2).

Table 2. Assumptions on Relative Lifetime of Refurbished Compared to New

| Product Category | Product | Average Case | Best Case | Worst Case |
|---|---|---|---|---|
| **Mobile Tech** | Smartphones | 90% | 90% | 70% |
| | Tablet | 90% | 90% | 70% |
| | Smartwatch | 90% | 90% | 70% |
| | Drone | 90% | 90% | 70% |
| **Computing** | Laptop | 85% | 100% | 70% |
| | Monitor | 90% | 90% | 70% |
| | Desktop | 90% | 90% | 70% |
| **Home Goods** | Vacuum | 90% | 90% | 70% |
| | Chainsaw | 90% | 90% | 70% |
| | Air Fryer | 90% | 90% | 70% |

## Displacement rate (DR)

The displacement rate of refurbished products is likely to be greater than that of reused product. Anthesis obtained information from eBay on the relative price of refurbished devices compared to new and then applied published price elasticity of demand ($e_p$) to calculate the displacement rate of the average and best case. Price elasticity of demand is the ratio of the percentage change in quantity demanded of a product to the percentage change in price:

$$e_p = \frac{\Delta Q\ (\%)}{\Delta P\ (\%)}$$

Where Q is the quantity demanded and P the price.

As the displacement rate is the percentage of refurbished devices that replace new products (i.e, not causing additional demand), the displacement rate calculated as follows:

$$DR = 1 - \Delta Q = 1 - e_p \Delta P$$

Price elasticities were obtained from the literature (Roberson 2016, Duch Brown et al. 2014, Fujita et al. 2008).

In the worst-case scenario, the same displacement rate used in the eBay Recommerce Methodology were applied. Sellers' interviews were also used to inform the displacement rates.

Displacement rates are summarized in Table 3.

Table 3. Assumed Displacement Rates

| Product Category | Assumed Price Reduction | Displacement Rate | | |
|---|---|---|---|---|
| | | Average | Best | Worst |
| Mobile Tech | 23% - 55% | 65% - 80% | 90% - 95% | 56% |
| Computing | 25% - 37% | 75% - 80% | 90% - 95% | 56% |
| Home Goods | 30% - 50% | 70% - 85% | 80% - 95% | 56% |

## Avoided landfill and incineration

Data from U.S. EPA (2020) were used for the rates of U.S. landfilling, incineration, and recycling of the devices. Devices sent to landfill or to incineration were considered as waste.

End-of-life paths are summarized in Table 4. GHG emission factors were derived from ecoinvent 3.8.

Table 4. End-of-Life Paths for Devices in the US

| Product Category | Recycling | Landfilling | Incineration |
|---|---|---|---|
| Mobile Tech | 38.5% | 53.4% | 8.1% |
| Computing | 38.5% | 53.4% | 8.1% |
| Home Goods | 5.6% | 75.9% | 18.5% |

## Other assumptions

A series of other assumptions were required to calculate the net impacts of refurbishing including on:

- Lifetime of new device (See Table 5);
- Energy consumption of new device and relative energy consumption of refurbished device (see Table 6);
- Refurbishing efficiency: through sellers, it was determined that the refurbishing process would be very efficient and a refurbishing efficiency of 99% was assumed;
- Energy required for refurbishing: energy for refurbishing was assumed half of that for assembly of the original device where available (see Table 7); where not available, it was omitted based on the results of the other devices;
- Parts being replaced and related transportation: parts being replaced were based on sellers' interviews and existing literature (see Table 8). It was assumed that in the best-case parts would be manufactured locally and transported by trucks (250 km) and in other cases they would be air shipped from China (11,000 km); and
- Devices transportation routes (Table 9).

In addition, the following GHG emission factors were used:

- Truck transportation: 0.093 kg CO2eq./tkm (U.S. Life Cycle Inventory Database);
- Air transportation: 0.752 kg CO2eq./tkm (U.S. Life Cycle Inventory Database); and
- US electricity production: 0.587 kg CO2eq./kWh (Federal LCA Commons).

Table 5. Lifetime of New Device

| Product Category | Product | Assumed Lifetime |
|---|---|---|
| **Mobile Tech** | Smartphones | 3 years |
| | Tablet | 5 years |
| | Smartwatch | 4 years |
| | Drone | 2 years |
| **Computing** | Laptop | 4 years |
| | Monitor | 10 years |
| | Desktop | 5 years |
| **Home Goods** | Vacuum | 8 years |
| | Chainsaw | 6 years |
| | Air Fryer | 5 years |

Table 6. Energy Use of New and Refurbished Device

| Product Category | Product | Energy Use of New Device (kWh/d) | Relative Energy Use of Refurbished Device | | | |
|---|---|---|---|---|---|---|
| | | | Average | Best | Worst | |
| **Mobile Tech** | Smartphones | 0.015 | 100% | 100% | 120% | Energy Use Calculator |
| | Tablet | 0.032 | 100% | 100% | 120% | Energy Efficient Living |
| | Smartwatch | Omitted | 100% | 100% | 120% | Omitted |
| | Drone | | 100% | 100% | 120% | General Information on Drones |
| **Computing** | Laptop | 0.055 | 100% | 100% | 120% | Eco Cost Savings |
| | Monitor | 0.142 | 100% | 100% | 120% | Energy Efficient Living-Laptop Use |
| | Desktop | 0.832 | 100% | 100% | 120% | Energuide.be |
| **Home Goods** | Vacuum | 0.137 - 0.192 | 100% | 100% | 120% | Assuming 50h/yr and a power rating of 1400W (1000W for best case) |
| | Chainsaw | Chainsaws use gas. It was determined that only small variations in fuel efficiency compared to new would eliminate GHG benefits of refurbishing. In the case study, we assumed no difference in fuel consumptions. | | | | |
| | Air Fryer | 0.136 | 100% | 100% | 120% | Assuming 20 min/ twice a week, 1425W |

Table 7. Energy Required for Refurbishing

| Product Category | Product | kWh per device |
|---|---|---|
| **Mobile Tech** | Smartphones | 0.22 |
| | Tablet | 0.16 |
| | Smartwatch | Omitted due to very low contribution |
| | Drone | Omitted due to very low contribution |
| **Computing** | Laptop | 0.83 |
| | Monitor | 12 |
| | Desktop | 1.4 |
| **Home Goods** | Vacuum | 3.7 |
| | Chainsaw | Omitted |
| | Air Fryer | Omitted |

Sources of energy required for refurbishing:
- Ecoinvent 3.8
- Gallego-Schmid et al. (2016)

Table 8. Part Being Replaced

| Product Category | Product | Average* | Best | Worst |
|---|---|---|---|---|
| **Mobile Tech** | Smartphones** | Battery, LCD, back plate | Battery | Battery, LCD, back plate |
| | Tablet** | Battery, outside casing, screen | Battery | Battery, outside casing, screen |
| | Smartwatch** | USB cable, strap, shell, battery | Strap, battery | USB cable, strap, shell, battery |
| | Drone** | Propeller, sensor, motor, battery | Propeller, battery | Frame, propeller, sensor, motor, battery |
| **Computing** | Laptop | Screen, laptop casing and keyboard, motherboard | Screen, battery | Motherboard, screen, laptop casing and keyboard, battery |
| | Monitor | Screen, motherboard | Screen | Screen, motherboard |
| | Desktop | Hard drive, RAM | Hard drive, RAM | Hard drive, RAM |
| **Home Goods** | Vacuum | Floor brush, furniture tool, flexible hose, hose collar and handle, extension tube | Flexible hose, hose collar and handle | Floor brush, furniture tool, flexible hose, hose collar and handle, extension tube |
| | Chainsaw | Chain, other steel parts representing 10% of steel | Chain | Blade, chain, other steel parts representing 10% of steel |
| | Air Fryer | Basket | Basket | Basket |

*Average case was set up to be relatively conservative with regards to the parts being replaced.
**Based on sellers' interviews, it was determined that for mobile tech, parts would be sourced from unsaleable new devices in the best case.

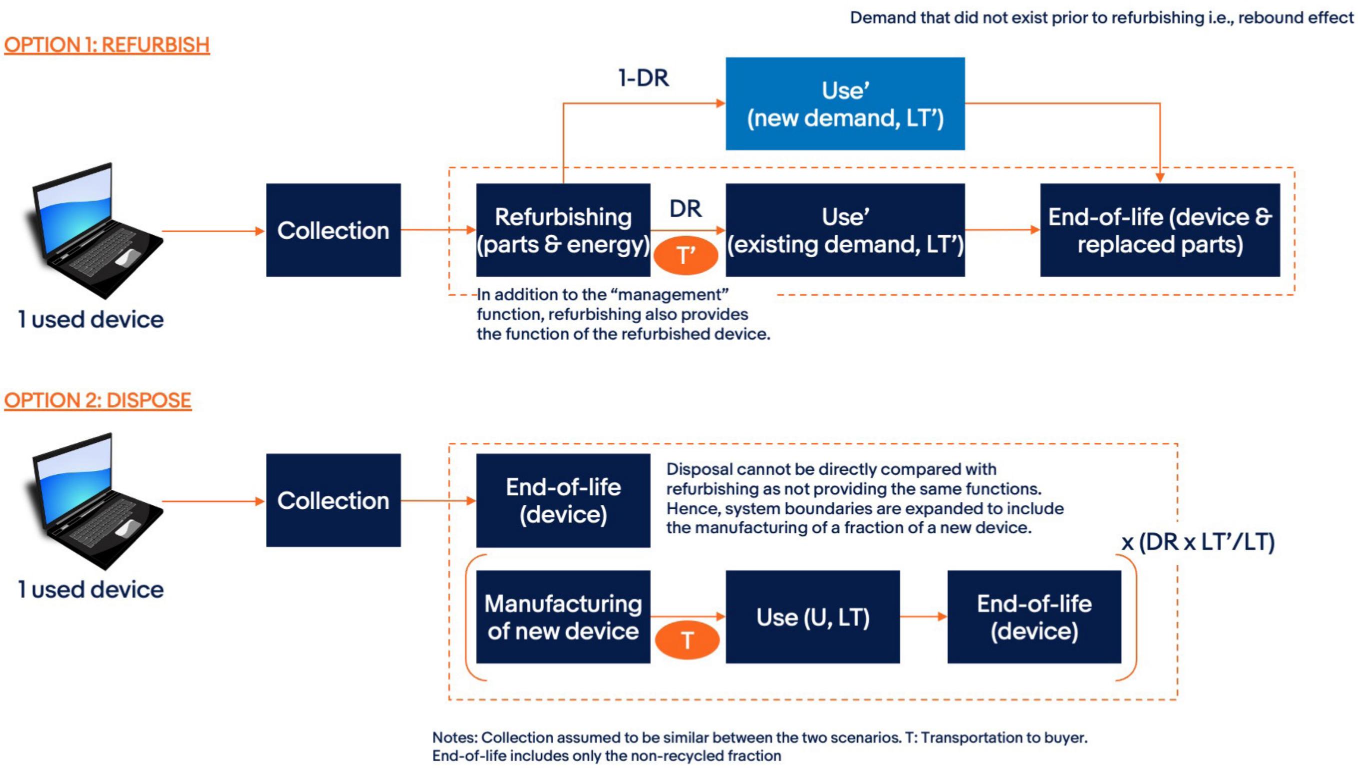
Table 9. Transportation Assumptions (All Products)

| Product | Average | Best | Worst | Assumptions |
|---|---|---|---|---|
| New Device | Overseas | Overseas | National | Overseas: From China (11,000 km, by air)<br>National: From midway US (2,500 km, by truck)<br>Local (500 km) |
| Refurbished Device | National | Local | National | |

## Calculations

The detailed calculation framework used in the case study is illustrated in Figure 1. This calculation framework compares the disposal of a device with the refurbishing of the same device. In the disposal scenarios it is necessary to manufacture a new device. The detailed calculation framework considered the full life cycle of the product. Based on the results, however, it was determined that differences in the end-of-life GHG between the disposal and refurbishing scenarios were not very significant for the results and could be omitted. Note that this is true in the U.S. as most of the non-recycled material ends up in the landfill and might not be true where incineration is the main disposal option of non-recyclable materials, especially plastic. Similarly, if there was no reason to believe that the refurbished device would consume notably more energy than a newer version, the use phase could also be omitted, leaving us with "cradle-to-gate" system boundaries.

Figure 1. Detailed Calculation Framework



### Net impact of refurbishing – Simplified calculation approach

The net impact of refurbishing is calculated by subtracting the impact of the disposal scenario from the impact of the refurbishing scenario:

$$Net\ impact = Impact_{Refurbishing} - Impact_{Disposal}$$

A negative net impact means that the refurbishing reduces the impact compared to disposal (creating a net benefit). Impact can be calculated for a variety of metrics including GHGs and waste.

In the simplified approach, the impact of the refurbishing scenario consists of the impact associated with the energy used in refurbishing the used device, with producing the parts and transporting them to the refurbishing location, and with transporting the device (T') to the user. It is calculated as follows:

$$Impact_{Refurbishing} = Refurbishing(parts + energy) + T'$$

In the simplified approach, the impact of the disposal scenario consists of manufacturing (MFG) and transporting (T) a quantity of devices needed to fulfill the same function as the refurbished device. This is achieved by multiplying manufacturing and transportation by the overall displacement rate. The impact of the disposal scenario is calculated as follows:

$$Impact_{Disposal} = \frac{DR \times LT'}{LT}(T + MFG)$$

## Exclusions

There are additional burdens associated with eBay operations and the selling and buying of goods online. For example, the packaging of sold pre-owned products, delivery of the product from seller to buyer, energy use associated with data center use and computer use for the duration of the transaction. These burdens could be subtracted from the benefits to provide “net avoided burden” for each impact category, but these are considered to be relatively minor compared to the manufacture of a new product, so these are excluded from the current study.

The collection of the device for disposal is assumed to be the same as the collection of the device for refurbishing.

## Potential further simplifications

After applying the simplified calculation framework to multiple devices, it was found that some other factors could be omitted due to their low relative contribution to the calculated net impact. These include:

- Differences in transportation of the device to the user (T and T’) with the exception of cases where the weight of the replaced parts are very low compared to the weight of the device itself (e.g., vacuum);
- Refurbishing energy where yield of refurbishing is relatively high; and
- Transportation of new parts.

## Rebound effect

In this case study, we assumed that only a proportion of refurbished products displaces the purchase of a new product. The rebound effect is the impact from using the refurbished product that does not replace or displace the purchase of a new product. This parameter recognizes that some reused products are additional purchases that would not have been bought as new products. Rebound effect is calculated as follows:

$$Rebound\ effect = (1 - DR)Use'$$

Rebound effect is outside the boundary of the case study because the savings from purchasing refurbished items may result in consumption of other items, and/or additional consumers having access to purchase the item in the first place. However, it was calculated for information purposes. It was shown that in many cases, rebound effect was relatively small compared to the benefit of refurbishing with the exception of devices with smaller benefits and for which the use-phase energy is more significant (e.g., vacuum, drone, chainsaw). The lower the displacement rate, the greater the rebound effect.

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### Glossary

**C2C** - Consumer to consumer

**B2C** - Business to consumer

**GHG** - Greenhouse Gas

**LT** - Lifetime (New)

**LT'** - Lifetime (Reused/Refurbishd)

**DR** - Displacement Rate

**LCA** - Life-cycle assessment

**Q** - Quantity demanded

**P** - Price

**U** - Use

**T** - Transportation of device

**MFG** - Manufacturing

$e_p$ - Price elasticity of demand

## About Anthesis

Anthesis is the Sustainability Activator.

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We exist to shape a more productive and resilient world by helping organisations transition to new models of sustainable performance.

Our team combines broad and deep sustainability expertise with the commercial and operational capabilities it takes to conceive and deliver real change.