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# Carbon Methodology

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## What's in Amazon's 2023 Carbon Footprint?

A carbon footprint measures the total greenhouse gas (GHG) emissions caused by the direct and indirect activities of a company.[1] These emissions are broken into three categories—Scope 1, 2, and 3 emissions. Scope 1 emissions come directly from a company's operations, such as the fuel used by Amazon's delivery fleet. Scope 2 emissions are indirect emissions resulting from the generation of purchased energy, such as the electricity consumed by Amazon's facilities and onsite electric vehicle fleet.[2] Scope 3 emissions include activities that take place beyond a company's operational boundary, for example, the production of Amazon devices such as the Kindle, or purchase of packaging materials used in our fulfillment operations.

To calculate Amazon's carbon footprint, we use the operational control approach to account for a diverse set of direct and indirect emissions that occur upstream of, within, and downstream of our operations. Our boundary includes the following emissions sources:

- Amazon's last mile delivery fleet
- Amazon-operated freight, including trucks and airplanes
- Purchased delivery services (e.g., postal services) and other contracted freight
- Energy used in our operations, such as fulfillment centers, data centers, physical stores, and other facilities
- Amazon-provided packaging used in our fulfillment operations
- Amazon-branded product manufacturing, such as Echo devices, Kindle e-readers, Amazon Basics, Whole Foods Market brands, and other Amazon private brands products
- Our customers' use of Amazon devices
- Amazon devices end-of-life treatment
- Capital goods, such as emissions from building construction, vehicles, and manufacturing of servers and equipment
- Goods and services that enable our operations, such as business travel, office supplies, corporate events, and other outside services and expenditures
- Employee commuting
- Customers' trips to Amazon's physical stores
- Refrigerants used for cooling in our data centers, corporate offices, grocery stores, and fulfillment centers

We evaluate the quantity of GHG emitted for each of these activities by multiplying the amount of activity conducted (e.g., miles traveled or gallons of fuel burned) by its emissions factor (e.g., grams of carbon dioxide equivalent ($CO_2e$) per kilowatt-hour (kWh) of electricity used), which provides a representative value for the $CO_2e$ associated with that activity.[3] Once the emissions for our activities are calculated, we sum them to produce the carbon footprint for Amazon's business, spanning our physical and online retail businesses, cloud computing, device manufacturing, and beyond.

Our approach to quantifying our carbon footprint reflects the complexity of our business by combining both operational and financial records from Amazon operations around the world. We first estimate our carbon emissions for all activities within our boundary using a spend-based environmental assessment model, then enhance the accuracy with process-based calculations or life cycle assessment (LCA) models, when applicable. Each year, we work to continuously improve our estimates and assumptions used for emissions calculations.

## This carbon footprinting approach consists of these scientific models:

1. **Financial:** We combine data on Amazon's spending with industry-specific, spend-based emissions factors (e.g., a standard amount of $CO_2e$ emissions associated with every dollar of spending on a particular activity). We use this model to reflect carbon emissions from activities such as the construction of Amazon buildings, the manufacturing of Amazon's private brands products, equipment used in our warehouses, and purchased goods and services such as office supplies and advertising services.
2. **Transportation:** We track the emissions resulting from shipping products to Amazon warehouses, between warehouses, and outbound to our customers' homes, Amazon lockers, and other pickup points. This includes estimated emissions from customers' trips to physical stores.
3. **Energy:** We account for the impacts of purchased electricity, and back-up power generation and heating used in our offices, data centers, and warehouses, as well as the renewable energy matched to electricity use across global operations.
4. **Refrigerants:** We include the emissions that occur across our global operations from the cooling and refrigeration occurring within our facilities.
5. **Packaging:** We measure the materials and processes behind all the boxes, mailers, and other packing items Amazon uses in our fulfillment operations.
6. **Amazon Devices:** We developed a specialized carbon footprint model to address the complexity of the manufacturing, use, and end-of-life of Amazon devices, including Echo devices, Kindle e-readers, Fire Tablet, Fire TV, Ring, and Blink. This starts at the component level—including where components are sourced and how they are manufactured into products—and extends to customers' use of the product and the eventual product end-of-life.
7. **Employee Commute:** We estimate emissions associated with our employees' transit between their homes and worksites using survey results on how our employees regularly come into work (car, bus, walking, biking, shuttle, etc.) and the distance they travel.

Our team uses Amazon Web Services (AWS) cloud technologies to implement these seven models in order to transform activity and spend data into emissions measurements for Amazon's specific business activities (e.g., shipping, packaging). We then compile the outputs of these calculations to assemble a companywide carbon footprint and identify the biggest emissions sources for each of our businesses. The results are designed to equip teams with actionable data and metrics to help them reduce carbon emissions. For example, this allows us to track activities such as the total emissions associated with one-day shipments as they travel through our fulfillment network, including the emissions from fulfillment centers (energy model), delivery (transportation model), and packaging (packaging model).

Our carbon footprint meets the widely adopted international standard of the GHG Protocol (GHGp).[4] Scope 1 and Scope 2 were independently assured by Ernst & Young LLP, and Scope 3 was independently verified by Apex.

As measurement techniques evolve, we adapt the way we measure and report our footprint, including the recalculation of prior-year(s) data to help datasets be compared over time. This may occur, for example, when we refine a calculation methodology, add new activity data as it becomes available, or when we improve the way we collect data from our existing sources. When the change is significant, we apply the current year's models, calculation methods, emissions factors, and company structure to prior-year(s) data to calculate the comparable total carbon emissions.

The following sections elaborate on the science and data behind each of the emissions models we've built to measure Amazon's carbon footprint.

## Financial Emissions Model

Using the Economic Input-Output Life Cycle Assessment (EIO LCA) method, our spend-based model combines expenditure data from Amazon's general ledger with industry-specific, spend-based emissions factors (e.g., 1,390 grams of $CO_2e$ per dollar of truck transport) published by the U.S. Environmental Protection Agency (EPA) and other peer-reviewed academic and government sources.[5] EIO LCA emissions factors account for the "cradle-to-gate" emissions required to produce one dollar of goods or services from any industry, including emissions from the extraction of raw materials, energy use, supply-chain transportation, and manufacturing. This method leverages economic input-output data assembled by governments to track the "recipe" of inputs required to produce any good or service. For example, producing $10,000 of computers in the U.S. requires $1,466 from the computer storage device manufacturing sector, $491 from the printed circuit assembly sector, etc.[6] EIO LCA accounts for the carbon emissions from producing each of these intermediate inputs, and from the production of all inputs from further up the supply chain.

We apply EIO LCA by mapping our expenditures to one or more industry sectors and multiplying the appropriate emissions factors by the dollars spent. For example, spending on parcel delivery by third-party carriers is mapped to the couriers and messengers sector (i.e., 355 grams of $CO_2e$ per dollar) and shipping boxes are mapped to paperboard container manufacturing (i.e., 615 grams of $CO_2e$ per dollar). This method is the most efficient way to tie all corporate activity into an approximated carbon footprint. Outside of Amazon, this method is commonly used to estimate carbon footprints by a variety of organizations, from major corporations that disclose their carbon emissions, to government entities such as the U.S. Department of Defense and even individuals who wish to understand the environmental impact of their personal activities.[7]

## Transportation Emissions Model

The transportation of products to customers is an integral part of Amazon's business. Trips differ by mode, purpose, productivity, timing, and other localized variables, resulting in a broad range of emissions factors associated with transportation activities. To account for this complexity, we use a robust modeling framework that estimates carbon emissions at the trip level and accommodates different levels of data availability. We give priority to fuel- and distance-based calculations, but if this information is not available, we rely on a spend-based approach to calculate emissions. The scope of our assessment includes transportation activities managed by Amazon and our third-party transportation providers, as well as the emissions generated from customers' trips to Amazon retail and Whole Foods Market stores.

### Emissions Factors for Transportation

Transportation activities generate carbon emissions through the combustion of fossil fuels (when vehicles are driven), manufacturing of vehicles, and the supply chain for fuels. The emissions model for transportation covers emissions associated with "well-to-wheels" impacts. This is both the emissions associated with well-to-tank (e.g., extraction, refinement, and distribution of fuels) and tank-to-wheels emissions created from the use of transportation fuels. Similarly, we account for the cradle-to-gate emissions of vehicle manufacturing for the fleet we own.

For well-to-tank impacts, the emissions model estimates the carbon intensity of the "well" fuels (e.g., grams of $CO_2e$ per megajoule) based on data and logic from Argonne National Laboratory's Greenhouse gases, Regulated Emissions, and Energy use in Technologies (GREET) model.[8] GREET is an LCA tool used to evaluate various transportation fuels such as diesel, gasoline, hydrogen, natural gas, and biofuels. For tank-to-wheel, we use transportation fuel-related emissions factors from both GREET and the UK's Department for Environment, Food and Rural Affairs (Defra). Fuel consumption rates for vehicles are based on fleet averages from a variety of country- and region-specific sources, including the U.S. EPA, U.S. Department of Energy, European Union, United Nations, and the International Council on Clean Transportation.

### Customer Trips to Stores

We created a model that calculates the aggregate emissions from customer trips to Amazon's physical stores (e.g., Whole Foods Market) using publicly available travel behavior information from the Federal Highway

Administration's National Household Travel Survey (NHTS). This model focuses on the following three variables that affect emissions for this category of activities:

- **Distance driven:** We use NHTS data to estimate the typical distance a customer drives for "goods purchasing" based on their setting (e.g., urban, suburban, or rural). We assume customers only travel to a single destination and that all trips are direct and round trip.
- **Mode of transportation used:** NHTS data indicates how likely a customer is to use a certain mode of transportation among the following five categories: car, light-duty truck (e.g., truck, SUV, van), transit (e.g., bus, rail), non-motorized (e.g., walking, biking), and other.
- **Total customer trips per year:** We estimate the number of customer trips to each physical store based on the store's setting (e.g., urban, suburban, or rural).

After assembling the data and emissions factors for all vehicle and transportation modes, and estimated trips per store, we multiply the distance traveled by each mode by the appropriate emissions factor to each store. Finally, we then multiply that product by the number of total customers in a year.

## Energy Emissions Model

We calculate the carbon footprint of energy used from purchased electricity, and fuel used for back-up power generation and heating across Amazon's facilities, including data centers, fulfillment network facilities, retail stores, and corporate offices. Electricity emissions factors account for direct power plant emissions, transmission, and distribution losses, while fuel emissions factors account for combustion of fuels such as natural gas used in heating systems. The largest source of carbon emissions for facilities is the electricity consumed in our operations. We collect usage data from our facilities around the globe and process data from utility invoices to gain visibility into electricity and fuel usage. When usage data is unavailable, we either use financial data to estimate the electricity or fuel used by taking the amount paid divided by the regional average price (e.g., dollar per kWh), or estimate the usage based on the usage from facilities with similar characteristics (e.g., size, type, location). In the case of data center back-up power generation, the fuel usage estimate is based on the intensity of electricity use at the site. We then calculate carbon emissions by multiplying actual or estimated usage by the appropriate emissions factor (e.g., regional electricity grid mix, $CO_2e$ per kWh, or fuel combusted $CO_2e$ per liter).

For electricity specifically, we use the GHGp's market-based method to demonstrate how renewable energy investments, such as the Amazon Wind Farm Texas, reduce our consumption of grid electricity.[9] Using this standard method, we account for yearly reductions in Amazon's electricity emissions to meet our goal of matching 100% of the electricity consumed by our global operations with renewable energy. See our Renewable Energy Methodology for a more detailed description of this calculation.

Calculating the carbon emissions of energy relies on accurate emissions factors data from a variety of local, national, and regional sources. For example, electricity consumed by a site is multiplied by an emissions factor for its locality. Carbon from electricity generation varies widely by utility provider, state, country, and region due to the variety of technologies used for generation. Some countries rely heavily on coal, while other regions use significant amounts of low-carbon wind or hydropower. To address this challenge, we built a geospatial emissions model that uses the most granular data available for electricity generation. In this way, any Amazon facility can be placed on a map and associated with the most precise possible emissions factor. In the U.S., the authoritative emissions factor sources come from the EPA's eGRID data (electricity emissions by U.S. grid sub-region). The International Energy Agency provides average electricity emissions per kWh for almost every country in the world. In some cases, such as Australia and Canada, we use state-level, province-level, or even supplier-specific emissions factors, which allow for geographically specific calculations. Similar to transportation, we use fuel combustion emissions factors from the UK's Defra in our energy model.

## Refrigerants Emissions Model

Emissions related to cooling and refrigeration are present across Amazon's global operations. These occur through normal business processes such as the cooling of our data centers, corporate offices, and fulfillment network facilities, and refrigeration for our Whole Foods Market stores and other grocery operations. We calculate the emissions associated with refrigerant materials across Amazon's facilities through a combination of data collection and, where primary data is unavailable, estimation based on each facility's type and size, or intensity of electricity usage in the case of data centers. Amazon's refrigerant emissions are represented by total leakage of refrigerant material that occurs through normal operations multiplied by the global warming potential (GWP) of the specific material used.

## Packaging Emissions Model

We built a detailed emissions model to quantify the carbon footprint of each type of Amazon packaging (e.g., corrugated boxes or mailers) from production to end-of-life. Carbon emissions are released during the raw material extraction, processing, manufacturing, and disposal of packaging. Our environmental packaging model quantifies the carbon footprint of every package from manufacture to end-of-life given key parameters such as material type, mass, and dimension. In total, the emissions model has produced life cycle carbon emissions factors for hundreds of types of packages based on Amazon's detailed data on packaging materials, thickness, and recycling rates. We applied region-specific packaging emissions factors (where available) on a per-package basis to outbound shipments to calculate total emissions from packaging. The calculation covers emissions from raw materials and intermediate products, transportation overbox manufacturing, and end-of-life packaging (i.e., recycling or disposal). This service uses industry-standard LCA data from commercial LCA databases to model the impacts of raw materials and manufacturing processes.

## Amazon Devices Emissions Model

We quantify the carbon footprint of Amazon devices sold during a given year using detailed data on the components of each device and the quantity sold each year. We produce detailed, parameterized models for our major device types, including Fire TV, Echo, Fire Tablets, Kindle, Ring, and Blink. We calculate the carbon footprint of each device type by inspecting the device's "Bill of Materials"—which details the mass and makeup of each component used in a device—and model life cycle emissions of each component using a mix of commercially and publicly available LCA databases. After each stage of the life cycle is modeled, our research team creates emissions factors for each device by aggregating the carbon emissions from the manufacturing, transportation, and device end-of-life phases. We scale these emissions factors by the quantity sold to estimate the carbon footprint associated with manufacturing, transportation, and the end-of-life treatment of all Amazon devices sold in a given year. To calculate the emissions associated with the use of our devices, we have established a methodology that uses telemetry data to determine the number of active devices in the field. We then multiply that by each device's average annual energy use. See our Devices Product Carbon Footprint Methodology for more information.

In order to match our customers' use of their devices with renewable energy sources, we calculate the emissions associated with the electricity grid that corresponds to the country in which the device is reporting. The electricity consumption is matched via renewable energy investments in accordance with the GHGp market-based boundary to offset average electricity grid emissions. Overall, annual emissions for devices are then determined by combining the annual emissions from all life cycle phases.[10]

## Employee Commute Emissions Model

We developed a model to estimate the GHG emissions associated with employees commuting to and from work at Amazon locations. The model follows the recommendation from GHGp for employee commute emissions, using a distance-based approach. First, we conducted a representative survey to understand how employees commute each day and what mode of transportation they use, such as walking, carpooling, biking, driving alone, or taking public transportation. Second, we estimated GHG emissions factors based on the distances employees reported traveling, the percentage of employees using each transportation mode,

and the associated mode's tailpipe emissions factor based on available national, regional, and industry data sources. Finally, we multiplied the emissions factors by the number of employees and the frequency of their commutes to calculate the Amazon employee commute carbon emissions.

[1] Amazon calculates and reports our carbon footprint in accordance with "The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard (Revised Edition)," including the "GHG Protocol Scope 2 Guidance (An amendment to the GHG Protocol Corporate Standard)" and "Technical Guidance for Calculating Scope 3 Emissions (Supplement to the Corporate Value Chain (Scope 3) Accounting and Reporting Standard)," published by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). We refer to this collectively as the GHG Protocol (GHGp).

[2] Amazon reports emissions according to GHGp's market-based method (MBM) in both Scope 2 and Scope 3 (as applicable), which accounts for renewable energy Amazon purchases to support our operations.

[3] GHG emissions are converted into the standard unit of carbon dioxide equivalent ($CO_2e$) via global warming potential (GWP). For example, 1 kilogram of methane has a GWP of 28, meaning that those methane emissions are equivalent to 28 kilograms of carbon dioxide ($CO_2$). This conversion reflects the fact that methane traps heat 28 times more effectively than $CO_2$ over a 100-year time horizon.

[4] WRI and WBCSD's GHGp delineates what actions fall within scope for international standards for corporate footprinting.

[5] When using the term "spend" in this document, we are referring to the United States Dollar (USD).

[6] Li, M., Ingwersen, W.W., Young, B., Vendries, J., Birney, C. useeior: An Open-Source R Package for Building and Using US Environmentally-Extended Input–Output Models. Appl. Sci. 2022, 12, 4469. Retrieved online: https://doi.org/10.3390/app12094469.

[7] Henderson, A., Bruckner, M., Scanlon, K., Ingwersen, W. The USEEIO framework to create IO models: application to the DoD and case demonstration. LCA XVIII, Fort Collins, CO, September 25-27, 2018. Retrieved online: https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=NRMRL&dirEntryId=343341.

[8] Wang, M., Elgowainy, A., Lu, Z., Baek, K. H., Bafana, A., Benavides, P. T., Burnham, A., Cai, H., Cappello, V., Chen, P., Gan, Y., Gracida-Alvarez, U. R., Hawkins, T. R., Iyer, R. K., Kelly, J. C., Kim, T., Kumar, S., Kwon, H., Lee, K., Lee, U., Liu, X., Masum, F., Ng, C., Ou, L., Reddi, K., Siddique, N., Sun, P., Vyawahare, P., Xu, H., Zaimes, G. The Greenhouse gases, Regulated Emissions, and Energy use in Technologies Model® (2022 .Net). Computer Software. USDOE Office of Energy Efficiency and Renewable Energy (EERE). 10 Oct. 2022. Retrieved online: https://doi.org/10.11578/GREET-Net-2022/dc.20220908.2.

[9] Hurst, Kara. "Our Largest Wind Farm Yet: Amazon Wind Farm Texas." About Amazon, 15 Sept. 2015, www.aboutamazon.com/news/sustainability/our-largest-wind-farm-yet-amazon-wind-farm-texas

[10] See our Renewable Energy Methodology for more information on the Devices Renewable Energy matching calculation.