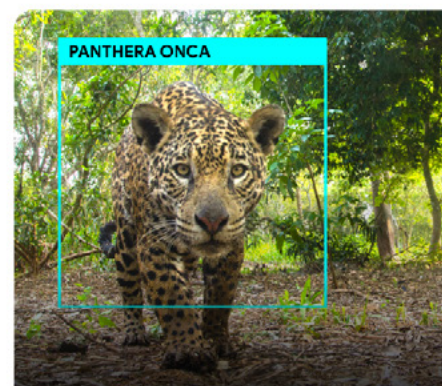
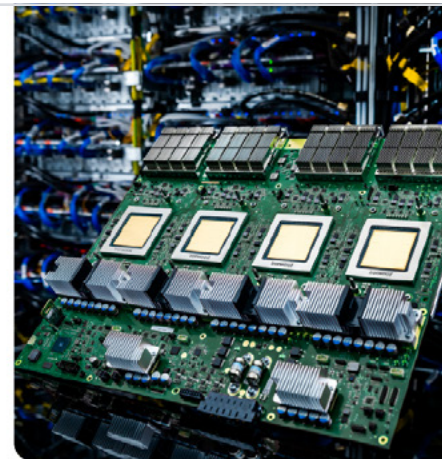
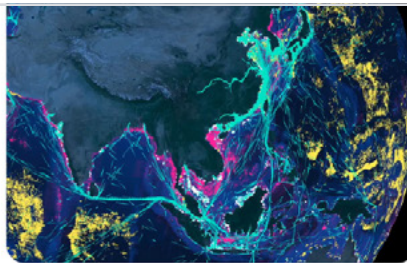


AI's Potential for the Planet (and Beyond)

Amin Vahdat, Ben Gomes, James Manyika, Kate Brandt, and Ruth Porat



At Google, we are focused on developing AI that assists, empowers, and inspires people in almost every field of human endeavor. Our goal is to improve the lives of as many people as possible, and we believe that AI can unlock transformational benefits across four key areas: for people, the economy, science, and society.

We're making progress in all these areas, ranging from supporting small and large businesses from every U.S. state that are using AI to grow, improving health diagnostics such as breast cancer screening, accelerating research in multiple fields of science, to helping children improve their reading skills, and so much more.

We also believe that AI can help address some of humanity's biggest challenges, including protecting the planet we all call home and the people who live on it. We see three primary avenues for environmental and societal impact:

- **Mitigating carbon emissions** by unlocking new efficiencies in high-impact sectors and activities;
- **Transforming the energy ecosystem** by accelerating the development of next-generation clean sources, making long-term bets on technologies like fusion, and optimizing the grid; and
- **Harnessing AI for climate adaptation and ecosystem protection**, from strengthening crisis resilience against natural disasters to monitoring biodiversity.

At the same time, we recognize that AI's growth creates its own new environmental challenges that need to be managed responsibly. Realizing the benefits of AI requires investing in data centers, which increase demand for electricity and water. Pursuing AI responsibly means understanding and mitigating these challenges.

At Google, we're taking a deliberate, full-stack approach to manage AI's growth responsibly and minimize its environmental footprint. This means we're focused on making our entire AI stack (including applications, models, software, and hardware) more efficient, investing in and quickly scaling new clean energy sources, and deploying climate-conscious, locally tailored water stewardship practices. Moreover, we're committed to ensuring that our energy use doesn't impact people in the communities in which we operate. In early 2026, we signed the White House Ratepayer Protection Pledge, demonstrating our confidence that energy growth and ratepayer protection can go hand-in-hand.

As an information and computer science company focused on innovation and breakthrough progress, we have ambitious moonshot goals for the impact we hope to achieve. While we're excited about our progress in minimizing AI's footprint and maximizing its positive environmental impact, success is not guaranteed and no company alone can ensure that AI delivers a net-positive future for the planet. Turning this potential into a reality will require focused efforts by Google and other AI developers, as well as broader collective efforts that bring together researchers, developers, governments, and local communities to manage risks and scale new solutions.

Ultimately, we believe that if AI is developed and harnessed responsibly and collaboratively, its environmental benefits will vastly outweigh its costs. From making industries more efficient, to monitoring air quality, to protecting communities from natural disasters—AI can serve as a force multiplier in addressing some of the world's most pressing environmental challenges.

This paper details our approach to minimizing AI's footprint while maximizing its positive impact on the environment and the people and communities who depend on it.

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Moving forward together

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Overview: Assessing AI's implications for the environment

AI opens up new possibilities to improve the quality of people's lives around the world. The purpose of this paper is to assess the growing environmental footprint of the data centers that power AI and actions that can be taken to ensure its environmental benefits vastly outweigh its costs.

From making industries more efficient, to monitoring air quality, to protecting communities from natural disasters—AI can accelerate addressing some of the world's most pressing environmental challenges. But a net-positive outcome isn't an inherent trait of the technology, and success will require focused effort to ensure that AI has a net-positive impact on the environment and the people and communities who depend on it.

In this paper we offer a **focused assessment of AI's implications for the environment** in two sections:

- **AI's environmental benefits:** We detail AI's potential to reduce carbon emissions, strengthen crisis resilience, and help protect ecosystems.
- **AI's environmental costs:** We assess the growing resource demands of data center infrastructure—specifically electricity and water—and outline Google's approach to minimize our operational footprint.

References to AI in this paper refer to the “full stack”—a cohesive ecosystem of innovation where frontier models, custom silicon, and the software that surrounds them are co-evolved as a single unit. By designing the full stack in tandem, we deliver the scale and efficiency required to solve the world's most complex global challenges. This full-stack approach is how we work to decouple AI's growth from its associated environmental impact, making the technology more efficient and more sustainable.

Google's annual footprint metrics referenced in this paper are sourced from our [2025 Environmental Report](#), which covers our 2024 fiscal year. However, some third-party research and Google examples reflect more recent data and developments. We'll report on our 2025 footprint metrics in our upcoming 2026 Environmental Report.



| Our planet, as seen via Google Earth.

Unlocking AI's potential for environmental benefits

Google develops AI that assists, empowers, and inspires people in almost every field of human endeavor; drives economic progress; and improves lives, enables scientific breakthroughs, and helps address humanity's biggest challenges.

One of these challenges is protecting the environment and the communities around the world who depend on it, and we're especially excited about AI's potential to both offset the environmental costs associated with AI and address some of the most pressing issues facing the planet. Specifically, at Google we're focused on:

- Accelerating carbon reduction
- Strengthening crisis resilience
- Advancing ecosystem protection

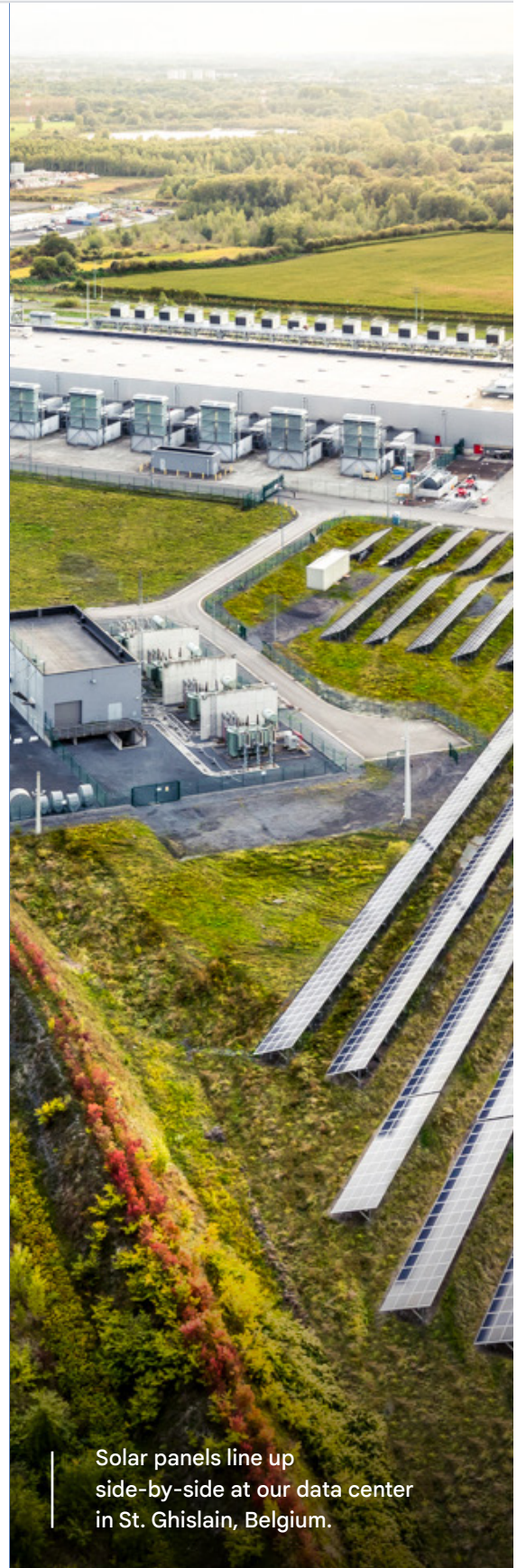
In addition, as AI is increasingly adopted across a wide range of economic sectors and industrial activities, we're optimistic that it will unlock new efficiencies that reduce energy demand and carbon emissions.

Mitigating climate change in high-impact sectors

A 2025 study in *Nature* estimated that the use of AI in just three sectors (power, food, and mobility) could reduce global emissions by 3.2–5.4 gigatonnes (GT) of CO₂e annually by 2035,¹ more than India's emissions in 2024² and significantly greater than the projected emissions from data centers that will power AI activities.³

AI offers more than just the promise of reducing carbon emissions in the future—it has already started to enable real-world reductions. Google is building novel solutions across a broad array of sectors, including power, transportation, and food and agriculture—and we're excited about their early results. In 2024 alone, just five of our AI products and features enabled others to collectively reduce an estimated 26 million metric tons of GHG emissions (tCO₂e),⁴ roughly equivalent to the emissions from the annual energy use of over 3.5 million U.S. homes.⁵ For context, Google's total emissions in 2024 were 11.5 million tCO₂e.⁶

We're still at the beginning of our journey to unlock AI's environmental potential, but these examples point the way to an exciting future where AI unlocks efficiencies and opportunities across a wide range of industry sectors and natural systems, creating benefits for people and the planet at a global scale.



Solar panels line up side-by-side at our data center in St. Ghislain, Belgium.

We aspire to help individuals, cities, and other partners collectively reduce 1 GT of their carbon equivalent emissions annually by 2030. To put the scale of this aspiration into perspective, 1 GT is comparable to the annual emissions of Japan.⁷

This monumental ambition represents one of the most consequential environmental contributions Google can help make for the planet, and we believe our technology can make it happen. This effort is a way for us to use our unique technological capabilities, state of the art AI research, and global reach to inspire and enable others to mitigate climate change. These solutions also provide co-benefits that improve people's daily lives, from saving drivers money on fuel to reducing city congestion and more.

Power

Meeting AI's energy needs is not only an urgent challenge, but also a generational opportunity to unlock an abundant clean energy future with widespread economic and societal benefits. We're harnessing AI to unlock innovation across the energy sector, leveraging a wide range of technical capabilities and partnerships to advance the next generation of clean technologies, tackle emissions from power generation, and increase grid reliability.

Some examples of how Google is working to innovate in this sector:

Grid optimization

A [collaboration](#) between Google, [Tapestry](#), and grid operator PJM aims to develop AI-driven data capabilities to speed up grid interconnection—with the goal of making electricity more reliable and

affordable for the 67 million people PJM serves in the United States. Tapestry is also [collaborating](#) with Chile's national grid operator, [Coordinador Eléctrico Nacional](#), to accelerate its transition to renewable energy, and [working](#) with the largest electric utility in New Zealand to improve efficiency and resilience.

Industry transformation

Google Cloud is using AI to unlock new innovation across the electricity industry. In 2025, we announced a collaboration with [Westinghouse Electric Company](#) to accelerate nuclear reactor construction and enhance operations of existing nuclear power plants, and a partnership with [NextEra Energy](#) to optimize field operations and enable a more reliable and resilient grid.

Scaling solar

Google's [Solar API](#) is making it easier to bring more clean energy online. Using machine learning, high-resolution imagery, and advanced modeling, the Solar API maps solar potential data for nearly 540 million buildings in over 40 countries,⁸ enabling solar installers, city planners, and energy companies to target rooftops with the highest potential.

Commercial fusion

AI is also accelerating research on promising next-generation clean energy sources like fusion. In October 2025, Google DeepMind [announced](#) a partnership with Commonwealth Fusion Systems to apply AI to unlock scientific advances that'll pave the way for commercial fusion power, including quickly and accurately simulating plasma behavior and developing novel real-time control strategies.

Transportation

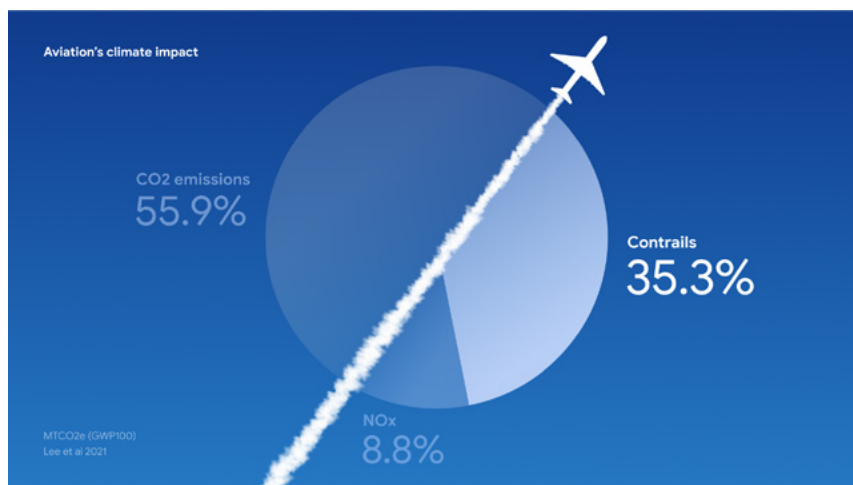
We're building AI-powered transportation solutions to help users save fuel, time, and money. Fuel-efficient routing in Google Maps analyzes factors like a vehicle's engine type, real-time traffic, and road conditions to pick the most fuel-efficient path. We estimate that it saved users fuel and cumulatively enabled more than 2.7 million metric tons of GHG emissions reductions in 2024 alone⁹—that's equivalent to taking approximately 630,000 gasoline-powered cars off the road for a year.¹⁰

Our Green Light initiative uses AI and Google Maps driving trends to optimize traffic light timing, ensuring that cars spend less time idling and more time moving. Our analysis from intersections implementing Green Light recommendations indicates the potential to reduce stops at intersections by up to 30% and reduce emissions at intersections by an average of over 10%.¹¹ This solution is being implemented in cities around the world, including in Brazil.

Just as AI can optimize travel on the road, it can help reduce the climate impacts of transportation in the sky. Contrails (the line-shaped clouds that sometimes appear behind airplanes) account for roughly 35% of aviation's global warming impact (Figure 1).¹² Google Research partnered with Breakthrough Energy and American Airlines to develop AI models that analyze atmospheric data to predict contrail formation and identify routes where they can be avoided.

In our most recent study, Google's AI contrail forecasts were integrated into American Airlines flight planning software and used in a trial of 2,400 transatlantic flights that were part of the airline's standard schedule. For the flights that successfully flew the contrail avoidance plans, there was a 62% reduction in contrail formation rate compared to the control group. We're working to scale this solution in Western Europe in collaboration with EUROCONTROL.

Figure 1
Contrails account for roughly 35% of aviation's global warming impact.



Food and agriculture

The global agricultural sector is critical to both human wellbeing and the natural environment: it feeds over 8 billion, employs roughly a quarter of the global labor force,¹³ and uses almost half of the world's habitable land.¹⁴ AI holds tremendous potential to help increase efficiency and mitigate emissions from food and agriculture through improved geospatial reasoning, weather prediction, and biological modeling. We're excited about the opportunities in this sector, and are working to develop new solutions that benefit both agricultural communities and the natural systems that support them.

For instance, the [Agricultural Landscape Understanding API](#)—developed by Google and partners—is currently deploying remote sensing and AI in India to help farmers precisely identify field boundaries, water bodies, and vegetation, enabling more efficient resource management. Google Earth Engine supports many [partners and customers](#) in the agricultural sector—including the USDA, RegrowAg, Corteva, Bayer, and Unilever—providing tools to reduce fertilizer pollution, optimize water usage, and improve crop production.

Increasing resilience to weather and extreme events

AI-powered tools can help save lives and safeguard livelihoods when disaster strikes. Consider wildfires as one example. Globally, an estimated 100 million people and physical assets amounting to \$215 billion were exposed to wildfires during the March 2024 to February 2025 fire season.¹⁵ The World Economic Forum found that AI-enabled early detection systems could drastically reduce the frequency of catastrophic wildfires by enabling faster containment.¹⁶

Google's AI products are helping communities anticipate, prepare for, and respond effectively to environmental risks—supporting people in protecting lives and livelihoods when disaster strikes.

Our mission is to make information accessible and useful, and nowhere is accurate, timely information more vital than during a crisis. Our crisis resilience solutions provide actionable information on weather and extreme events to help people stay prepared, safe, and resilient. Our ultimate aspiration is to enable a world where no one is surprised by a natural disaster: we're focused on accurately predicting natural disasters to keep as many people as possible safe.

Weather

The first step toward better preparation is better weather forecasting. We recently introduced [WeatherNext 2](#), a family of state-of-the-art AI models that learn directly from vast amounts of historical weather data to generate affordable, fast, and accurate weather prediction—often 10 to 15 days in advance.

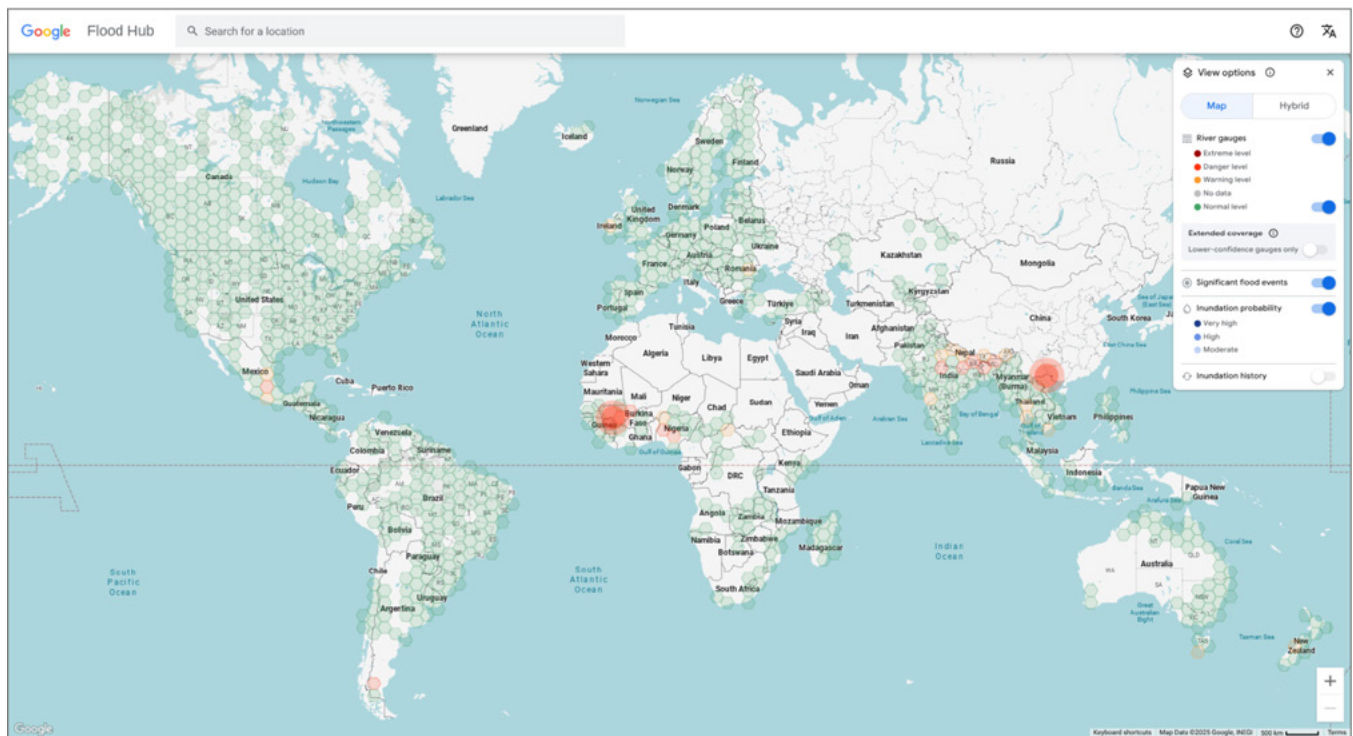
To tackle complex atmospheric phenomena, [NeuralGCM](#)—a Google Research model—combines traditional physics-based modeling with machine learning to simulate Earth's atmosphere. This model [has been used](#) by the University of Chicago's Human-Centered Weather Forecasts Initiative to more accurately predict the monsoon season in India. With the help of NeuralGCM, 38 million farmers in India received AI-powered forecasts to determine when to plant their crops during the summer of 2025, in anticipation of the monsoon season.

Floods

FloodHub displays forecasts for riverine floods up to seven days in advance using a breakthrough global hydrological AI model. Our flood forecasting information now covers more than two billion people in around 150 countries for the most significant and impactful riverine flood events (Figure 2).¹⁷ In 2024, we generated more than 1,100 crisis alerts that shared critical flood information, including mappings of estimated flooded areas, which were viewed by more than 33 million users.

More recently, in 2026, we added urban flash flood forecasts to Flood Hub. By leveraging a new AI-powered methodology, we can predict the risk of flash floods in urban areas up to 24 hours in advance. We focused our initial launch on urban areas and are actively working to improve the model's generalization to rural areas, reduce the spatial resolution for more hyper-local forecasts, and integrate even more real-time weather data sources.

Figure 2
Flood Hub view showing coverage for riverine floods.



Cyclones

[Weather Lab](#) features our experimental [cyclone predictions](#). We partnered with the U.S. National Hurricane Center, among others, to support their forecasts and warnings during the 2025 cyclone season—critical work given that cyclones endanger lives and devastate communities, with tropical cyclones causing \$1.4 trillion in economic losses over the past 50 years.¹⁸

Wildfires

Our AI-powered [wildfire boundary tracking](#) tool uses satellite data to refresh fire maps every 15 to 20 minutes, offering a near real-time picture of an existing fire's spread. These updates appear in Google Search, Google Maps, and push notifications sent to nearby users. In 2024, our [crisis alerts](#) provided timely wildfire information to over 26 million users across more than 480 wildfire events around the world.

We're also working to detect wildfires faster, before they become devastating blazes, and provide better information as they unfold. That's the idea behind [FireSat](#), a partner-driven initiative that uses high-resolution multispectral satellite imagery and AI to provide near real-time insights on wildfires. The first satellite [launched](#) in early 2025, with plans for three more to be deployed in 2026, for a total of more than 50 in the years to come, led by the Earth Fire Alliance coalition. Once fully operational, the program will provide near real-time data on the location, size, and intensity of all wildfires on Earth.

Protecting the planet's vital ecosystems

Thriving ecosystems power thriving communities. From the food people eat to the future of our economies, human wellbeing and opportunity are deeply tied to the health of our planet.

But the engine of our progress is under strain. The World Wildlife Fund reports a staggering 73% decline in wildlife populations since 1970¹⁹—a loss that erodes ecosystem resilience and threatens vital life-support systems. And because over half of global GDP is dependent on nature, ecosystem degradation creates significant risks to the global economy and human well being.²⁰ This is one reason why the World Economic Forum ranks biodiversity loss among the greatest risks to global stability over the next decade.²¹

AI provides the toolkit to meet this moment. By detecting early warning signals before ecosystems hit irreversible tipping points, we can move from observation to intervention. By unlocking geospatial insights, we're empowering researchers and communities to protect, manage, and restore the natural systems that sustain us all.

Geospatial technologies

We've spent over two decades organizing petabytes of satellite, climate, and ecosystem data into a comprehensible view of how the Earth is changing—powering tools that monitor issues like [illegal logging](#) and [overfishing](#).

Today, AI enables us to make that data more useful than ever, leveraging powerful tools like [Google Earth](#) and [Google Earth Engine](#) to turn raw insights into real-world solutions with wide applications. Our recently-launched [Google Earth AI](#) combines state of the art predictive models and Gemini's advanced reasoning capabilities to enable enterprises, cities, and nonprofits to achieve deeper understanding of our planet.

One of the AI models integrated into Google Earth AI is Google DeepMind's [AlphaEarth Foundations](#), which functions like a virtual satellite. It accurately and efficiently characterizes the planet's land and coastal environments—providing scientists with a better picture of planetary change and enabling better analysis and decision making on food security, deforestation, urban expansion, and water resources.

For more than two decades, Google has provided researchers with a clearer view of the changing planet through transformative geospatial tools. Building on this long-standing work, we're combining efforts from across Google toward an important aspiration: helping nature and people flourish together with AI-powered tools to empower governments, businesses, and communities to conserve 30% of the world's land and oceans by 2030.

By evolving from a 3D digital twin of the globe to delivering actionable AI-powered nature insights, we aim to accelerate global conservation efforts and support the restoration of the vital ecosystems that sustain both humanity and the planet.

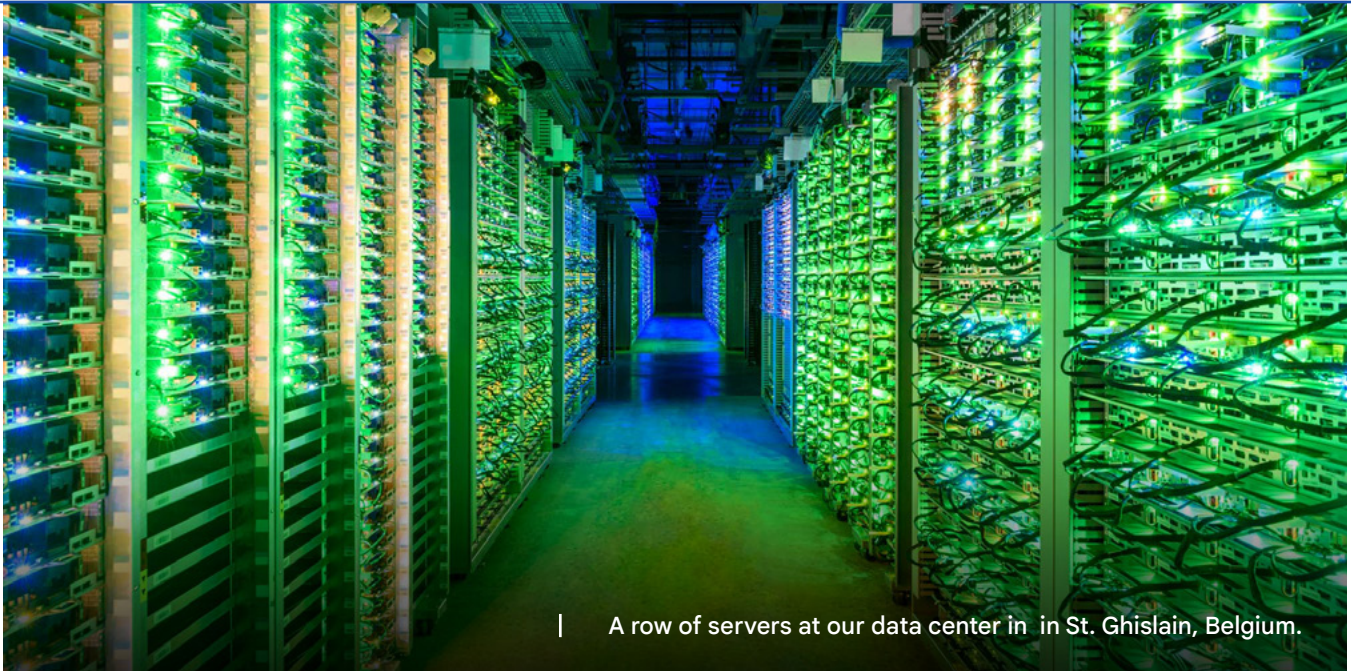
Nature insights

Empowering experts with AI can transform what historically involved years of manual analysis—identifying species, detecting patterns, and predicting change—into quicker, more accurate, and larger-scale action. We're developing advanced tools that synthesize complex data to reveal new insights into the past, present, and future of our planet.

It starts with making sense of the massive amounts of data researchers are already collecting. For example, we developed [Perch](#)—an advanced, open-source AI model—to analyze bioacoustic data at unprecedented speed and scale, enabling ecologists to identify species and monitor ecosystem health in near-real time. Already, Perch has helped researchers at the University of Hawaii [find Honeycreeper sounds](#) nearly 50 times faster than their usual methods, enabling them to monitor more species of Honeycreeper over greater areas.

AI can also help fill gaps when data is limited. Our [Species Distribution Modeling](#) uses Graph Neural Networks to infer where species live even if they haven't been well studied in the wild, enabling researchers to identify critical habitats for protection. For example, in a pilot to map the endangered Australian Greater Glider, the models successfully identified highly suitable habitats in areas where species observation data was scarce or non-existent.

We're also leveraging AI to help forecast future environmental conditions through research initiatives like [ForestCast](#). In October 2025, we released a [paper](#) and the first dataset dedicated to training deep learning models to predict deforestation risk. This research opens the door to moving from merely measuring deforestation after it happens to preventing it before it starts.



| A row of servers at our data center in in St. Ghislain, Belgium.

Managing AI's environmental costs and challenges

Realizing the benefits of AI—including for the environment—requires investing in data centers, which in turn increases demand for electricity and water to operate and cool them. This represents the resource costs of AI: the local and global inputs and environmental impacts associated with operating its physical infrastructure.

At Google, we're taking a deliberate, full-stack approach to manage AI's growth responsibly and minimize its environmental footprint. This means prioritizing efficiency across every layer of our AI systems—from physical infrastructure and specialized hardware to models and consumer products—to decouple AI's growth from its associated resource demands.

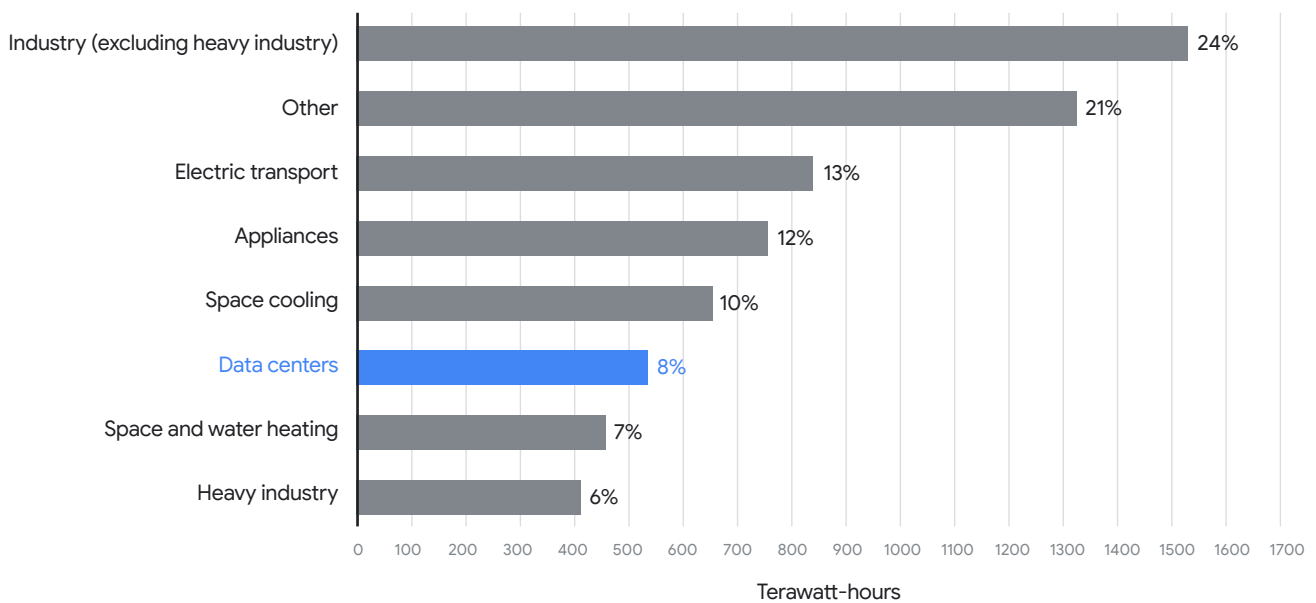
While electricity and water are the primary focus of this paper, AI infrastructure has additional impacts including the land use required for siting facilities, the extraction of raw materials for the manufacturing of high-performance chips, and the management of electronic waste and biodiversity impacts throughout the supply chain. For more details on how we're working to minimize impact on these other resources, refer to Google's [2025 Environmental Report](#).

Powering AI with efficiency, next-generation energy, and grid flexibility

Forecasting the trajectory of a rapidly evolving technology like AI is inherently difficult, but recent analyses have begun to shed light on the complex interplay between AI's growth and its electricity demand.

According to the IEA, global data center electricity consumption—driven in part by AI—is projected to more than double from 2024 to 2030.²² This trajectory positions data centers to account for roughly 8% of global electricity demand growth through 2030, making them a meaningful driver of demand alongside sectors like industrial manufacturing (24%) and electric transport (13%) (Figure 3).²³

Figure 3
Increase in electricity demand by sector from 2024 to 2030 (Source: IEA).²⁴



Even with this growth, data centers are projected to consume just 3% of total global electricity by 2030.²⁵ This relatively small footprint offers a disproportionately large opportunity: the intelligence provided by AI could be used to scale efficiencies and reduce energy demand across the sectors projected to use the other 97%.

Beyond these global averages, data center development is not evenly distributed around the world, and some regions are likely to see data centers make up higher shares of future local electricity consumption. In the United States, for example, Lawrence Berkeley National Laboratory projects that data centers could consume between 6.7–12% of electricity by 2028,²⁶ raising concerns about the adequacy of grid infrastructure and impacts on electricity costs.

This growth will also have climate implications: the IEA estimates that meeting data centers' electricity demand could add between 0.3 and 0.5 GT of CO₂e emissions annually by 2035.²⁷ For context, total electricity emissions are projected to be approximately 10 GT in 2035.²⁸

Electricity powers nearly every aspect of the economy and society, and it's crucial that infrastructure is developed responsibly to avoid raising prices for consumers. A 2025 study by Lawrence Berkeley National Laboratory found that U.S. states with the highest load growth between 2019 and 2024 generally experienced lower retail price increases or even price reductions, as fixed grid costs were spread across a larger volume of electricity sales.²⁹

Data center operators can further help protect consumers from rate increases by paying for the cost of new generation themselves. At Google, ensuring our expansion does not burden local communities or ratepayers is a core part of our responsible growth strategy, and we are putting this commitment into practice through new regulatory structures like the [Clean Transition Tariff](#) and "[bring-your-own capacity](#)" siting approaches.



Norther Offshore wind farm in Belgium (92 MW for Google).

To support all our products and digital services—including AI—Google's total data center electricity consumption grew by 27% in 2024, compared to 17% growth in the prior year. To manage this rising demand, we're pushing the frontier of every aspect of AI energy use—from chip-level efficiency to first-of-a-kind investments in the next generation of clean electricity sources and flexible data center design.

Efficiency

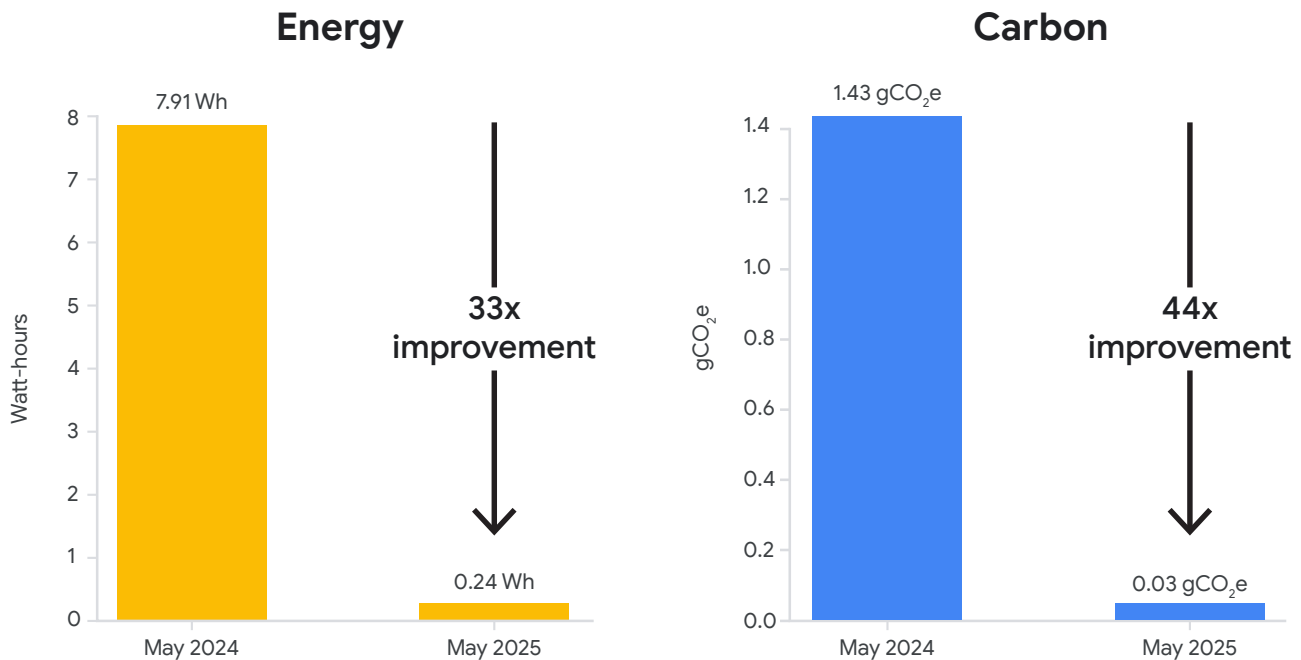
Our AI systems are becoming more efficient through research-driven improvements across our software,

hardware, and data center infrastructure. In 2024, the data centers that house our servers delivered over six times more computing power per unit of electricity than they did just five years previously,³⁰ and used 84% less overhead energy than the industry average.³¹

Over a 12 month period (May 2025 vs. May 2024), the energy and total carbon footprint of the median Gemini Apps text prompt dropped by 33 and 44 times, respectively, all while delivering higher quality responses (Figure 4).³²

Figure 4

Energy and carbon efficiency improvements per median Gemini Apps text prompt from May 2024 to May 2025.



In 2025, we published a [first-of-its-kind study](#) on the [lifetime emissions](#) of our TPU hardware—from raw material extraction and manufacturing to energy consumption during operation. We've [updated](#) the results for Ironwood, our seventh-generation TPU, which demonstrated an approximately 3.7x improvement in Compute Carbon Intensity³³ compared to TPU v5p, the previous generation of performance-optimized TPUs.³⁴

Generation and the grid

We're working with communities, utilities, governments, and other power users to strengthen the grid with more reliable and affordable energy, while helping as many people as possible benefit from AI.

This commitment begins with how we source our power. Google is one of the largest corporate purchasers of clean energy, and from 2010 to 2024, we signed more than 170 agreements to purchase over 22 gigawatts (GW) of clean energy generation, with 8 GW contracted in 2024 alone³⁵—the largest annual total in our history at the time, and twice the volume we contracted for the prior year.

We've also scaled our efforts to accelerate the next generation of [clean energy](#), through catalytic efforts to commercialize promising technologies including [advanced nuclear](#), [fusion energy](#), [enhanced geothermal](#), [hydropower](#), [long-duration storage](#), and [natural gas with carbon capture and storage](#). We're making these investments with an eye toward system-level impact: helping technologies scale to mass global deployment by de-risking early implementations and reducing long-term costs, turning Google's growth into an engine for global decarbonization.

Beyond generation, we're also investing in the physical infrastructure of the grid. For example, we're [partnering](#) with CTC Global to accelerate the deployment of advanced carbon core conductors in the United States, which can double the power transfer capacity of existing transmission corridors in months for a fraction of the cost of building new ones.

To ensure others don't bear the cost of these kinds of grid improvements or other new grid infrastructure necessary to meet our demand, we developed the [Capacity Commitment Framework](#) (CCF). The CCF is a transparent contractual model where large energy customers promise to pay for infrastructure costs triggered by their growth—shielding American families from these expenses while ensuring they benefit from a more affordable and reliable grid. The CCF has already been adopted by several utilities across the United States.

We believe that our greatest impact on electricity lies not only in advancing carbon-free energy for our own operations, but also in accelerating decarbonization of electrical grids around the world. That's why back in 2020 we set a moonshot to run on 24/7 carbon-free energy on every grid where we operate by 2030. We're advancing toward this ambitious goal by purchasing carbon-free energy, accelerating new and improved technologies, and transforming the energy system through policy, partnerships, and advocacy.

Demand response

Finally, we're optimizing how we use power and interact with the grids that serve our operations. For years, we've been working to make our data centers consume power more flexibly, which enables us to shift or reduce power demand during certain hours or times of the year. Demand flexibility allows large electricity loads like data centers to be interconnected more quickly, reduces the need for new transmission and power plants, and helps grid operators manage power grids more efficiently.³⁶ In August 2025, we announced new, first-of-a-kind agreements to operationalize these capabilities in partnership with utilities, specifically targeting machine learning workloads with the aim of supporting grid reliability and cost-saving benefits in the places where these capabilities are deployed. And as of early 2026, we've signed 1 GW of demand response with utility partners, harnessing our electricity growth for smarter utilization of U.S. electricity systems.

Minimizing AI's water footprint through smarter use and replenishment

At Google, we're committed to replenishing more water than we consume and helping improve water quality and ecosystem health in the communities where we operate—recognizing what a vital asset water is for the planet.

When compared to other industries, AI's projected freshwater consumption is relatively small. Research from Lawrence Berkeley National Laboratory estimated that data centers in the United States could use between 40–74 billion gallons of water per year by 2028,³⁷ or roughly less than 1% of the water that Americans use on their lawns annually.³⁸

Despite their relatively low aggregate water consumption, data centers can have an impact in their local watershed, as national averages don't reflect the spatial variation in local water demand and scarcity. This underscores the importance of responsible infrastructure development. Research from Cornell University found that using best practices—such as smart siting and advanced cooling technologies—have the potential to significantly reduce the water footprint of AI.³⁹

Responsible water use

As our business continues to grow to meet the demand for AI, so does our water use—with our overall water consumption increasing by 28% from 2023 to 2024. We're working to carefully manage this growth by making informed, locally tailored decisions that prioritize responsible water stewardship, even as demand for our services expands around the world.

Model water efficiency

Responsible water use for AI starts with making our models highly efficient. We've estimated that the median Gemini Apps text prompt uses about 5 drops of water (0.26 milliliters).⁴⁰ By reducing the electricity required for computation, we minimize cooling demands for our infrastructure and thus our direct water consumption, as well as the indirect use of water to generate electricity.

Climate-conscious cooling

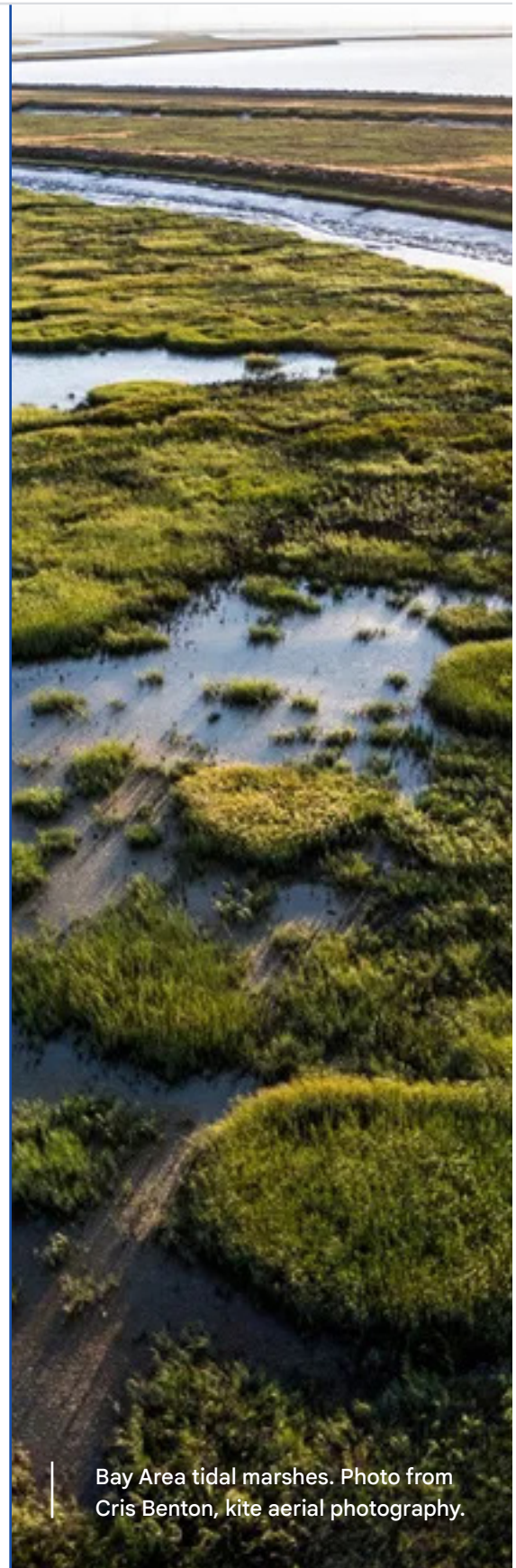
Our climate-conscious approach to cooling takes into account site-specific factors to determine the most responsible cooling system for each data center campus. This approach recognizes that water is the most efficient means of cooling in many places and, when used responsibly, water cooling can reduce

emissions compared to more energy-intensive air cooling methods. However, in locations with high water risk—such as our facilities in Waltham Cross, United Kingdom; Mesa, Arizona; and Canelones, Uruguay—we utilize alternatives like air cooling. In 2024, 72% of our freshwater withdrawals came from sources at low risk of water depletion or scarcity.⁴¹

Replenishment

Our approach to water stewardship goes beyond managing our consumption: we aim to replenish more water than we consume and improve water quality and ecosystem health in the communities where we operate. In 2024, our water stewardship projects replenished approximately 4.5 billion gallons of water, roughly 64% of our 2024 freshwater consumption.⁴² And more recently, we've grown our portfolio to 165 water stewardship projects, as of the end of 2025. Many of these projects also improve water quality, support ecosystems, and expand community access to water.

In 2021, we announced our ambition to replenish 120% of the freshwater volume we consume, on average, across our offices and data centers by 2030, and help restore and improve the quality of water and health of ecosystems in the communities where we operate.



Bay Area tidal marshes. Photo from Cris Benton, kite aerial photography.

Moving forward together

While we're excited about our progress in minimizing AI's footprint and maximizing its positive environmental impact, no company alone can ensure that AI delivers a net-positive future for the planet. This will require a collective effort that brings together researchers, developers, governments, and local communities to manage risks and scale new solutions.

Key actions include:

- **Investing in the foundations:** Accelerating progress requires an expansion of high-quality, primary open data collection and sustainable data infrastructure. Everyone must treat climate and nature-related data as a common good.
- **Developing open and accessible models:** The industry needs to prioritize open, transparent AI systems that can be customized and deployed worldwide. This lowers the cost of innovation and builds necessary trust in the technology.
- **Deepening capacity sharing:** The gap between AI developers and energy and nature practitioners must be bridged. True collaboration means creating “translators” who can link technical expertise with on-the-ground climate and conservation needs.

- **Committing to inclusive development:** AI must be built with—not just for—the communities most affected by the climate and nature crises. This includes respecting indigenous data sovereignty and ensuring that expertise is not concentrated solely in the Global North.
- **Managing AI's footprint:** AI developers must lead by example, managing the energy, water, and other resource impacts of AI operations through efficiency, carbon-free energy, and the responsible use of water and other resources.

AI is a revolutionary technology: Never before have technical breakthroughs and scientific progress so quickly materialized into impactful, real-world solutions, and we believe this is only the beginning.

But realizing AI's net-positive impact on the environment isn't guaranteed. It requires a deliberate and careful balance: minimizing the technology's environmental footprint while scaling its application to environmental challenges in order to maximize its positive outcomes for the planet.

This demands collective action—operating data centers more sustainably, developing open and accessible models, and equipping more people with AI skills and tools through education and partnerships—to scale new solutions.

Google is committed to being a leader and partner to unlock a positive AI future, sharing our technology and insights to enable positive change. Together, we can push the frontiers of innovation to build a brighter future for people and the planet.

- 1 “Green and Intelligent: the Role of AI in the Climate Transition,” Nature, June 2025.
- 2 According to the Our World in Data’s [Carbon Emissions Database](#), India’s total carbon emissions were approximately 3.19 GT of CO₂e in 2024.
- 3 “Green and Intelligent: the Role of AI in the Climate Transition,” Nature, June 2025. This paper notes that the estimated emissions reductions (3.2–5.4 GT of CO₂e) outweigh the estimated increase in emissions from data centers and AI (0.4–1.6 GT of CO₂e).
- 4 To estimate aggregate enabled emissions reductions, we first estimated annual reductions for five products and features individually (Google Earth Pro, Solar API, Nest thermostats, fuel-efficient routing, and Green Light) and then combined the totals. For details about the individual calculation methodologies, refer to endnotes 89, 16, 91, 17, and 86, of our [2025 Environmental Report](#).
- 5 “Greenhouse Gas Equivalencies Calculator,” U.S. Environmental Protection Agency, November 2024, accessed June 2025.
- 6 This figure reflects our “ambition-based” emissions boundary, which represents the subset of emissions from our total carbon footprint that are within the boundaries we’ve set for our climate ambitions. For more details, refer to our [2025 Environmental Report](#).
- 7 “Japan Country Profile: CO₂ and Greenhouse Gas Emissions,” Our World in Data, accessed March 2026.
- 8 The Solar API estimates the rooftop solar potential of buildings around the world using high-resolution, 3D models of individual roofs from our aerial imagery in Google Maps. We’ve counted the number of individual buildings for which we have data, and which can be queried via a lat-long in [Google Maps Platform](#).
- 9 Google uses an AI prediction model to estimate the expected fuel or energy consumption for each route option when users request driving directions. We identify the route that we predict will consume the least amount of fuel or energy. If this route is not already the fastest one and it offers meaningful energy and fuel savings with only a small increase in driving time, we recommend it to the user. To calculate enabled emissions reductions, we tally the fuel usage from the chosen fuel-efficient routes and subtract it from the predicted fuel consumption that would have occurred on the fastest route without fuel-efficient routing and apply adjustments for factors such as: CO₂e factors, fleet mix factors, well-to-wheels factors, and powertrain mismatch factors. This figure covers estimated enabled emissions reductions for the calendar year, from January through December. Enabled emissions reductions estimates include inherent uncertainty due to factors that include the lack of primary data and precise information about real-world actions and their effects. These factors contribute to a range of possible outcomes, within which we report a central value. The data and claims have not been verified by an independent third-party.
- 10 “Greenhouse Gas Equivalencies Calculator,” U.S. Environmental Protection Agency, November 2024, accessed June 2025.
- 11 Reductions in stops estimates are based on early data points from Google’s analysis of traffic patterns before and after recommended adjustments to traffic signals that were implemented during tests conducted in 2024 and 2025. The reduction in stops can vary significantly, in some cases exceeding 30% for a period of time. Emissions reductions estimates are modeled using a Department of Energy emissions model. A single fuel-based vehicle type is used as an approximation for all traffic, adjusted for country-level fleet mix from IEA data. These data points are averaged from coordinated intersections, and are subject to variation based on existing scenarios. We expect these estimates to evolve over time and look forward to sharing continued results as we perform additional analysis.
- 12 “The Contribution of Global Aviation to Anthropogenic Climate Forcing for 2000 to 2018,” Atmospheric Environment, January 2021. Calculated using [Supplementary data](#) to compare the global warming potential (GWP100) of contrails to the total global warming potential of the three primary aviation pollutants (CO₂, NO_x, and contrails).
- 13 “Employment in Agriculture,” Our World in Data, accessed February 2026. According to the World Bank Group, agriculture represented 26% of total employment worldwide in 2024.
- 14 “Half of the World’s Habitable Land is Used for Agriculture,” Our World in Data, February 2024.
- 15 “State of Wildfires 2024–25,” Earth System Science Data, October 2025.
- 16 “The Power of AI in Wildfire Prediction and Prevention,” World Economic Forum, June 2025.
- 17 The estimated population covered for significant events is as of July 2025, based on the forecasted flood risk area, using the [WorldPop Global Project Population dataset](#). Significant flood events are events categorized based on an internal rating scheme that assesses events on a number of factors and meets a predetermined threshold.
- 18 “Tropical cyclone,” World Meteorological Organization, accessed January 2026.
- 19 “Living Planet Report 2024,” World Wildlife Fund, October 2024.
- 20 “Nature Risk Rising: Why the Crisis Engulfing Nature Matters for Business and the Economy,” World Economic Forum, January 2020.
- 21 “The Global Risks Report 2025,” World Economic Forum, January 2025.
- 22 “World Energy Outlook 2025,” IEA, November 2025.
- 23 “Energy Demand from AI,” IEA, April 2025, accessed January 2026. We use the term “industrial manufacturing” for the IEA category “Industry excluding heavy industry.” This category includes sectors that primarily rely on electricity (e.g., machinery, textiles), distinct from “heavy industry” sectors like steel and cement that utilize large amounts of raw heat.
- 24 “Energy Demand from AI,” IEA, April 2025, accessed January 2026.
- 25 “Energy and AI: World Energy Outlook Special Report,” IEA, April 2025.
- 26 “2024 United States Data Center Energy Usage Report,” Lawrence Berkeley National Laboratory, December 2024.
- 27 “Energy and AI: World Energy Outlook Special Report,” IEA, April 2025.
- 28 “Energy and AI: World Energy Outlook Special Report,” IEA, April 2025. This figure is calculated based on the IEA’s projection that data centers will emit roughly 0.3 GT of CO₂ in 2035, which represents approximately 3% of the global power sector’s total emissions.
- 29 “Factors Influencing Recent Trends in Retail Electricity Prices in the United States,” The Electricity Journal, December 2025.

- 30 According to Google's platform-neutral measurement analyzed over a five-year period from 2019–2024.
- 31 PUE is a standard industry ratio that compares the amount of non-computing overhead energy (used for things like cooling and power distribution) to the amount of energy used to power IT equipment. For example, a PUE of 2.0 means that for every watt of IT power, an additional watt is consumed to cool and distribute power to the IT equipment. A PUE closer to 1.0 means nearly all the energy is used for computing. According to the Uptime Institute's 2024 Global Data Center Survey, the global average PUE of respondents' data centers was 1.56. The overhead energy use comparison was calculated as follows: $(1 - (\text{Google's overhead energy use} [0.09] \text{ divided by the industry average overhead energy use} [0.56])) \times 100 = 84\%$.
- 32 A point-in-time analysis quantified the energy consumed per median Gemini App text-generation prompt, considering data from May 2025. Emissions per prompt was estimated based on energy per prompt, and applying Google's 2024 average fleetwide grid carbon intensity. Water consumption per prompt was estimated based on energy per prompt, and applying Google's 2024 average fleetwide water usage effectiveness. These findings do not represent the specific environmental impact for all Gemini App text-generation prompts nor are they indicative of future performance. The results of the analysis from May 2025 were compared to baseline data from the median Gemini App text-generation prompt in May 2024. Energy per median prompt is subject to change as new models are added, AI model architecture evolves, and AI chatbot user behavior develops. The data and claims have not been verified by an independent third-party.
- 33 To help manage the environmental impact of AI workloads, we monitor the Compute Carbon Intensity (CCI) of our AI accelerator hardware. CCI is defined in [An Introduction to Life-Cycle Emissions of Artificial Intelligence Hardware](#) as the estimated amount of CO₂ equivalent emitted for every utilized floating-point operation (CO₂e/FLOP). This metric provides a holistic, chip-level view by including both the embodied emissions associated with manufacturing, transportation, and data center construction (scope 3), as well as the operational emissions associated with running these chips in data centers (scope 1 and 2).
- 34 Following the methodology published in an [August 2025 technical report](#), we quantified the full lifecycle emissions of TPU hardware as a point-in-time snapshot across Google's generations of TPUs as of January 2026. The functional unit for this study is one AI computer deployed in the data center, which includes one or more accelerator trays (containing TPUs) connected to one host tray (i.e., a computing server). Peripheral components beyond the tray (e.g., rack, shelf, and network equipment) and auxiliary computing and storage resources are excluded from the calculation of embodied and operational emissions. We include the electricity used in data center cooling in operational emissions. To estimate operational emissions from electricity consumption of running workloads, we used a one month sample of observed machine power data from our entire TPU fleet, applying Google's 2024 average fleetwide carbon intensity. To estimate embodied emissions from manufacturing, transportation, and retirement, we performed a life-cycle assessment of the hardware. Data center construction emissions were estimated based on Google's disclosed 2024 carbon footprint. These findings do not represent model-level emissions, nor are they a complete quantification of Google's AI emissions. Based on the TPU location of a specific workload, CCI results of specific workloads may vary.
- 35 The total GW figure represents primarily PPAs, and includes some generation from targeted clean energy investments where we also receive EACs. Actual generation may vary from the signed amounts based on changes during construction or project terminations.
- 36 ["Rethinking Load Growth: Assessing the Potential for Integration of Large Flexible Loads in US Power Systems,"](#) Duke University, accessed January 2026.
- 37 ["2024 United States Data Center Energy Usage Report,"](#) Lawrence Berkeley National Laboratory, December 2024.
- 38 ["About WaterSense,"](#) U.S. Environmental Protection Agency, June 2025, last accessed April 2026.
- 39 ["Environmental Impact and Net-Zero Pathways for Sustainable Artificial Intelligence Servers in the USA,"](#) Nature Sustainability, November 2025.
- 40 A point-in-time analysis quantified the energy consumed per median Gemini App text-generation prompt, considering data from May 2025. Emissions per prompt was estimated based on energy per prompt, and applying Google's 2024 average fleetwide grid carbon intensity. Water consumption per prompt was estimated based on energy per prompt, and applying Google's 2024 average fleetwide water usage effectiveness. These findings do not represent the specific environmental impact for all Gemini App text-generation prompts nor are they indicative of future performance. For more details, refer to ["Measuring the Environmental Impact of Delivering AI at Google Scale,"](#) Google, August 2025.
- 41 For details about the calculation, refer to the Methodology section in the Appendix of our [2025 Environmental Report](#).
- 42 For details about this calculation, refer to the Methodology section in the Appendix of our [2025 Environmental Report](#).