How Google is supporting the circular economy

Google

For the vast majority of Earth's existence, our planet functioned as the quintessential circular system. The Sun's energy nourished trees into life, and once they fell, microorganisms broke them down into soil and nutrients, fuelling the next generation of growth. The notion of 'waste' did not exist — everything had a use.

It is only in the past few hundred years that humans have interrupted this cycle. With the rise of the Industrial Age came a linear economy built around the consumption of natural resources. Energy was turned into goods and products that we used — and then threw away.

This sliver of Earth's history improved the lives of billions of people, but it came at a tremendous cost to the planet's future. At our current pace, humanity needs 1.75 Earths to sustain our consumption of natural resources. We have been running a resource deficit since the 1970s that accelerates every year according to the Global Footprint Network, and by 2050, humanity will generate 3.5 Gt of solid waste annually[1].

To protect our planet while continuing to improve lives, we need to decouple economic growth from the consumption and disposal of finite resources. That is the core premise of the circular economy, which aims to minimize waste and maximize reuse of existing materials.

The circular economy also offers a critical pathway to mitigate climate change, because recycled and reused resources have lower carbon footprints. For example, improving the circulation and reuse of uncontaminated steel would avoid 500 Mt of new steel production by 2050, saving more than 1 billion tonnes of carbon emissions per year[2].

Figure 1. Zero-waste data centres. Google uses several circularity strategies at its globally owned and operated data centres, such as repairing components whenever possible to extend the life of servers.

Fortunately, the opportunity is as vast as the need. By making the most of our finite resources, we can not only thrive within planetary boundaries, but we can also generate an estimated US$4.5 trillion[3] in new economic output by 2030 and support efforts to achieve net-zero carbon emissions across the economy.

Google is committed to accelerating the transition to a circular economy in which business creates environmental, economic and community value through the maximum reuse of finite resources. To help inspire others toward a similar goal, we are sharing some of the lessons we have learned from our circularity programme — and the challenges that remain.

OUR THREE CIRCULARITY PRINCIPLES

Since our founding, Google has made it a core value to operate our business in an environmentally sustainable way. In 2007, we became the first major company to be carbon neutral for our operations. As of 2022, our sustainability programme takes a comprehensive view across carbon, water, ecology and circularity. We aim to achieve net-zero emissions across all of our operations and value chain — including our consumer hardware products — by 2030, to replenish 120% of the water we consume by the same year, and to become a circular Google within this more sustainable world.

Our approach to circularity is anchored around three core principles:

1. *Design-out waste and pollution.* This means designing for circularity from the start, enabling existing products to become future resources.
2. *Keep products and materials in use.* This means extending the effective life of products or materials as long as is safely possible, to make the most of all the resources that went into their creation.
3. *Promote safe and healthy materials.* This means designing products with materials that are safe for both people and the planet, recognizing that these materials will be used and reused long into the future.

These foundations are embedded into all aspects of our business operations, from

the data centres we operate to the campuses we build, the products we create, the suppliers we work with, and the culture we encourage. The following section describes some of the progress we have made in each of these areas.

ZERO-WASTE DATA CENTRES

Google owns and operates 23 global data centres filled with servers and other equipment that provide reliable service to the billions of people who use our products every day. Our circularity goal for these centres is to achieve 'zero waste', defined as minimizing waste generation and maximizing the reuse of products and materials as much as possible while diverting 90% or more of solid waste from landfills.

As of 2022, seven of our 23 data centres have met this zero waste to landfill target and we are continuously making investments to advance waste diversion and recycling across our operations (**Fig. 1**). Additionally, since 2015, 32.6 million hardware components have been resold into the secondary market, and in 2021, 27% of upgrade components were from refurbished inventory[4,5].

Our approach to data-centre circularity starts with identifying the life-cycle stage of data-centre components. From there we apply several circularity strategies:

- *Maintain*. Whenever possible, we repair components to extend the life of servers.
- *Refurbish*. When a server or equipment is decommissioned, we create an inventory of usable, refurbished components that are stored for future reuse.
- *Reuse*. Any excess components are resold on the secondary market, following a rigorous security process.
- *Recycle*. Components that cannot be reused or resold are sent to an electronics waste-recycling partner.

Proof point: European data centre in Denmark. One of our newest European data centres, located in the Danish town of Fredericia, achieved zero-waste to landfill from day one — and continues to make important progress. Site management is working with a waste partner to recycle additional material that is otherwise sent to waste-to-energy recovery. This has required close partnership with staff and our vendors to find innovative solutions for waste collection and separation.

CIRCULAR CAMPUSES

Google has offices in over 180 cities spanning nearly 60 countries. We take a holistic approach to circularity in our offices and campuses, which starts by designing buildings with healthy materials and continues with reducing food and plastic waste in our workspaces. Our three key areas of office circularity are:

- *Food waste*. Our food programme aims to reduce waste through composting, donation and tracking use to right-size orders. We recently announced a goal of sending zero food waste to landfills — and cutting food waste in half for each Google employee — by 2025. We also use behavioural nudges that encourage Googlers to take only the food they will eat. For example, by reducing the depth of our cafeteria bowls by an inch, we found that Googlers took smaller portion sizes, which reduced leftover plate waste by 30–50% (ref. 6).
- *Plastics waste*. We work to reduce single-use plastics and other plastic waste through a series of interventions, including procurement, operational changes and workspace design. These efforts include eliminating the purchase of single-use plastics wherever possible and making reusable drinking options (like our sustainable hydration stations) easy to use in our micro-kitchens.
- *Building and construction materials*. In developing our office spaces, we promote circularity through a number of practices, including procuring salvaged and reused materials in construction projects, designing our facilities to enable zero-waste operations, and setting ambitious waste-diversion targets to keep material out of landfills. For example, since 2012, we have had a robust salvage programme, working with non-profits to find new homes for usable building components such as doors, plumbing fixtures and tiles.

Proof point: Bay View and Charleston East campuses. Our new Bay View and Charleston East campuses mark significant steps forward for our circularity programme (**Fig. 2**). At both locations, we vetted thousands of building materials against the Living Building Challenge (LBC) Red List to eliminate 'worst in class' materials and chemicals with the goal of creating a safer, more circular environment. Both campuses incorporated salvaged materials into the building design, and both aim to reduce future renovation waste through highly flexible and reconfigurable work areas. At Charleston East, in particular, more than 22,000 imperial tons of construction waste had been diverted as of October 2021, and 530,000 pounds of drywall waste was recycled as part of a closed-loop wallboard initiative. With these efforts, Charleston East is set to be one of the largest projects ever to attain an LBC Materials Petal certification for healthy building materials.

PRODUCT AND HARDWARE DESIGN

Millions of people use Google products like Pixel, Nest, Home and Fitbit every day, making these products a circularity priority area. Our product circularity approach involves several strategies:

- *Using recycled materials*. We are committed to using recycled or renewable content in at least 50% of plastic across the product portfolio by 2025, prioritizing recycled plastic wherever possible. For example, the Nest Audio enclosure — which is composed of fabric, housing, a foot and a few smaller parts — is made from 70% post-consumer recycled (PCR) plastic. Our materials scientists and design engineers developed a custom PCR plastic in partnership with our suppliers, and we work closely with them to expand the market for recycled materials, including those we develop specifically for our products.
- *Practicing circular design*. We focus on material reuse and extending the useful life of our products as part of the fundamental design process. For example, we have a goal of making all packaging plastic-free and 100% recyclable by 2025. We also provide a number of repair options, such as making a full range of spare parts for Pixel 2 through Pixel 6 Pro products, including batteries, replacement displays and cameras, and we will provide at least five years of security updates for the Pixel 6 and Pixel 6 Pro, as well as future Pixel phones, from the date we start selling them on the US Google Store. Additionally, for Google Nest, we issue critical bug fixes and patches for at least five years after launch.
- *Eliminating waste*. We are committed to achieving Underwriters Laboratory (UL) 2799 Zero Waste to Landfill certification at all final assembly manufacturing sites by 2022. We are also reducing

Iwan Baan for Google

Figure 2. Circularity at Bay View and Charleston East. These new Google campuses feature many circularity strategies, such as incorporating salvaged materials to promote reuse and designing flexible spaces to reduce renovation waste.

packaging waste from our suppliers when they ship parts to our manufacturing sites. Additionally, for consumers, we are developing tools and programmes to help people properly recycle electronic goods. For example, we recently made it easier for people to find out where they can recycle or dispose of electronic goods using Google Maps and Search. And we continue to research and pilot new ways for customers to recycle e-waste, including through a doorstep-recycling pilot programme in Denver, Colorado.

- *Promoting safer chemistry*. We strive to select materials to use in our products that have a chemical composition that is safe for both people and the planet — both now and far into the future. For example, we make our restricted substances specification publicly available while also aiming to use safer flame retardants and eliminate antimicrobials across all of our products by 2023.

Proof point: recycled aluminium. As part of our work toward a more circular Google, we developed a 100% recycled aluminium alloy to meet our Google Pixel performance standards, validated by a third-party certifier (**Fig. 3**). The Pixel 5 was our first phone to incorporate this recycled aluminium, which not only eliminates the use of mined aluminium in the enclosure and reduces waste but also lowers the carbon footprint of manufacturing the enclosure by 35% (based on a third-party-verified life-cycle assessment) compared to using virgin aluminium. At the time of writing, the aluminium inside the back housing of the Pixel 5, 6 and 6 Pro is made with 100% recycled content. We also want other companies to benefit from our work and for other manufacturers to use this alloy in their products. That is why we require our suppliers to make this alloy available to manufacturers across the electronics industry.

For more information about our sustainability claims, please visit https://store.google.com/magazine/sustainability.

ENABLING EVERYONE

Even as we work to build a more circular Google, we recognize that realizing a circular economy will take everyone's participation. To support broader adoption of core circularity practices, we are building tools and partnerships that enable and empower others to reduce waste and reuse materials. A few notable efforts are as follows:

- *Enabling better recycling*. We have now made it easier for people to find out where they can recycle electronics, batteries, glass bottles, clothing and other goods using Google Maps and Search. Local merchants and shops can show the recycling services they offer, and more people can find these options just by searching something like "battery recycling near me" (**Fig. 4**). People can also suggest edits to the available recycling options at a location, helping others in their community find the right place for them.
- *Helping officials cut plastic pollution*. Every year, rivers carry millions of tonnes of plastic into oceans. We partnered with the United Nations Environment Programme (UNEP) to develop a new machine-learning model that shows a highly accurate view of plastic pollution, with a launch demo focused on the Mekong River in Thailand. This open-source model empowers local government to take action and scale new solutions.
- *Facilitating household circularity*. We have empowered people to take action on circularity in their everyday lives with our interactive tool, Your Plan, Your Planet. The tool features lessons on extending the life of household goods, along with a teachers' companion guide for schools. It also includes tips around water conservation, energy savings and more.

CIRCULARITY'S ROLE IN CLIMATE CHANGE

While the circular economy is critical from a global resource

perspective, it is also essential to addressing climate change. Simply put, the world cannot achieve a net-zero carbon-emissions target without the circular economy.

Global greenhouse gas emissions are expected to reach 51 Gt by 2050 (ref. 7). About 45% of that comes from 'embodied' emissions, or carbon generated from the production of new buildings, cars, clothing, food and other common goods or products. The circular economy has a key role in stopping the disposal of embodied carbon en route to a net-zero world. Every piece of waste represents a new product that will be created from scratch — and thus a missed opportunity to cut embodied emissions.

We can seize that opportunity and cut up to 10 Gt of carbon by 2050 (ref. 7) through several circular strategies described in greater detail elsewhere in this article, including:

- *Deconstruction*. Make better use of buildings through practices like deconstruction and reuse, low-carbon construction materials such as mass timber, and retrofitting or repurposing existing spaces.
- *Circular design*. Reduce the need for new products and materials by supporting longer product lifecycles, reuse programmes and recycling.
- *Recycled materials*. Use recycled materials to create new goods and products, as recycled resources generate significantly lower greenhouse-gas emissions than virgin resources during production.

EMERGING OPPORTUNITIES

As we build on our progress in the years to come, we see a number of exciting areas with the potential to further accelerate the transition to a circular economy.

Artificial intelligence

Artificial intelligence (AI) is becoming a tool to help address challenges facing many industries, and waste is no exception. Recent estimates suggest that AI's ability to design-out food waste can create US$127 billion in annual value by 2030, and its ability to improve consumer electronics is valued at US$90 billion a year[8]. Our 2019 white paper identified three primary ways that AI can support circularity:

1. *Design circular products, components and materials*. For example, AI can generate insights that help significantly shorten the design timeline of microchips, which reduces the total amount of materials needed for research and development.
2. *Operate circular business models*. For example, our food team, in collaboration with X, Alphabet's moonshot factory, is using AI to speed up the food-inspection process, strengthening the supply chain and reducing waste.
3. *Optimize circular infrastructure*. For example, AI-powered computer vision can help industrial robots classify waste on assembly lines with very high accuracy, leading to better sorting at recycling facilities.

Deconstruction and reuse

Roughly 11% (ref. 9) of global emissions come from construction and the creation of new building materials — an impact that is locked-in forever and cannot be reduced through technological improvements. Commercial deconstruction and reuse practices can help address this impact by promoting the use of low-carbon materials and encouraging adaptation of commercial buildings. Our 2019 white paper identified the following areas of opportunity for deconstruction and reuse in office development:

- *Design and build for circularity*. Development projects can prioritize healthy materials (including mass timber where feasible), design adaptable spaces that can change without needing extensive renovations, design for disassembly to avoid demolition waste, and create a deconstruction plan from the start. Regulation has an important role to play in supporting these practices.
- *Set-up salvage for success*. Cities can support salvage practices by requiring salvage plans during the building permitting phase and otherwise incentivizing the practice. Buildings can develop salvage inventories from the start that can make it easier to reuse or save equipment and materials throughout the life of the space.
- *Scale and diversify the deconstruction workforce*. Local jurisdictions can require 'salvage-ready' contractors for commercial projects and should support workforce training in deconstruction as a specific growth skill.
- *Strengthen the regional reuse marketplace*. There are a number of ways to strengthen the reuse market and support the circular economy of commercial buildings, including setting salvage targets, embracing virtual salvage marketplaces, and requiring salvage during public project procurement.

Figure 3. Recycled aluminium in hardware. Google developed a 100% recycled aluminium alloy, validated by a third-party certifier, to improve circularity in the Pixel phone.

Electronic waste

Electronic waste (e-waste) is one of the world's fastest growing waste streams. In 2019, only 17% of e-waste was recycled globally, according to Statistica. The rest often ends up in landfills, is improperly disposed of in the environment, or 'hibernates' — the practice of keeping a product that is no longer in active or regular use — in our homes. This practice limits the ability to recycle usable materials and e-waste, meaning that more new resources must be consumed to create new products.

In 2021, we conducted an assessment of why consumers engage in product hibernation instead of recycling and identified the following areas of opportunity[10] (it should be noted that there are usually multiple factors in a decision to hibernate a product, and that the key factors differ by product, so pursuing all of these areas is critical to maximize electronic recycling):

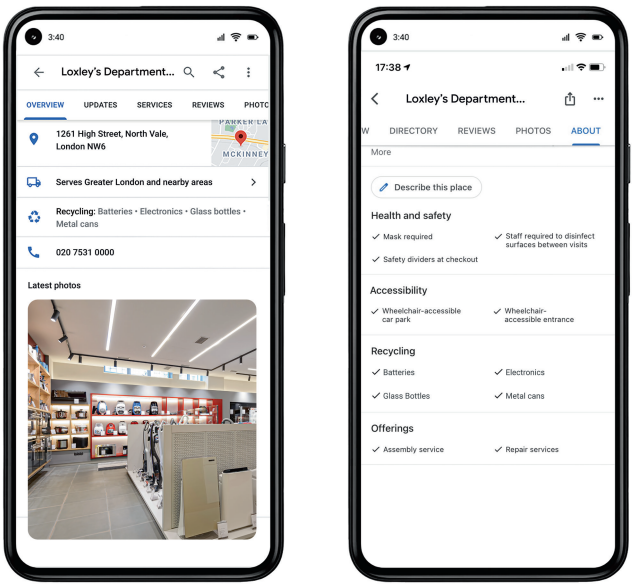

Figure 4. Search 'battery recycling near me'. Google Maps and Search now make it easier for people to find places near them that recycle a variety of goods, such as batteries, eletronics and glass.

- *Low handoff-option awareness or convenience.* Consumers may lack information about proper recycling methods or facilities or find that option inconvenient. Google is working to address this problem through Maps and Search programmes (described earlier) that help identify and access local e-waste recycling options.
- *Compensation expectations (financial or social).* Consumers often expect compensation for their e-waste, although this exchange can be social in nature, taking the form of product donations.
- *Keeping spare products.* Consumers often keep old products in case they need to replace a broken one. Stronger repair programmes can help, such as our programme for the Google Pixel described earlier.
- *Data retrieval and removal.* Consumers often hold on to products because they lack easy or reliable ways to transfer or erase data from the devices.
- *Device nostalgia.* Consumers often feel an emotional attachment to their devices, which causes reluctance to part with them.

CHALLENGES AHEAD

We are excited by the progress made by Google's circularity programme to date, as well as by the opportunities on the horizon. We also recognize the many systemic challenges hindering even greater progress — some of which we identify below. Overcoming these and other barriers will be critical to realizing the circular economy as soon as possible.

Improving data availability

The circular economy aims to make the most of every resource we use. To do that requires high-quality, standardized data enabling the market to identify, manage and value all the resources available at any given time. For example, rather than seeing a piece of plastic as an item to use and discard, we should see it as bits of information that tell us how it can be reused, what it is worth in terms of recycling, and where it is needed. Such data should inform capital investments, infrastructure priorities, business plans, policy interventions and more — as such, we view data availability as a key to accelerating the transition toward the circular economy. This challenge is one we feel particularly inspired to help solve as a data company, working alongside others.

Scaling innovation

The circular economy is in a similar place to where renewable energy was a few decades ago: we knew where we needed to go but often lacked the right technologies to help companies, governments and households get there in a cost-competitive way. Innovation helped bridge that gap, with the rise of advances such as new silicon systems to capture sunlight, larger wind turbines to capture energy and longer-lasting batteries to power electric vehicles. We need similar innovation around the way products and materials are designed, manufactured, used, reused, or recycled back into the economy. We need accelerators, venture funding and other forms of support focused on turning great circularity ideas into leading technologies. We plan to leverage Google's ingenuity, technical leadership, cultural influence and talented people to help do just that.

Embracing the future

Meeting this moment demands a spirit of exploration and discovery. In nature's circular system, it is the novel adaptations that pave a new path. Similarly, we need innovative thinkers to inspire a shared sense of purpose around this new direction and rally collective action. For our part, we can help by connecting billions of people every day and sharing our own lessons and experiences.

MOVING FORWARD TOGETHER

The circular economy, by definition, connects everyone. It is in that spirit of cooperation that we describe the approach Google is currently taking, recognizing that we do not have all the solutions and that true progress will span the global economy. We need business leaders to partner across industries and reduce costs, governments to incentivize action and protect the public good, innovators to keep looking ahead and thinking big, and people everywhere to know that no action is too small.

AUTHORS

Mike Werner, lead for circular economy
Eric Jaffe, editorial lead for real estate

ADDRESS

Google, 1600 Amphitheatre Parkway, Mountain View, CA 94043, USA.

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