Reaching Net Zero Carbon by 2040

Measuring, Mapping, and Reducing Carbon the Amazonian Way

The amount of carbon dioxide in the world's atmosphere is at the highest level seen in 3 million years. Human activities such as burning fossil fuels, clearing forests, and cultivating lands for agricultural use contribute to climate change by emitting carbon dioxide (CO_2) and other greenhouse gases (GHGs) that trap heat in the atmosphere. We're already seeing the effects, from rising average temperatures to stronger and more frequent storms, drought, and wildfires.

At Amazon, we see climate change as a major threat to our customers, the environment, and our world. We share the scientific consensus of the Intergovernmental Panel on Climate Change (IPCC) that holding global temperature increases below 1.5 degrees Celsius is needed to avoid the worst effects of climate change on humans and our planet. This will require global net human-induced CO_2 emissions to decline 40-60% by 2030 (from 2010 levels) and reach net zero by 2050.[1]

[1] *IPCC, 2018: Summary for Policymakers. Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. World Meteorological Organization, Geneva, Switzerland, 32 pp. Retrieved online.*

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CARBON METHODOLOGY

We recognize the urgency to act to limit the global rise in temperature and have set one of the world's most ambitious timelines to reach net zero carbon emissions by 2040—a decade ahead of what is required to meet the goals of the Paris Agreement.[2]

Achieving this goal begins with measuring our carbon footprint, identifying how to drive carbon reductions across every part of our business, and equipping our teams with the tools, knowledge, and resources to act. Our vision for a carbon neutral future means Amazon's buildings are fully powered by renewable energy; our fleets run on renewable electricity and other zero-carbon fuels; and the indirect emissions sources throughout our supply chain are zeroed out through renewable energy, energy efficiency, sustainable materials, carbon sequestration, and other carbon reduction measures. We are already investing heavily in carbon reduction technologies and will continue to explore, develop, and adopt cutting-edge strategies to reach carbon neutrality by 2040, including our intent to add 100,000 fully-electric vehicles to our global delivery fleet.

We have a comprehensive understanding of the carbon emissions across our business and have done extensive analysis to develop science-based targets, strategies, and metrics to reduce them. We are excited to share the science and technology behind our carbon footprint and our path to building a carbon neutral future.

What's in Amazon's Carbon Footprint?

A carbon footprint measures the total GHG emissions caused by the direct and indirect activities supporting a company. 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 burned by Amazon's delivery fleet.[3] Scope 2 emissions come from the generation of purchased energy, like the electricity used to power Amazon facilities.[4] Scope 3 emissions include all other activities that take place beyond a company's direct operations, for example the production of Amazon packaging and devices.

To calculate Amazon's carbon footprint, we account for a diverse set of direct and indirect emissions that occur both upstream and downstream of our operations. We set a comprehensive system boundary that 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*
- *Electricity used in our fulfillment centers, data centers, physical stores, and other facilities*
- *Amazon packaging*
- *Amazon product manufacturing, such as Echo devices, Kindles e-readers, AmazonBasics, Whole Foods Market brands, and other Amazon Private Brands products*
- *Our customers' use of Amazon devices*
- *Capital goods, such as emissions from building construction, manufacturing of servers and equipment, and the production of other Amazon infrastructure*
- *Corporate operating expenses, such as business travel, office supplies, corporate events, outside consulting services, and other expenditures*
- *Customers' trips to Amazon's physical stores (e.g., Whole Foods Market)*
- *Refrigerants used for cooling in our data centers, corporate offices, grocery stores, and fulfillment centers*

[2] The long-term temperature goal of the Paris Agreement is to "limit global temperature increase to well below 2 degrees Celsius, while pursuing efforts to limit the increase to 1.5 degrees," and the IPCC's 1.5-degree report states that global net carbon dioxide emissions should reach zero by 2050.

[3] Amazon uses the "operational control" approach detailed in the GHG Protocol to define the activities that contribute scope 1 emissions to our footprint.

[4] Amazon reports emissions according to the GHG Protocol's "market-based" method, which accounts for renewable energy Amazon purchases to support its operations.

We evaluate the quantity of GHG emitted for each of these activities by taking the amount of the activity conducted (e.g., miles travelled or gallons of fuel burned) multiplied by its appropriate life cycle "emissions factor" (e.g., grams CO_2 per kilowatt-hour (kWh) of electricity used), which provides a representative value for the carbon dioxide emissions associated with that activity. Once the emissions for all activities are calculated, we sum them to produce the total carbon footprint for Amazon's entire 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. Our team of researchers and scientists have combined cutting-edge life cycle assessment (LCA) science and Amazon Web Services (AWS) big data technology to develop a robust software solution that processes billions of operational and financial records from Amazon's operations across the world to calculate our carbon footprint. The software estimates carbon emissions for all activities within our system boundary using a dollar-based environmental assessment model, then enhances the accuracy of carbon-intensive activities with detailed, process-based LCA models.

This hybrid carbon footprinting approach consists of five scientific models:

1. ***Financial:*** *We combine data on Amazon's spending with industry-specific, dollar-based emissions factors (e.g., a standard amount of carbon dioxide pollution associated with every dollar of spending on a particular activity). We use this model to capture carbon emissions from activities like the construction of Amazon buildings, the manufacturing of Amazon's Private Brands products, equipment used in our warehouses, office supplies, and other purchased goods and 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. ***Electricity:*** *We account for the impacts of the energy consumed by our offices, data centers, and warehouses, as well as the benefits of the renewable energy we generate around the globe.*
4. ***Packaging:*** *We look carefully at the materials and processes behind all the boxes, mailers, and other packing items Amazon adds to the products we sell.*
5. ***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, Blink, and all others. 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.*

Our software uses AWS cloud technologies to implement these five models in order to transform physical and financial data into emissions measurements for Amazon's specific business activities (e.g., shipping, packaging). We then use the outputs of these calculations to assemble a company-wide 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 system would allow us to track activities like the total emissions associated with one-day shipments as they travel through Amazon's fulfillment network, including the emissions from fulfillment centers (electricity model), delivery (transportation model), and packaging (packaging model).

Our carbon footprint meets the widely adopted international standard of the GHG Protocol,[5] and has been independently audited and verified by Apex according to the International Organization for Standardization's ISO 14064-3 verification protocol.

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 dollar-based model combines expenditure data from Amazon's general ledger with industry-specific, dollar-based emissions factors (e.g., 1,556 grams CO_2 equivalent[6] (CO_2e) per dollar of truck transport) published by the U.S. Environmental Protection Agency (EPA) and other peer-reviewed academic and government sources. 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.[7] EIO LCA accounts for the carbon emissions from producing each of these intermediate inputs, and from the production of all inputs the further we travel up the supply chain.

We apply EIO LCA by mapping Amazon's 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., 224 grams of CO_2e per dollar) and shipping boxes are mapped to paperboard container manufacturing (i.e., 807 grams of CO_2e per dollar). This method is the most efficient way to ensure that every corporate activity has 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 like the U.S. Department of Defense and even individuals who wish to understand the environmental impact of their personal activities.[8]

[5] The World Resources Institute (WRI) and World Business Council for Sustainable Development's (WBCSD) GHG Protocol delineates what actions fall within scope for international standard for corporate footprinting.
[6] GHG emissions are converted into the standard unit of CO_2e via Global Warming Potentials (GWPs). For example, one kilogram of methane has a GWP of 28, meaning that those methane emissions are equivalent to 28 kilograms of CO_2. This conversion reflects the fact that methane traps heat 28 times more effectively than CO_2 over a 100-year time horizon.
[7] Yang, Y., W. Ingwersen, T. Hawkins, M. Srocka, D. Meyer. USEEIO: a New and Transparent United States Environmentally Extended Input-Output Model. Journal of Cleaner Production. Elsevier Science Ltd, New York, NY, 158:308-318, (2017). Retrieved online.
[8] Henderson, A., M. Bruckner, K. Scanlon, W. Ingwersen. 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.

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. The scope of our assessment includes transport 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, the manufacturing of vehicles, and the supply chain for fuels. The emissions model for transportation covers emissions associated with "well-to-wheels" impacts—extracting, refining, distributing, and consuming transportation fuels—and "vehicle" impacts—manufacturing, maintaining, and disposing of vehicles. These impacts are reported as emissions factors on a grams of CO_2e per kilometer traveled basis.

The transportation emissions model relies on two separate tools to quantify these impacts. For well-to-wheel 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 Transportation (GREET) model. GREET is an LCA tool used to evaluate various transportation fuels like diesel, gasoline, hydrogen, natural gas, and biofuels. 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 for Clean Transportation.

For vehicle impacts, the emissions model estimates the emissions associated with vehicle manufacturing (including batteries), maintenance, and disposal using commercial LCA software that maintains up-to-date repositories of peer-reviewed LCA emissions factors. Estimates for lifetime vehicle distance driven are based on a report for the International Resource Panel of the United Nations that reviews vehicle life expectancy around the world. In total, our vehicles model compiles emissions factors for fleet vehicles operating across the world and can produce emissions factors for over 100 well-to-pump fuel pathways.

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). Future versions of this model may incorporate customer survey data. 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 these data and emissions factors for all vehicle and transportation modes, we multiply the distance traveled by each mode by the appropriate emissions factor, then multiply that product by the number of total customers in a year.

Packaging Emissions Model

We built a detailed emissions model to quantify the carbon footprint of each type of Amazon packaging (e.g., corrugate 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 like material type, mass, and dimension. In total, the emissions model has produced life cycle carbon emissions factors for hundreds of packages based on Amazon's detailed data on packaging materials, thickness, and recycling rates. We applied region-specific packaging emissions factors 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 package end-of-life (i.e. recycling or disposal). This service uses industry-standard LCA data from commercial LCA tools to model the impacts of raw materials and manufacturing processes.

Electricity Emissions Model

We calculate the carbon footprint of purchased electricity 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. The largest source of carbon emissions for our facilities is the electricity used to power 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 actual consumption data is unavailable, we estimate electricity consumption by taking the amount paid for electricity (USD) divided by the regional average electricity price (USD per kWh). We then calculate carbon emissions by multiplying the electricity consumed by facilities (kWh) by the emissions factor associated with the regional electricity grid mix (CO_2e/kWh).

When we purchase solar and wind energy, we use the GHG Protocol's market-based method to demonstrate how renewable energy purchases—from Amazon Wind Farm Texas, for example—reduce our consumption of grid electricity.[1] Using this standard method we can account for yearly reductions in Amazon's electricity emissions as we make progress toward our goal of powering our global infrastructure with 100% renewable energy.

Calculating the carbon emissions of electricity relies on accurate emissions factors data from a variety of local, national, and regional sources. 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 capture these factors, 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 sources come from the EPA's eGrid data (electricity emissions by U.S. grid sub-region). The International Energy Agency (IEA) provides average electricity emissions per kWh for almost every country in the world. Some countries, like Australia and Canada, report state or province-level emissions data, which allows for even greater granularity of data.

Amazon Devices Emissions Model

We quantify the lifetime carbon footprint of Amazon devices sold during a given year using detailed data on the components of each device, their use-phase energy use, and the quantity sold each year. We produce detailed, parameterized models for our major device types, including Fire TV, Echo, Fire Tablets, Kindle, Ring Doorbells, and Blink. We calculate the carbon footprint of each device type by inspecting the device's "bill of materials"—which details the mass and make-up of each component used in a device—and modeling life cycle emissions of each component using commercial LCA databases. The use-phase emissions are modeled by multiplying the total power consumption over the device's life by the electricity emissions factor in the country or region where the device is sold. 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, use, and device end-of-life phases. Finally, we scale these emissions factors by the quantity sold to estimate the total carbon footprint of Amazon devices sold in a given year.

Setting out to Reach Net Zero Carbon by 2040

The first step toward achieving net zero carbon emissions by 2040 is understanding the carbon footprint of our company in a way that captures the full breadth of our operations and how each part of our business can drive reductions. Our work to quantify our carbon footprint allows us to identify the most significant contributors of carbon emissions across Amazon and prioritize carbon reduction activities that will have the greatest impact on lowering our footprint. We are committed to using our advanced technologies and innovative culture to systematically track our progress toward driving carbon emissions out of our operations.

As Amazon evolves as a company, so too will our approach to driving carbon reductions. This will require ongoing iteration, improvements, and experiments to do more for our customers while emitting less carbon. We will continuously seek to improve our ability to obtain more granular data on our own operations and develop new models that will enable us to reduce carbon faster and more efficiently. We aim to make this information easily available to our customers, investors, and other stakeholders at every step of the journey.