Amazon Devices Product Carbon Footprint Methodology

Our Amazon Devices and Services sustainability science team developed a product carbon footprinting calculation model through the life cycle assessment ("LCA") framework by combining state-of-the-art scientific models and the best available data. Our modeling methodology aligns with internationally recognized standards (e.g., Greenhouse Gas ("GHG") Protocol Product Standard,[1] International Standards Organization ("ISO") 14067[2]). As the science and data evolve, we will make improvements to our modeling methodology.

In the following document, we summarize our: 1) goal and scope, 2) method for building out the life cycle inventory, 3) method for estimating carbon emissions, 4) method for data quality assessment and sensitivity analysis, 5) path to net-zero carbon through generation-over-generation product carbon footprint reductions, and 6) critical review process.

1. Goal and Scope

The goal of calculating our product carbon footprint is to first accurately measure and estimate our product's carbon footprint, and then identify opportunities to reduce its carbon emissions. We calculate two carbon footprint metrics: 1) the total carbon emissions across all life cycle stages of one device or accessory, in kg CO_2e; and 2) the average carbon emissions per year of the estimated device lifetime, in kg CO_2e/use-year. The second metric incorporates device lifetime extension into our carbon footprint model to assess the carbon emissions normalized per year of useful life. This aligns with our key carbon reduction strategy to build more durable and longer-lasting devices.[3,4]

For a generic device, we define our system boundary to be cradle-to-grave (Figure 1), where we account for the primary material composition and manufacturing ("MFG") process of each mechanical ("ME") component and packaging, the production and assembly of each electronic ("EE") component, the full device assembly, the transportation of the device to the customer, the electricity consumed by the device, and the end-of-life treatment of the device. The packaging waste from incoming components to the final assembly facilities are excluded due to limited data availability, and our estimation that it is immaterial to the overall product carbon footprint. We will continue to monitor this exclusion in future model updates. In addition, some of our final assembly sites are certified by UL's Zero Waste to Landfill.[5] We use the cut-off method and assume any processes after initial treatment for recycling or reuse are a part of the downstream product's life cycle.

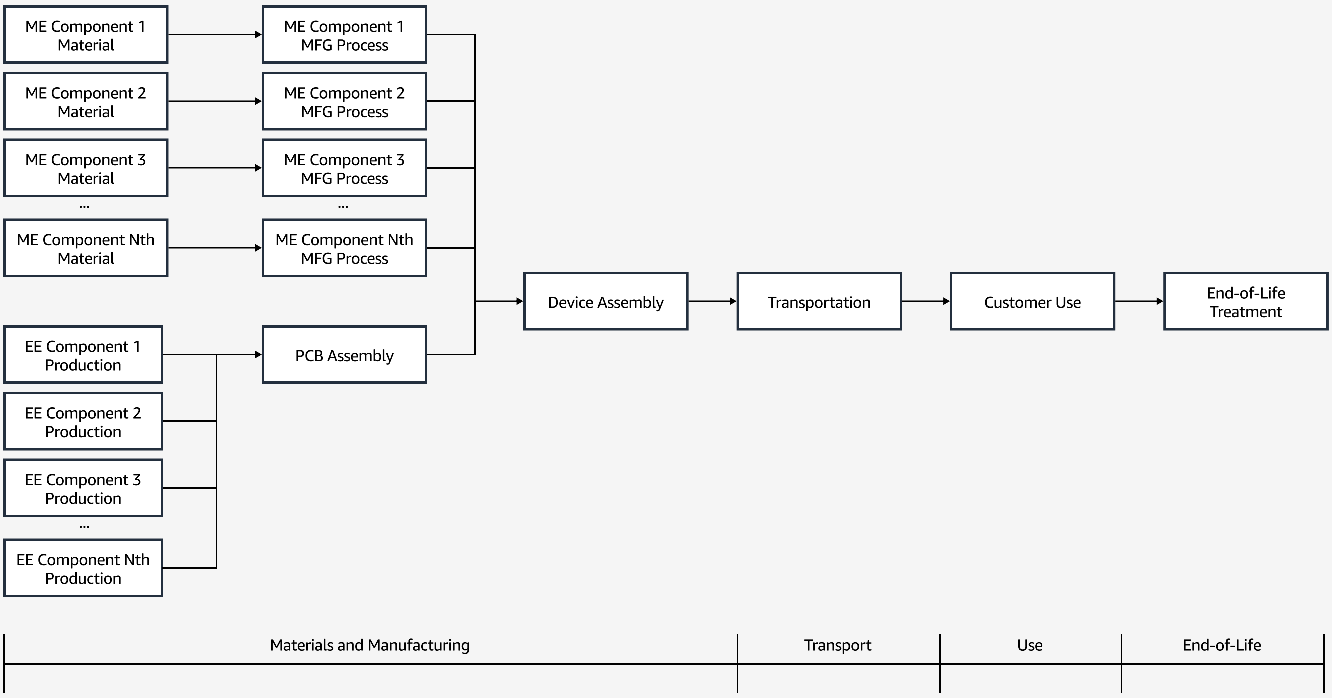

Figure 1. Illustrative Example of the System Boundary of Our Product Carbon Footprint

To calculate a carbon footprint for each device, carbon emissions are aggregated across the materials and manufacturing (E_{MFG}), transportation (E_T), use (E_U), and end-of-life phases (E_{EOL}):

$$E_{Device} = E_{MFG} + E_T + E_U + E_{EOL}$$

See **Appendix 1** for the full mathematical model.

2. Building an Inventory

We model out each life cycle stage based on input data collected from our business operations and supply chain:

1) To model materials and manufacturing emissions, we start with a device's bill of materials ("BOM") from our Product Lifecycle Management ("PLM") system. For each part, we specify the major material type or electronic ("EE") component, the major manufacturing processes, and measure and assign a part level weight (or other physical attribute). Yield losses are accounted for at each level of the BOM from a series of manufacturing and assembly processes based on a multi-level BOM structure. For manufacturing and assembly processes, we default to using industry average estimates to determine yield loss, energy consumption, water use, and direct GHG emissions in production. For certain components and materials where data is available, we collect primary data from our suppliers to supplement our secondary data. In some cases, we also conduct component disassembly to collect detailed material composition. We determine the energy consumption and GHG emissions during the manufacturing process by assigning them proportionally to one unit of product based on total consumption and production volume.

2) To model transportation emissions, we regionally account for transporting the product from final assembly to the end customer. We use data collected from our PLM system to determine a pallet weight and unit density for inbound transportation, and we collect data on how many units are shipped inbound by each mode of transportation. In addition, we account for the outbound packaging and transportation determined by a transportation model for Amazon's corporate carbon footprint and an average packaging estimate. Transportation emissions associated with deeper supply chain tiers are often included in the materials and manufacturing emissions, and therefore they are excluded from this stage. Outbound transportation emissions are allocated based on the number of product units being transported.

3) To model energy consumption from customer use, we collect energy consumption data derived from device-specific energy models that characterizes the energy consumption of that device type in different modes of operation. We then utilize field-based data or lab measurements to determine the amount of time that similar devices spend in each mode of operation. For devices without valid field-based lifetime data, we use reliability life of the device as a conservative estimation of device lifetime. For devices with historical field data, we partner with the device teams to understand the expected device lifetime based on best available prediction methods. With the assumed device lifetime, we then compute the expected energy consumption over the life of the device.

4) To model end-of-life, we estimate the ratio of end-of-life products that are sent to each disposal pathway based on the US Environmental Protection Agency's ("US EPA") average disposition pathways for consumer electronics.[6] We also account for transportation and/or treating the end-of-life materials. In our end-of-life footprint assessment, we use the cut-off recycling allocation method, which excludes any recycling credit in the calculation.

3. Estimating Carbon Emissions

After constructing the inventory model of activities, these activities are mapped to best available emission factors from either primary collected data or secondary data from internationally-recognized life cycle assessment databases (e.g., ecoinvent[7] and GaBi[8]), academic literature, or other verified industry studies. Our Amazon Devices and Services sustainability science team also develops new emission factors (EF) using process-based parameterized LCA models where needed, with the primary data collected from our suppliers (e.g., display, battery and magnet). We update our EF database on an annual basis. When multiple emission factors are available, we selected the best representative data based on its technological, geographical, and temporal closeness to the activities in the inventory. To assess the climate change impacts of GHGs for collected inventory data, we use Global Warming Potential 100 ("GWP100") characterization factors provided in the Intergovernmental Panel on Climate Change ("IPCC") Sixth Assessment Report ("AR6"), released in 2021.[9] We default to using GWP100, including land use change and biogenic emissions, for all emission factors. If an emission factor deviates from this, we review and get alignment with a third-party as part of our methodology review.

The following summarizes our process for estimating carbon emissions from manufacturing, transportation, use, and end-of-life:

1) *Materials and Manufacturing* – Each activity derived from the BOM is mapped to an emission factor based on available data that indicates the material and technological representativeness of the emission factor to the given activity. These emissions are summed together to result in the total carbon emissions due to materials and manufacturing. Yield losses are accounted for at each level of the BOM.

2) *Transportation* – Transportation emissions are calculated at a per device level based on applying emission factors associated with the mode and distance traveled for the average trip. For outbound, we use the average emissions per unit as determined by a transportation model used for Amazon's corporate carbon footprint, which has been verified by a third-party.

3) *Product Use* – Lifetime energy consumption (kWh) is first calculated based on an obtained energy model and device lifetime. The carbon emissions are calculated by applying an average country-specific emission factor to the lifetime energy consumption of the device. A decrease in emissions is then calculated as an additional line item to account for the renewable energy that Amazon procures to match our use phase energy consumption. We report our product footprints including and excluding the application of renewable energy from our renewable energy matching program. To account for renewable energy in the device's use phase, we use an accounting approach that aligns with our own Scope 2 carbon reporting. This approach matches the forecasted expected lifetime energy consumption of a device with forecasted generation of environmental attributes (e.g., renewable energy certificate or "REC") from power purchase agreements ("PPAs") or bridge RECs in the regions of the device's operation. See more information on our renewable energy matching methodology here.

4) *End-of-Life (EoL)* – Emission factors are applied based on US EPA average disposition pathways for consumer electronics,[6] and they are mapped to emission factors from ecoinvent[7] and the US EPA Waste Reduction Model.[10]

4. Data Quality Assessment and Sensitivity Analysis

4.1 Data Quality Assessment

All of the data collected for the LCA model should be the most accurate, consistent, and representative data with regards to the goal and scope of the study. Our Amazon Devices and Services sustainability science team reviews the collected data thoroughly to check for any potential data quality issues before performing the LCA analysis. We have performed a data quality assessment and sensitivity analysis of our LCA model according to the below criteria:

4.1.1 Accuracy

Accuracy is evaluated based on the type of data that is used to model the carbon emissions (supplier-specific, calculated, proxy, etc.). It is also evaluated based on completeness of the inventory collected, as well as the representativeness of the background data. The data quality assessment of each life-cycle phase and the average accuracy in each criterion is summarized below. As we improve our background data and models, we do an inspection on an annual basis to calculate the variation attributed to the latest background data and model updates.

1) *Materials and Manufacturing – Medium.* For each device, we obtain a complete BOM and map each component to a representative emission factor based on available data. Most of our emission factors are secondary emissions data from ecoinvent,[7] GaBi,[8] other industry sources, or academic literature. We have established a hierarchical approach for modeling electronic components based on available data. We recognize that this life cycle stage has a medium degree of uncertainty, but we assume the uncertainty will be very similar in comparison across each device, and therefore our modeling approach here aims to simplify the model to align with our levers of control.

2) *Transportation – High.* For inbound transportation, we account for transporting the product from final assembly where we have obtained the actual shipments of similar products and their average distances around the globe, as well as the actual splits of mode type (e.g., air, ocean, truck) for these trips. In addition to our inbound estimation, we use our actual average emissions per unit for outbound (to our end customers), and therefore we believe this is a highly accurate estimate.

3) *Product Use – Medium.* We have detailed energy models to characterize the energy consumption of a device in different modes of operation (e.g., music play, video play, idle, low power mode), and these models are validated by actual benchtop and field measurements. We utilize field-based data (if available) or lab simulations with our product knowledge to estimate how long our average customers would spend in each mode. This gives us an average energy consumption for each device that we can then use to calculate a lifetime energy consumption based on the expected device lifetime. We use regional emission factors based on the location of the use for each device and generate regionalized use-phase carbon emissions estimation. Some uncertainty still exists around the expected lifetime and modes of operation, so this emission estimate is assigned to be moderately accurate. For the renewable energy component of the use phase, this is forecasted based on our expected lifetime energy consumption and our expected renewable energy portfolio. See more information on how we will verify this over the life of the product here.

4) *End-of-Life (EoL) – Low/Medium.* These emissions have been estimated based on average US EPA data.[6,10] We expect this to have high uncertainty. Since this life cycle stage is a small fraction of the overall carbon footprint, we do not believe it will impact the overall device results.

4.1.2 Consistency

Consistency - High across all stages. Consistency is evaluated based on the assumptions used in the model and the data sources used for the background data. Each life cycle stage calculation of a device is based on the same parameterized model. Therefore, assumptions are identical across each device, and the background data and model used are identical across each device.

4.1.3 Representativeness

Representativeness - Medium. Representativeness is evaluated based on if we are using the most up-to-date emission factors that are reflective of the most representative technology and geographical boundaries. For background data, we use the most up-to-date versions of ecoinvent[7] and GaBi.[8] We have had to apply proxies based on the lack of data for some of our components. The source of each applied emission factor is included in the results of each device and reviewed by a third-party (See Section 6).

4.1.4 Sensitivity

Based on our analysis of our parameterized carbon footprint model, we assess that our largest uncertainties are in the manufacturing stage, and specifically around integrated circuit (“IC”) production, printed circuit board (“PCB”) production, and display production, as well as the location of use:

1) *IC production* - We highlight IC data as a source of uncertainty. We model IC emissions based on parameters such as die size, technology node, and package type. When data is not available, we measure the die size for the top five critical ICs in a device, and default to a conservative emission factor estimation based on known parameters.
2) *PCB production* - We model PCB emissions based on total board area (with scrap), PCB type, number of layers, and/or mass. We choose and scale a background dataset based on the availability of these parameters.
3) *Display production* - We model display emissions based on active screen area, display type, and/or mass. While uncertainty is moderate, we assume that it is similar from device to device as our supply base is relatively consistent across device portfolio.
4) *Location of use* - We model use-phase emissions based on energy consumption and location of use of the device. Since emissions from energy consumption vary across different energy portfolios, we generate regionalized use phase emissions at the country level.

4.2 Data Quality Improvement Overtime

Estimating a device’s carbon footprint is a complex and data-intensive process. Our methodological approach: 1) ensures that we meet or exceed the bar following the internationally recognized standards (e.g., GHG Protocol Product Standard[1], ISO 14067[2]) for public disclosure, 2) covers as many emissions sources as possible to identify hotspots, 3) aligns the granularity of the data to the granularity of our decision-making, and 4) acknowledges the need for iterative improvements over time. Even so, there are a number of model uncertainties and limitations associated with our approach and we strive to improve data quality for significant processes.

Materials and Manufacturing: The current methodology for the materials and manufacturing phase relies heavily on industry-average emissions data from international LCA databases. Although this provides a good estimate and allows for assessment speed, over time, we are aiming to collect more primary emissions data for key components, as well as more energy consumption data for assembly in our supply chain. This will improve the accuracy and actionability of our manufacturing emissions and minimize the use of estimation techniques.

Product Use: Use-phase emissions usually have a high contribution in a device's carbon footprint, and we implemented regionalized energy use at country level to avoid using a global average emission factor for all regions. We continue improving the estimation of device lifetime and energy models based on actual device usage data to improve the reliability of our use phase emissions.

4.3 Uncertainty Assessment

Assessing uncertainty in LCA is important for understanding reliability and robustness of the results in the context of decision-making. Uncertainty occurs in all phases of an LCA and originates from various sources. The main uncertainty type addressed in our model is parameter uncertainty from collected data, emission factor data, and parameter data. In our product LCA modeling process, we use the commonly applied approach for quantifying uncertainty in LCA: the pedigree method.[11] The pedigree approach is used to characterize the quality of LCA model parameters across five categories: reliability, completeness, geographical correlation, temporal correlation, and further technological correlation. We convert each data quality score into a variance to represent inherent variability. In the future, we plan to perform Monte Carlo simulation of the LCA model to generate uncertainty distributions and associated statistics for uncertainty communication.

5. Our Path to Net-Zero Carbon

Our LCA model and results enable us to establish an accurate baseline of our product carbon footprint. It allows us to identify the most significant contributors to our product carbon emissions and prioritize our carbon reduction efforts. Some of the key carbon reduction levers we have identified across the full life cycle of our devices are: 1) maximizing energy efficiency for the use phase, 2) matching the remaining electricity consumption with renewable electricity for the use phase,[12] 3) increasing the longevity of our devices,[3,4] 4) increasing the use of renewable energy in our supply chain, 5) using more recycled and renewable materials, and 6) using lower carbon transportation solutions. After we maximizing those carbon reduction levers, we would neutralize the remaining carbon emissions with high quality carbon credits through technological or nature-based climate solutions. Learn more about Amazon's approach to carbon neutralization.

Our Amazon Devices and Services sustainability science team works closely with our product teams and engineering teams to provide guidance for carbon reduction levers across all life cycle stages at an early stage. This close collaboration enables us to identify and implement improvements that can be made to the existing device, as well as to inform our new product ideation. We strive to reduce our product carbon footprint iteratively generation over generation. See Appendix 2 for the mathematical calculation for the generation-over-generation carbon emissions comparison.

As we continue our journey to reach net-zero carbon emissions by 2040 through measurement, reduction, and neutralization of our Amazon Devices products, our Amazon Devices and Services sustainability science team will continuously seek to improve our data and model. We'll ensure our modeling methodology aligns the granularity of the data to the granularity of our decision-making, enabling us to reduce the carbon footprint of our devices most efficiently.

6. Critical Review Process

Our model methodology and each individual product carbon footprint is reviewed by The Carbon Trust. Throughout the assurance process, the Carbon Trust dives deep into the methodology, data quality, major assumptions, inputs and outputs, as well as governance mechanisms that are in place. Through this process, the Carbon Trust provides a reasonable level of assurance.

Appendix 1: Mathematical Model for the Devices Product Carbon Footprint

To calculate a carbon footprint for each device, carbon emissions are aggregated across the materials and manufacturing (E_{MFG}), transportation (E_T), use (E_U), and end-of-life phases (E_{EOL}):

$$E_{Device} = E_{MFG} + E_T + E_U + E_{EOL}$$

1.1 Materials and Manufacturing Phase

We use a cradle-to-gate carbon assessment to analyze the material and process impacts for each part of a product and to build an overall emissions inventory. Assume that a product has N number of parts found in its BOM, and each part could be a material, EE component, or an assembly process. The cradle-to-gate materials and manufacturing emissions (E_{MFG}) is the sum of the emissions from each part (E_{part_n}).

$$E_{MFG} = \sum_{n=1}^{N} E_{part_n}$$

The following sub-sections expand on the emission calculations for each type.

1.1.1 Assembly/Manufacturing Process

The assembly impact accounts for the emission-generating activities associated with sub-assembly or final assembly process. The manufacturing impact accounts for the emission-generating activities associated with transforming input materials into a finished good. Each manufacturing/assembly process may involve primary material inputs, energy, water, and direct GHG emissions in the facility. Therefore, the process impact for a component is equal to the emissions from electricity (E_{elect}), natural gas (E_{gas}), water (E_{water}), and direct GHG emissions ($E_{ghg,direct}$).

$$E_{process} = E_{elect} + E_{gas} + E_{water} + E_{ghg,direct}$$

Electricity emissions (E_{elect}) are equal to the amount of electricity consumed (b_{elect}) multiplied by an electricity emission factor (ef_{elect}) that is country-specific for the manufacturing location:

$$E_{elect} = b_{elect} * ef_{elect}$$

Natural gas emissions (E_{gas}) are equal to the amount of natural gas consumed (b_{gas}) multiplied by a natural gas emission factor (ef_{gas}) that is country-specific for the manufacturing location:

$$E_{gas} = b_{gas} * ef_{gas}$$

Water emissions (E_{water}) are equal to the amount of water consumed (b_{water}) multiplied by a water emission factor (ef_{water}):

$$E_{water} = b_{water} * ef_{water}$$

1.1.2 Materials

A material may be composed of one or more constituent materials (j). The material impact is equal to the sum of the mass of the constituent materials (m_j), multiplied by an emissions per mass material emission factor (ef_j), divided by a loss factor that accounts for waste generated in making the constituent material (L_j):

$$E_{material} = \sum_{j=1}^{J} \frac{m_j * ef_j}{L_j}$$

1.1.3 Electronic Components

For an off-the-shelf electronic component such as an IC, PCB, capacitor, and resistor, its impact may be scaled by mass or by area based on the EE component type and data availability.

If scaled by mass, the EE component impact is equal to the mass of the component (m), multiplied by an emission factor (ef) per reference mass (m_{ref}), divided by a loss factor (L) that accounts for waste generated in assembling the component:

$$E_{part,EE} = \frac{m * ef}{m_{ref} * L}$$

If scaled by area, the EE component impact is equal to the area of the component (a), multiplied by an emission factor (ef) per reference area (a_{ref}), divided by a loss factor (L) that accounts for waste generated in assembling the component:

$$E_{part,EE} = \frac{a * ef}{a_{ref} * L}$$

1.2 Transportation Phase

We account for transporting the product from final assembly to the end customer. In addition, we account for the outbound packaging emissions. Transportation emissions associated with deeper supply chain tiers are often included in the materials and manufacturing emissions, and therefore are excluded from this stage.

$$E_T = E_{inbound} + E_{outbound} + E_{outbound,packaging}$$

For inbound ($E_{inbound}$), we use a parameterized model that captures the number of units on a pallet (U), the pallet weight (W), and the average distance traveled per mode (d_k), multiplied by the emission factor per mode (ef_k):

$$E_{inbound} = \frac{W}{U} \sum_{k=1}^{K} d_k * ef_k$$

For outbound ($E_{outbound}$), we use the average emissions per unit as determined by a transportation model used for Amazon's corporate carbon footprint, which has been verified by a third-party. The transportation model measures or estimates the transportation emissions of individual trips, and allocates the trip-level emissions to each unit shipped by the number of product units.

For outbound packaging ($E_{outbound,packaging}$), the secondary packaging to ship our products from AFN to the end customer, we use the average emissions per unit that is calculated across all of our shipped products.

1.3 Use Phase

Electricity is required to power the use of all Amazon devices, and therefore has an associated carbon impact. The use-phase emissions for devices are equal to the amount of non-renewable electricity used by a device over its lifetime ($\varepsilon_{life,nonRE}$) multiplied by an average grid mix emission factor ($ef_{life,nonRE}$) , plus the amount of renewable electricity ($\varepsilon_{life,RE}$) used multiplied by its emission factor ($ef_{life,RE}$):

$$E_U = \varepsilon_{life,nonRE} * ef_{elect,nonRE} + \varepsilon_{life,RE} * ef_{elect,RE}$$

$$\varepsilon_{life} = \varepsilon_{life,nonRE} + \varepsilon_{life,RE}$$

For battery-powered devices, the lifetime energy consumption is equal to the battery capacity (C, measured in Wh), multiplied by the number of charging cycles over lifetime (η), divided by the charging efficiency (σ), divided by 1000 to convert Wh to kWh. Thus, lifetime electricity usage can be computed by the following:

$$\varepsilon_{life} = \frac{C * \eta}{1000 * \sigma}$$

For plugged-in devices, electricity is consumed at different rates over time as the device alternates between different power modes (e.g., idle, active, etc.). Each mode (k) has its own power rating and is measured in kilowatts. The kilowatt-hour consumption for a plugged-in device is equal to the sum of the power rating (P_k) per power mode, multiplied by the lifetime hours in that power mode (T_k), divided by the power adapter efficiency (σ):

$$\varepsilon^{life} = \frac{\sum_{k=1}^{K} P_k * T_k}{1000 * \sigma}$$

1.4 End-of-Life Phase

End-of-life phase impacts typically include transportation to the end-of-life treatment facility and the initial processing. The emissions from these activities are small relative to total carbon footprint of a device, so we implement a simplified model for the assessment. End-of-life emissions (E_{EOL}) are equal to the mass of the device (m_{device}) multiplied by the split for the zth disposal pathway (τ_z), multiplied by an emission factor for that given pathway (ef_z):

$$E_{EOL} = \sum_{z=1}^{Z} m_{device} * \tau_z * ef_z$$

1.5 Biogenic Carbon Emissions

We account for biogenic emissions and removals separately when applicable. The biogenic carbon removals are relevant to the material and manufacturing phase, and the biogenic carbon emissions are relevant to the end-of-life phase.

1.5.1 Biogenic Carbon Removal

Plants remove carbon dioxide from the atmosphere and store that carbon through the photosynthesis process. Biogenic carbon removal ($E_{bio,removal}$) is equal to the carbon fraction of bio-based materials (cf) multiplied by the mass of the bio-based material (m_v), scaled by the molecular weight between carbon dioxide (44 g/mole) and carbon (12 g/mole).

$$E_{bio,removal} = -\frac{44}{12} * cf * m_v$$

1.5.2 Biogenic Carbon Emissions

Three end-of-life treatment methods are included in our study: landfill, recycling, and combustion. The biogenic carbon emissions ($E_{bio,emissions}$) is equal to the sum of the ratio of each end-of-life disposal pathway (τ_z), multiplied by the biogenic emissions from each end-of-life treatment (E_z).

$$E_{bio,emissions} = \sum_{z=1}^{Z} \tau_z * E_z$$

1.6 Device Lifetime Consideration

To incorporate device lifetime extension into our carbon model, we introduce a new metric, carbon/use-year, or the amount of carbon emitted per year of device life. This metric allows us to measure the carbon benefits of things like using a more durable glass on a display, increasing RAM to encourage customers to use their device longer, or allowing the battery to be removed for increased refurbishment. Driving down carbon/use-year incentivizes us to design devices to last as long as technically feasible, driving down the carbon of our business in the long-term.

$$E_{\frac{Device}{use-year}} = \frac{E_{MFG} + E_T + E_U + E_{EOL}}{L_{avg}}$$

For devices with historical field data, we predict the lifetime of devices using best available prediction techniques. If the device does not have enough field data for either direct measurement or an accurate prediction, then we default to using the reliability life of the device.

$$L_{avg} = \frac{1}{12} \frac{\sum_{i=1}^{N} MAD_i(1 + \delta ARR_i)}{V}$$

Where L_{avg} is the average lifetime in years, MAD_j is the number of devices active in a given month (i) over (N) months, δARR_j is the correction factor applied for a reduction in the monthly replacement rate due to improvements in physical durability, and V is the total volume of devices sold. For new programs, we forecast MAD_j using a predictive model.

1.7 Materials Recycled Content Calculation

One of the carbon reduction levers is to use more recycled materials in our products, such as recycled aluminum and post-consumer recycled resin. The weight percentage of recycled materials ($wt\%\ recycled$) used in our devices is equal to the total weight of recycled materials ($m_{recycled}$) divided by the total weight of a device (m_{device}).

$$wt\%\ recycled = \frac{m_{recycled}}{m_{device}}$$

Appendix 2: Generation-over-Generation Comparison

The carbon footprint difference percentage between the current generation and its baseline ($E_{curr\text{-}gen\ vs.\ baseline}\%$) is equal to the absolute carbon emissions difference between the current generation ($E_{curr\text{-}gen}$) and its baseline ($E_{baseline}$), divided by the baseline's carbon emissions. If a product has a previous generation, its baseline would be its previous generation. If a product is a new product without a previous generation, its baseline would be a business-as-usual scenario of this product during early product development that doesn't consider the selected carbon reduction levers.

$$E_{curr-gen\ vs.\ baseline}\% = \frac{E_{curr-gen} - E_{baseline}}{E_{baseline}} * 100\%$$

Glossary of Terms

Bill of Materials ("BOM"): A comprehensive list of all raw materials, parts, components, and sub-assembles required to manufacture a product.

Cradle-to-Grave: It considers the full life cycle of a product, from raw material extraction and processing through production, use, and disposal.

Cradle-to-Gate: It considers partial life cycle of a product, including raw materials extraction, their transportation to a factory, processing and manufacturing activities until the material or product is ready to leave the factory gate.

Electronic ("EE") Component: Parts that control or manipulate the flow of electrons in circuits.

Emission Factors ("EF"): Values that represents the amount of pollutants or greenhouse gases that are released into the environment per unit of activity or product.

Greenhouse Gases ("GHG"): Gases that trap heat in the atmosphere including carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride.

Integrated Circuit ("IC"): A compact electronic circuit that contains many interconnected electronic components. ICs are also known as microchips or chips.

Inbound Transportation: Transportation from final assembly to the fulfillment network.

Life Cycle Assessment ("LCA"): A methodology to assess the environmental impacts associating with all life cycle stages of a product, from raw material extraction and processing through production, use, and disposal.

Mechanical ("ME") Component: Parts that perform a mechanical function in a product system.

Outbound Transportation: Transportation from the fulfillment network to our end customer.

Power Purchase Agreement ("PPA"): A contract between an energy provider and a customer for the purchase and sale of electricity at an agreed-upon price and for a specified period of time.

Printed Circuit Board ("PCB"): A fat board that is used to mechanically support and electrically connect electronic components using conductive pathways.

Product Lifecycle Management ("PLM"): A system that manages the entire lifecycle of a product from concept, through design and manufacturing, to service and disposal.

Random Access Memory ("RAM"): A type of computer memory that allows data to be accessed randomly, enabling fast read and write speeds for running software applications.

Renewable Energy Certificate ("REC"): A market-based instrument that represents the property rights to the environmental, social, and other non-power attributes of renewable electricity generation. Bridge RECs are attributes purchased to bridge any gap expected in PPA generation.

US Environmental Protection Agency ("US EPA"): An independent executive agency of the United States federal government tasked with environmental protection matters.

Endnotes

[1]Greenhouse Gas ("GHG") Protocol Product Life Cycle Accounting and Reporting Standard: https://ghgprotocol.org/product-standard published by World Resources Institute ("WRI") and the World Business Council for Sustainable Development ("WBCSD")

[2]International Standards Organization ("ISO") 14067:2018 Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification: https://www.iso.org/standard/71206.html published by the International Standards Organization

[3]Amazon devices are built to last—here's why: https://www.aboutamazon.com/news/devices/amazon-devices-are-built-to-last-heres-why published by Amazon

[4]A methodology for correlating annualized replacement rate (ARR) reduction to sustainability benefits: https://www.amazon.science/publications/a-methodology-for-correlating-annualized-replacement-rate-arr-reduction-to- sustainability-benefits published by Amazon

[5]UL's Zero Waste to Landfill (UL 2799 Standard) requires at least 90 percent diversion through methods other than waste to energy: https://www.ul.com/services/landfill-waste-diversion-validation published by UL Solutions

[6]US Environmental Protection Agency ("US EPA") Municipal Solid Waste Management (2018): https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials published by US Environmental Protection Agency

[7]ecoinvent: An international Life Cycle Assessment ("LCA") database in many areas such as energy supply, agriculture, transport, biofuels and biomaterials, bulk and specialty chemicals, construction materials, wood, and waste treatment: https://ecoinvent.org/ published by ecoinvent

[8]GaBi: A Life Cycle Assessment ("LCA") software with a content database that details the costs, energy and environmental impact of sourcing and refining every raw material or processed component of a manufactured item: https://sphera.com/life-cycle-assessment-lca-database/ published by Sphera

[9]Intergovernmental Panel on Climate Change ("IPCC") AR6: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change: https://report.ipcc.ch/ar6/wg1/IPCC_AR6_WGI_FullReport.pdf published by the Intergovernmental Panel on Climate Change

[10]US Environmental Protection Agency ("US EPA") Waste Reduction Model ("WARM"): https://www.epa.gov/warm/basic-information-about-waste-reduction-model-warm published by US Environmental Protection Agency

[11]Weidema, B. P., & Wesnæs, M. S. (1996). Data Quality Management for Life Cycle Inventories—An Example of Using Data Quality Indicators. Journal of cleaner production, 4(3-4), 167-174 published by Elsevier

[12]Reaching Net-Zero Carbon by 2040: Decarbonizing and Neutralizing the Use Phase of Connected Devices: https://sustainability.aboutamazon.com/devices_use_phase_decarbonization.pdf published by Amazon

For questions related to the Amazon Devices Product Carbon Footprint Methodology, please contact us through the Amazon Investor Relations Contact Us page.