Google

Environmental Report

2017 progress update

Google

Environmental sustainability at Google

At Google, our values reflect our belief in the fundamental importance of inclusion, openness, science, and commitment to the environment. Operating our business in an environmentally sustainable way has been a core value since our founding.

In 2016 we marked 10 years of operating as a carbon neutral company and announced that we'll reach 100% renewable energy for our global operations in 2017. When we committed to being carbon neutral in 2007, we knew that aggressive energy-efficiency initiatives, renewable energy, and carbon offsets would all be critical to our ongoing strategy, and over time we've learned and innovated across these areas in ways we couldn't have imagined a decade ago.

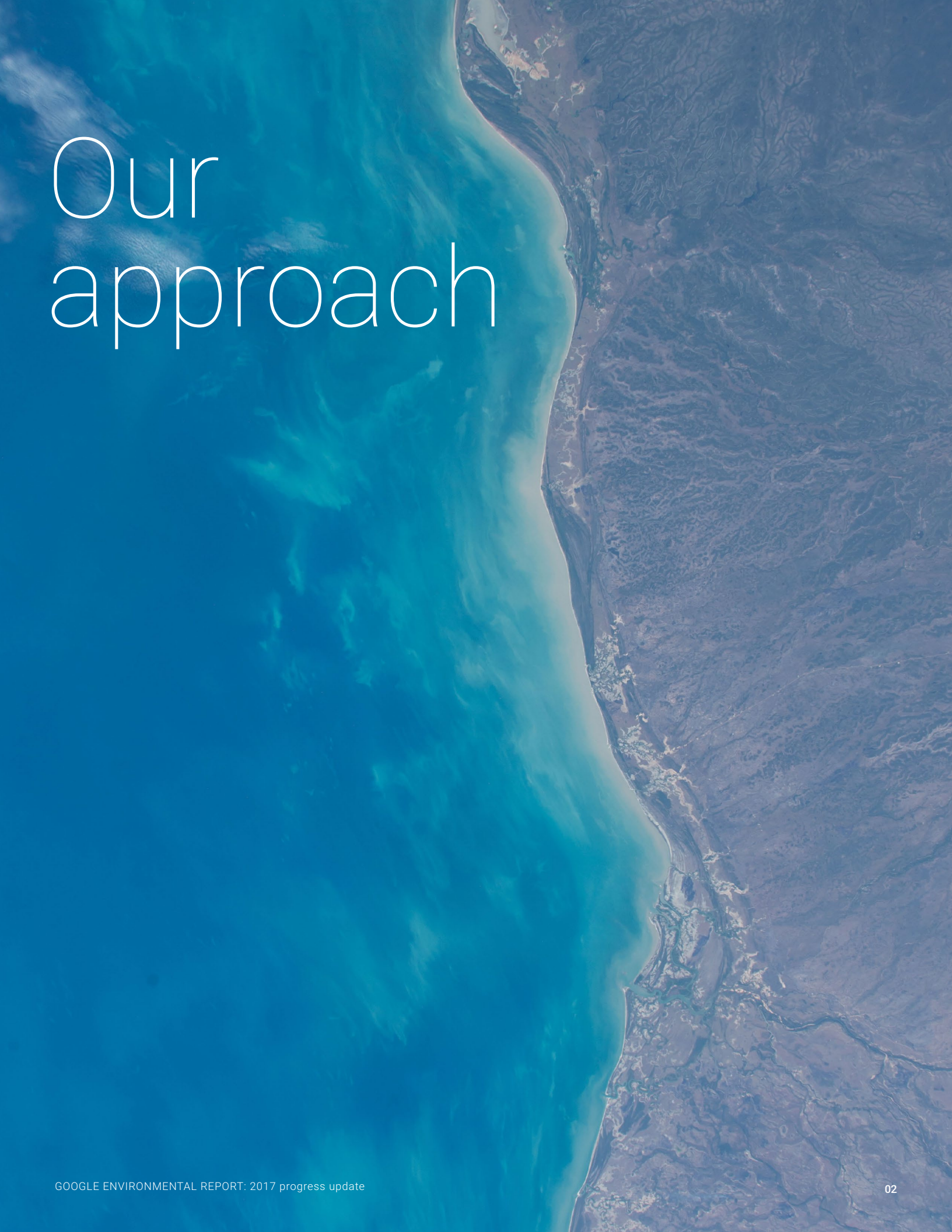
Our Earth Outreach program also recently celebrated its 10th birthday. Launched to give nonprofit groups the resources, tools, and inspiration they need in order to leverage the power of Google Earth and other mapping tools for their causes, Earth Outreach is now combining machine learning and cloud computing to build a living, breathing dashboard of the planet, creating new insights both in local communities and at global scale.

After years of reporting our carbon footprint and publishing information on our sustainability programs, in December 2016 we put our whole story in one place in our first environmental report. This update to that first report is a chance for us to close out 2016, which was a landmark year for our program, and share some of our progress on ongoing efforts. We think there's a lot to be proud of—but also a lot more important work to do.

We're more committed than ever to the environment, and we believe that businesses, governments, and citizens all have critical roles to play in ensuring that we have clean air, water, soil, and healthy forests. We'll continue working hard for a cleaner and more prosperous future for all.

Urs Hölzle
Senior Vice President of Technical Infrastructure
Google

Our approach



The Googleplex in Mountain View, California

Caption here

IN THIS SECTION

Mission and values

Our mission is to organize the world's information and make it universally accessible and useful. Fulfilling this mission—bringing the benefits of information not just to the 3 billion people who are already online but to the next 4 billion as well—requires us to use resources ever more efficiently.

We meet the challenges posed by climate change and the need for resource efficiency by working to empower everyone—businesses, governments, nonprofit organizations, communities, and individuals—to use Google technology to create a more sustainable world. This philosophy started with Googley decisions like building server casings from reused Legos and grew to building a global network of data centers that lead the industry in efficiency.

After all, the cheapest energy and water are what we don't use in the first place, and waste streams can offer new sources of value. In a growing number of regions, renewable resources like wind and solar are now less expensive than standard grid power, helping us save money over the long term. Google became carbon neutral in 2007, and since then, our carbon footprint has grown more slowly than our business—proof, 10 years later, that economic growth can be decoupled from environmental impact and resource use.

Addressing a global challenge

Humanity is consuming natural resources at an astonishing rate. During the 20th century, global raw material use rose at about twice the rate of population growth.[1] Every year humanity consumes far more than what the planet can naturally replenish. In 2016, global demand for resources was roughly 1.7 times what the Earth can support in one year.[2]

These statistics highlight the need to revisit the "take-make-waste" economic model that human societies have followed since the Industrial Revolution, in which we take a natural resource, make a product from it or burn it for fuel, and eventually send what remains to the landfill as waste. A major consequence of this model is climate change, one of the most significant challenges of our time. We believe that Google's scale, resources, and technological expertise can help the world meet its energy and resource needs in a way that drives innovation and growth while reducing greenhouse gas (GHG) emissions and the use of virgin materials and water.

Taking action

Demand for computing continues to skyrocket, with millions more people coming online every month, and data center capacity continues to expand to meet this need. But despite this growth, the total amount of electricity used by U.S. data centers has remained constant. Annual consumption increased by 90% from 2000 to 2005, but only by 4% from 2010 to 2014, largely due to data centers' ability to improve their efficiency as they scale.[3] As the use of mobile devices increases and more IT users transition to public clouds, we believe our industry can and must do better than just holding the line on energy use. We can actually lower it, serving more users while using fewer resources.

Google's energy consumption drives our biggest impact on the environment, and we've focused on tackling it through a threefold strategy for carbon neutrality. First, we pursue aggressive efficiency initiatives. Second, we purchase significant amounts of renewable energy and will reach 100% renewable energy for all our operations in 2017. Third, we buy carbon offsets for any remaining emissions we haven't yet eliminated.

We've long been a vocal advocate for greening electrical grids worldwide. We've supported strong clean-energy and climate-change policies committed to adding clean power to the grid by investing $2.5 billion in solar and wind projects and are partnering with governments and nongovernmental organizations to use Google technology and computing power to model the effects of climate change on both a global and a local level. We're also working to incorporate climate resilience strategy into our own operations.

Google Cloud Platform and G Suite applications like Gmail, Docs, and Drive are enabling millions of businesses to switch from locally hosted solutions to Google Cloud's highly efficient, renewable energy–based computing infrastructure. Research from the Lawrence Berkeley National Laboratory suggests that if all office workers in the United States moved their email and documents to the cloud, it would reduce IT energy use by up to 85%.[4]

Water is another top priority. The United Nations predicts that by 2025, two-thirds of the world's population could live in water-stressed conditions.[5] As a global company headquartered in drought-prone California, we're working to efficiently utilize water, particularly in our data centers, where we regularly redesign and enhance our cooling technologies and utilize water from nonpotable sources where feasible. We're also using Google technology to help researchers study global water challenges and awarding millions in grants to promising water-conservation solutions.[6]

Finally, we're changing how we think about waste. By repairing, reusing, and recycling products, we transcend the linear take-make-waste economy. We strive to embed these circular economy principles into everything Google does, from how we manage servers in our data centers to the materials we select to build and furnish our offices.

In fact, in October 2016 we announced that we're committed to achieving Zero Waste to Landfill for our global data center operations. Six of our 14 operating data centers have already reached 100% landfill diversion, and we're always looking for new ways to reduce waste in our journey to sustainably managing resources across Google. As a Global Partner of the Ellen MacArthur Foundation, we're also working with other leading companies to help bring initiatives like these to scale, thereby accelerating the transition to a circular economy.

Looking toward future opportunities

We believe global businesses like Google should lead the way in improving people's lives while reducing or even eliminating our dependence on virgin materials and fossil fuels. And we believe this can be done in a way that makes business sense, providing economic returns alongside societal benefits and positive environmental impacts.

Our end goal is a zero-carbon world where everyone everywhere has access to clean, carbon-free energy 24 hours a day, 365 days a year. This means empowering all energy users with cheap, clean options by continuing to drive down the cost of existing renewable energy sources like wind and solar and developing new policies, technologies, and tools that help users, businesses, and activists drive change.

Google tools are helping people measure the planet's health. Today anyone who is online can see the world change over recent decades, watching as cities grow, forests disappear, glaciers recede, and lakes dry up. We're also working with research and nonprofit organizations all over the world to monitor the Earth's vital signs. Our vision is to use our mapping, cloud, and machine learning technologies to create a living, breathing dashboard of our planet that can help inform everyday decisions for individuals, organizations, and nations today and for generations to come.

Our carbon footprint

We began calculating our annual carbon footprint in 2006. Every year since 2009, we've publicly reported the results to CDP, a global organization that asks companies to disclose information on their GHG emission performance and management. Our report received an A score from CDP for the past three years, and in both 2015 and 2016, we earned a spot on CDP's A List, which recognizes top reporting companies.

In 2016, our gross GHG emissions were 2.9 million metric tons of carbon dioxide equivalent (tCO_2e), but because of our renewable energy and carbon offset programs, our net operational carbon emissions were zero. Because of our emissions-reduction efforts, our carbon intensity has steadily decreased even as our company has grown and our energy use has correspondingly increased. Over the past five years, our carbon intensity per revenue and our carbon intensity per full-time equivalent employee both decreased by 55%, and our carbon intensity for electricity used at our data centers dropped by 59%. This means we're delivering our products and services with decreased carbon impacts, even before using carbon offsets to reach neutrality.

A decade of carbon neutrality

In 2007, Google committed to being carbon neutral, and we've met this goal every year since then. We reach carbon neutrality via three steps. First, we work to reduce our total energy consumption by pursuing aggressive energy-efficiency initiatives.

Second, we purchase significant amounts of renewable energy. Third, we buy carbon offsets for any remaining emissions we haven't yet eliminated.[7]

When we committed to carbon neutrality, we saw carbon offsets as an interim solution. As we continue to improve our energy efficiency and reach our target of operating with 100% renewable electricity, our need for carbon offsets will decrease.

When we do purchase carbon offsets, we follow stringent principles. We invest in high-quality, third-party-verified offsets, including landfill gas projects and animal waste management systems. All our offsets are additional, meaning that the projects reduce GHG emissions that would not be reduced through other incentives. We also ensure that the projects we invest in are permanent sources of carbon reduction or sequestration, rather than temporary solutions. Finally, whenever possible, we invest for the long term, which offers owners and developers the financial stability they need to continue operating.

Google has been carbon neutral for a decade now, and in that time, we've partnered with more than 40 carbon offset projects to offset more than 16 million tCO_2e.[8] We look forward to continuing to work toward net zero carbon in the decade to come.

LEARN MORE

2011 white paper: Google's Carbon Offsets: Collaboration and Due Diligence
2017 white paper: 10 Years of Carbon Neutrality

Golden Hills wind farm in California (43 MW for Google)

SPOTLIGHT

Capturing value from waste in upstate New York

Flares destroy methane gas at Oneida-Herkimer Regional Landfill in New York.

Oneida-Herkimer Regional Landfill in New York, one of Google's carbon offset project partners

500k

METRIC TONS OF CO_2e ELIMINATED

THIS LANDFILL GAS PROJECT HAS ELIMINATED HALF A MILLION METRIC TONS OF CARBON DIOXIDE EQUIVALENT, GENERATING MORE THAN HALF A MILLION CARBON OFFSETS.

One of Google's long-standing carbon offset project partners is Oneida-Herkimer Solid Waste Management Authority. This Authority operates the newest landfill in upstate New York, the Oneida-Herkimer Regional Landfill, which serves rural communities with a combined population of 300,000.

Our partnership goes back to 2010, when we decided to invest in the Authority's landfill gas project in its early stages. As organic waste decomposes inside a landfill, it creates methane gas, which is a significant contributor to climate change: methane is 28 times more potent than carbon dioxide and accounts for 16% of global GHG emissions.[9] Landfills in many U.S. states aren't required to capture or process methane if they don't reach a certain threshold of emissions, so by voluntarily collecting and destroying it, they can generate carbon offsets.

The Authority wanted to install a network of wells, pipes, and flares to capture and destroy the site's methane gas. Developing a carbon offset project provided the financial incentive for the initial investment. After vetting the project, Google committed to purchasing all the carbon offsets it would generate. This long-term investment provided the financial certainty the Authority needed to build and begin operating the gas-collection system three years earlier than planned. Since then, the project has eliminated half a million metric tons of carbon dioxide equivalent, generating more than half a million carbon offsets while ensuring the gas is properly handled.

Once a gas-collection system was in place, the Authority could then take further steps to fully utilize this resource. Rather than simply flaring off, or burning, the waste gas, the Authority commissioned a plant to convert it to electricity. This plant now produces enough renewable energy to power more than 3,300 local households and also provides a steady revenue stream to fund additional waste management initiatives for the community.

Revenue from selling carbon offsets has allowed the Authority to continuously expand the gas well field to capture even more methane. The money has also supported the launch and operations of other waste management initiatives, including electronics waste recycling and the safe disposal of hazardous household waste. Without the revenue stream catalyzed by the initial gas-collection project, the additional cost for these community programs would have to be borne by local residents and businesses.

This project is just one example of the many mutually beneficial long-term partnerships we've established through our carbon offset program. By enabling us to reduce our carbon footprint while reducing local air pollution, improving waste management, and increasing local revenue streams, each of these collaborations is a win for both Google and our communities.

Wells capture methane gas at Oneida-Herkimer Regional Landfill in New York.

Our journey to net zero carbon

Google is committed to reducing our carbon emissions and helping to increase the world's supply of clean energy. Here are some of our notable milestones over the past decade.

2007

We committed to **carbon neutrality** and purchased enough carbon offsets to bring our net annual emissions to zero for the first time.

Our Bay Area headquarters became a proving ground for renewable energy with a **1.6 MW rooftop solar installation,** the largest corporate rooftop solar array at the time.

2010

We became one of the first non-utility corporations to receive **permission from the Federal Energy Regulatory Commission** (FERC) to buy energy directly from wind and solar providers.

With FERC authority in hand, we made our **first purchase of renewable energy** by signing a 20-year power purchase agreement (PPA) with the Story County II wind farm in Iowa.

In addition to purchasing renewable energy for our operations, we began contributing to growing the clean energy market by making our **first renewable energy equity investment** with a $39 million commitment to the 170 MW Peace Garden wind farm in North Dakota.

2012

With the momentum from our purchases, we set a **goal to reach 100% renewable energy** for our operations.

Our total cumulative commitments reached **$1 billion in renewable energy equity investments.**

2014

We surpassed a cumulative total of **1 gigawatt (GW) of renewable energy purchased** for our operations.

2015

We nearly **doubled our renewable energy purchases** in a single year by entering into six new PPAs totaling 842 MW, the largest aggregate purchase of renewable energy ever by a non-utility, bringing our total contracts to more than **2 GW of renewable energy worldwide.**

Our total cumulative commitments reached **$2.5 billion in renewable energy equity investments.**

Bolstering our commitment to operate with 100% renewable energy, we **signed the American Business Act on Climate Pledge** and joined the RE100 campaign.

2016

We joined with Amazon, Apple, and Microsoft to promote federal mechanisms to grow cleaner sources of electricity in the United States.

By November, we had signed a cumulative total of 20 PPAs for **more than 2.6 GW of renewable energy.**

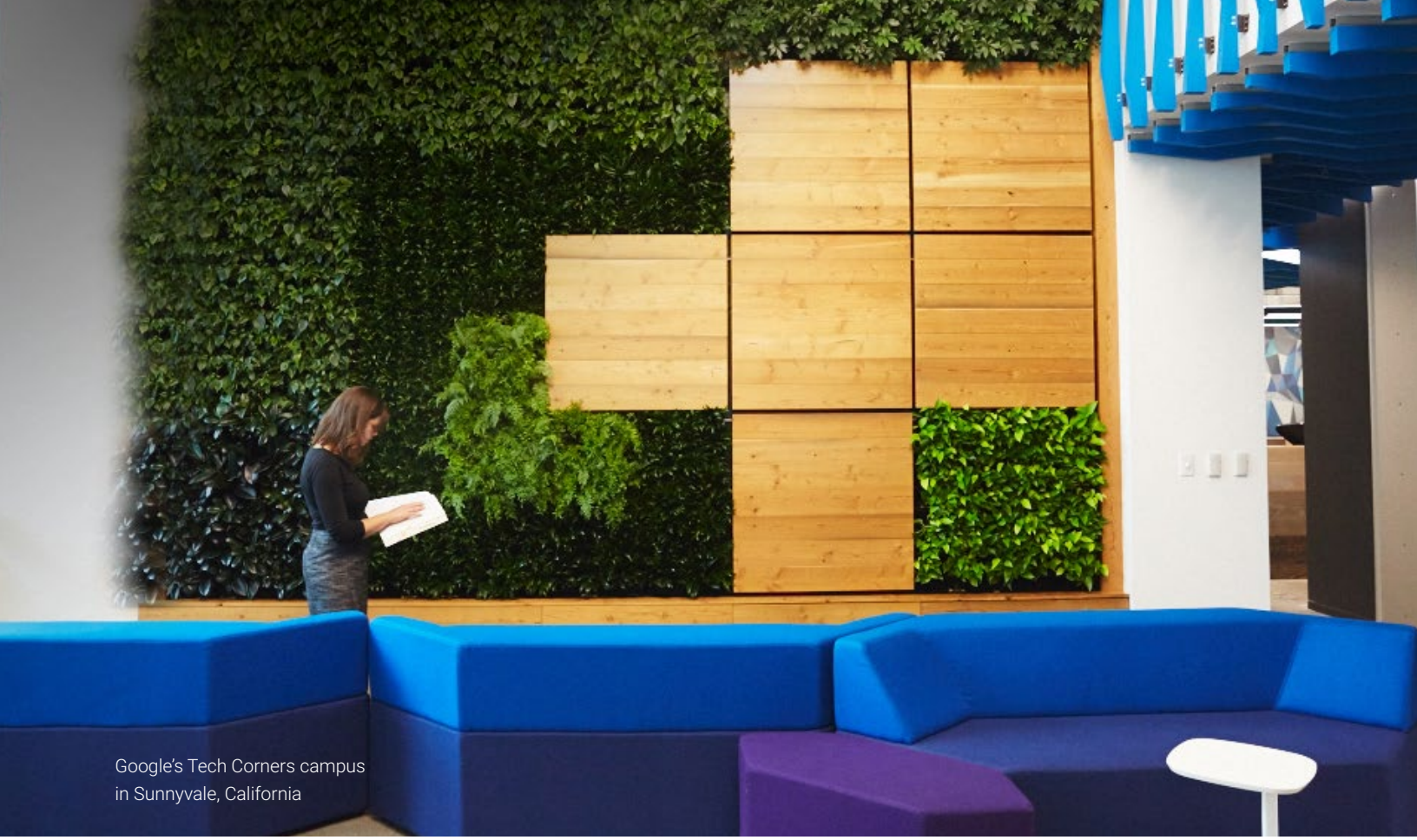
By the end of the year, we will have been **carbon neutral for 10 consecutive years**.

2017

We will reach

100%

renewable energy for our global operations.



Google's Tech Corners campus in Sunnyvale, California

Performance highlights and targets

The following four pages include highlights of the environmental initiatives discussed in this report. They provide a snapshot of our performance to date and our targets going forward. Together, they demonstrate how we're strengthening our business by reducing the environmental impact of our operations and working to empower people everywhere to live more sustainably.

For a more complete overview of our performance over time, see the environmental data tables and charts on pages 45 to 50.

Performance highlights

Designing efficient data centers

WASTE

100%
LANDFILL DIVERSION

Six of our operating data centers have achieved 100% landfill diversion, and one of these has also reached Zero Waste to Landfill.[10]

86%
WASTE DIVERTED

In 2016, we diverted 86% of waste from our global data center operations away from landfills.

36%
OF SERVERS REMANUFACTURED

In 2016, 36% of the servers Google deployed were remanufactured machines.

22%
OF COMPONENTS REFURBISHED

In 2016, 22% of the components we used for machine upgrades in our data centers were refurbished inventory.

ENERGY

50%
LESS ENERGY

On average, a Google data center uses 50% less energy than a typical data center.

1.12
PUE

In 2016, the average annual power usage effectiveness (PUE) for our global fleet of data centers was 1.12, compared with the industry average of 1.7—meaning that our data centers use nearly six times less overhead energy.

3.5x
COMPUTING POWER

Compared with five years ago, we now deliver more than 3.5 times as much computing power with the same amount of electrical power.

CERTIFICATIONS

14001 & 50001
ISO CERTIFICATIONS

We've achieved ISO 14001 (environmental management) and ISO 50001 (energy management) certifications for 12 of our 14 Google-owned and -operated data centers globally, which together represented more than 98% of our IT energy use in 2016.

Advancing renewable energy

GHG EMISSIONS

10 YEARS
OF CARBON NEUTRALITY

Google has been carbon neutral since 2007.

0
NET EMISSIONS

Because of our renewable energy and carbon offset programs, our net operational carbon emissions in 2016 were zero.

40
CARBON OFFSET PROJECTS

Over the past 10 years, we've partnered with more than 40 carbon offset projects to offset more than 16 million tCO_2e.

55% DECREASE
IN CARBON INTENSITY

Over the past five years, our carbon intensity per revenue and our carbon intensity per full-time equivalent employee both decreased by 55%.

ENERGY

100%
RENEWABLE ENERGY

We'll achieve 100% renewable energy for our operations in 2017.

2.6 GW
RENEWABLE ENERGY

Google is the world's largest corporate purchaser of renewable energy. We've signed 20 agreements to purchase a total of 2.6 GW of renewable energy—generating emissions savings equivalent to taking more than 1.2 million cars off the road.

$2.5 BILLION
IN EQUITY COMMITMENTS

Since 2010, we've committed to invest nearly $2.5 billion in renewable energy projects with a total combined capacity of 3.7 GW.

Performance highlights

Creating sustainable workplaces

WASTE

85%
LANDFILL DIVERSION

In 2016, we reached an 85% landfill diversion rate in the Bay Area and 78% for our offices globally.

1.5 MILLION POUNDS
OF FOOD WASTE AVOIDED

In 2016, Google avoided more than 700,000 kilograms (1.5 million pounds) of food waste in our cafés globally by tracking pre-consumer food waste and using this data to inform future production levels.

TRANSPORTATION

33,000 tCO_2e
SAVINGS

In 2016, the use of Google shuttle buses and corporate electric vehicles in the Bay Area resulted in savings of more than 33,000 tCO_2e. That's like taking 6,500 cars off the road every day or avoiding 152 million vehicle kilometers (95 million vehicle miles) every year.

WATER

40% REDUCTION
IN POTABLE WATER USE

From 2013 to 2016, we reduced potable liters of water used per Googler by 40% at our Bay Area headquarters.

CERTIFICATIONS

9.3 MILLION
SQUARE FEET LEED CERTIFIED

As of the end of 2016, 865,000 square meters (9.3 million square feet) of Google office facilities have achieved LEED (Leadership in Energy and Environmental Design) certification.

34%
LEED PLATINUM

As of the end of 2016, 34% of our LEED-certified square footage achieved a Platinum rating and 54% a Gold rating.

Empowering users with technology

ENABLING TECHNOLOGIES

1 BILLION KM
OF TRANSIT RESULTS

Google Maps provides more than 1 billion kilometers' worth of transit results per day, helping limit carbon emissions by giving people access to mass transit options, bike routes, and traffic information.

70,000
VESSELS MONITORED

Global Fishing Watch, powered by Google Cloud Platforms' machine learning algorithms, monitors the planet's fisheries and provides the first view over space and time, covering more than 70,000 of the largest commercial fishing vessels.

3 MILLION
AIR POLLUTION MEASUREMENTS

Through Project Air View, Google Street View cars equipped with air quality equipment made nearly 3 million measurements in the course of a year, creating one of the largest air quality data sets ever published and demonstrating the potential of neighborhood-level air pollution mapping.

10 PETABYTES
OF FREELY AVAILABLE GEOSPATIAL DATA

Global Forest Watch, Global Fishing Watch, Project Sunroof, and the DiSARM platform for malaria risk mapping have enabled tens of thousands of scientists around the world to easily analyze 10 petabytes of geospatial information, resulting in a deeper understanding of the planet.

CLOUD-BASED PRODUCTS

43 MILLION
MAPPED ROOFTOPS

Since 2015, Project Sunroof has mapped more than 43 million U.S. rooftops in 42 states. More than 2 million users have accessed the tool to make informed decisions about solar panel installation.

65%–85%
ENERGY SAVINGS

Businesses that switch to G Suite products like Gmail, Calendar, Docs, Drive, and Meet have reported reductions in IT energy use and carbon emissions by up to 85%.

98%
EMISSIONS REDUCTION

A business using Gmail can reduce the GHG emissions impact of its email service by up to 98% compared with running email on local servers.

1 MONTH = 1 MILE

Providing an active user one month of Google services creates about the same amount of GHG emissions as driving a car one mile.

Progress against targets

TARGET	DEADLINE	2016 PROGRESS	STATUS
Designing efficient data centers			
ENERGY			
Maintain or improve quarterly PUE at each Google data center, year over year.	Annual	The average annual PUE for our global fleet of data centers was 1.12. Our fleet-wide PUE has stayed constant at 1.12 for the past five years.	●
WASTE			
Achieve Zero Waste to Landfill for our global data center operations.	None	Six of our operating data centers have achieved 100% landfill diversion, and one of these has reached Zero Waste to Landfill.	○
CERTIFICATIONS			
Maintain ISO 50001 energy management system (EnMS) certification for all Google-owned data centers that meet certain operational milestones.	Annual	We maintained certification for 12 of our 14 data centers, which together represented more than 98% of our IT energy use. In 2016, our two newest data centers were not yet included in our EnMS, but only one of these facilities met the criteria for inclusion. We plan to add both of these sites to our ISO 50001 certificate in 2017.	⊘
Advancing renewable energy			
ENERGY			
Reach 100% renewable energy for our global operations.	None initially, now 2017	Our energy deals produced enough renewable electricity to cover 57% of our operations in 2016. Given our signed contracts for projects to come online, we'll reach 100% renewable energy in 2017.	◒
GHG EMISSIONS			
Maintain carbon neutrality for our operations.	Annual	We purchased enough renewable energy and high-quality carbon offsets to bring our net annual carbon emissions to zero. Google has been carbon neutral since 2007.	●
Creating sustainable workplaces			
CERTIFICATIONS			
Pursue third-party green or healthy-building certifications for office projects, such as LEED, WELL Building Standard, and Living Building Challenge.	Annual	865,000 square meters (9.3 million square feet) of Google office facilities have achieved LEED certification, with 34% achieving a Platinum rating and 54% a Gold rating.	○
GHG EMISSIONS			
Reduce single-occupancy vehicle commuting at our Bay Area headquarters to 45%.	None	Initial results indicate that for the Mountain View portion of our Bay Area headquarters, we have met and are already exceeding this goal.	◒
Provide electric vehicle charging stations for 10% of parking spaces at our Bay Area headquarters.	None	We have achieved a design standard of approximately 10% for new construction and tenant improvement projects in the Sunnyvale portion of our Bay Area headquarters.	◒
WASTE			
Reduce total waste per Googler at our Bay Area headquarters by 10% in 2016, compared with 2015.	2016	From 2015 to 2016, we reduced total waste per Googler by 2% at our Bay Area headquarters.	⊘
Set regional waste-reduction targets for our offices in 2017.	2017	On track.	◒
WATER			
Reduce potable water consumption per Googler at our Bay Area headquarters by 40% by 2016, compared with 2013.	2016	From 2013 to 2016, we reduced potable liters of water consumed per Googler by 40% at our Bay Area headquarters.	●
Set regional water-reduction targets for our offices in 2017.	2017	On track.	◒

● ACHIEVED ◒ ON TRACK ○ ONGOING ⊘ MISSED

About Google

As our founders explained in their first letter to shareholders, Google's goal is to "develop services that significantly improve the lives of as many people as possible." We believe in technology's potential to have a positive impact on the world. We also believe we're just scratching the surface. Our goal as a company is to remain a place of incredible creativity and innovation that uses our technical expertise to tackle big problems.

Google's innovations in search and advertising have made our website one of the most widely used and our brand one of the most recognized in the world. We generate revenue primarily through online advertising. Google's core products—Search, Android, Maps, Chrome, YouTube, Google Play, and Gmail—each have more than 1 billion monthly active users.

We also offer a broad collection of cloud-based products and services, including G Suite business productivity apps like Docs, Drive, and Calendar and satellite mapping and analysis platforms like Google Earth and Google Earth Engine. In recent years we've expanded into hardware solutions with products including Google Pixel, Chromecast, and Google Home.

We're a wholly owned subsidiary of Alphabet, which also includes companies such as Access, Calico, CapitalG, GV, Nest, Verily, Waymo, and X. As of December 31, 2016, we had more than $90 billion in total revenues and 72,053 full-time employees.

Google's headquarters are located in California, in the San Francisco Bay Area, United States. In this report the term "Bay Area headquarters" refers to our operations in both Mountain View and Sunnyvale. We own and lease office and building space, research and development labs, and sales and support offices across more than 150 cities, primarily in North America, Europe, South America, and Asia, and we own and operate 14 data centers across four continents.

About this report

The annual data in this report covers our 2016 fiscal year (January 1 to December 31, 2016). The spotlights also include data and stories from prior years to provide context, as well as some of our progress in 2017. Unless otherwise specified, all environmental performance data included in this report applies to Google Inc. The primary exception is our GHG emissions and energy use data, which covers operations of Google together with our parent company, Alphabet Inc.

LEARN MORE

For more information about our environmental sustainability initiatives, including case studies, white papers, and blogs, please see our Environment website and our *2016 Environmental Report*. Our *Creating a Responsible Supply Chain* report and Investor Relations website have more information on sustainability and corporate responsibility at Google.

Designing efficient data centers

Modular cooling units at Google's data center in Mayes County, Oklahoma

Overview

Google's data centers are the heart of our company, powering products like Search, Gmail, and YouTube for billions of people around the world, 24/7. We own and operate 14 data centers on four continents and continue to add new sites to better serve our customers. Each data center is a large campus whose facilities, servers, networking equipment, and cooling systems are designed from the ground up for maximum efficiency and minimal environmental impact.

For more than a decade, we've worked to make Google data centers some of the most efficient in the world, improving their environmental performance even as demand for our products has dramatically risen. We've done this by designing, building, and operating each one to maximize efficient use of energy, water, and materials.

To reduce energy use, we strive to build the world's most energy-efficient computing network by squeezing more out of every watt of power we consume. First, we outfit each data center with high-performance servers that we've custom designed to use as little energy as possible. We improve facility energy use by installing smart temperature and lighting controls and redesigning how power is distributed to reduce energy loss. We employ advanced cooling techniques, relying primarily on energy-efficient evaporative cooling, and use nonpotable water whenever possible. Finally, we apply machine learning to drive energy efficiency even further.

Our efforts have paid off: Google data centers use 50% less energy than typical data centers use.[11] Compared with five years ago, we now deliver more than 3.5 times as much computing power with the same amount of electrical power. In 2016,

DATA CENTERS: BY THE NUMBERS

50%
LESS ENERGY

On average, a Google data center uses 50% less energy than a typical data center.

1.12
PUE

In 2016, the average annual power usage effectiveness for our global fleet of data centers was 1.12, compared with the industry average of 1.7—meaning our data centers use nearly six times less overhead energy.

86%
WASTE DIVERTED

In 2016, we diverted 86% of waste from our global data center operations away from landfills.

ISO
14001 & 50001 CERTIFICATIONS

We've achieved ISO 14001 (environmental management) and ISO 50001 (energy management) certifications for 12 of our 14 Google-owned and -operated data centers globally, which together represented more than 98% of our IT energy use in 2016.

Seawater cooling plant at Google's data center in Hamina, Finland

the average annual power usage effectiveness (PUE)[12] for our global fleet of data centers was 1.12, compared with the industry average of 1.7[13]—meaning that Google data centers use nearly six times less overhead energy for every unit of IT equipment energy. Our fleet-wide PUE has stayed constant at 1.12 for the past five years.

Generating electricity requires water, so the less energy we use to power our data centers, the less water we use as well. The source of energy matters too: wind and solar energy require considerably less water to produce than do coal and nuclear energy. In 2016, using renewable energy for our data centers reduced our embedded water use by 45% on average compared with buying grid power.

In 2013, we became the first company in North America—and the only major internet company—to achieve a multi-site ISO 50001 energy management system certification. We also maintain a corporate multi-site ISO 14001 environmental management certification. Both of these voluntary third-party certificates cover all of our owned data centers globally once they meet certain operational milestones. In 2016, we maintained these certifications for 12 of our 14 data centers, which together represented more than 98% of our IT energy use. We plan to add our two newest facilities to our ISO 50001 certificate in 2017, once they meet operational criteria.

We're also working to design out waste, embedding circular economy principles into our server management by reusing materials multiple times. In 2016, 36% of Google's newly deployed servers were remanufactured machines, and 22% of components used for machine upgrades were refurbished inventory.

We're committed to achieving Zero Waste to Landfill[14] for our global data center operations by reducing the amount of waste we generate and finding better disposal options. Six of our operating data centers have achieved 100% landfill diversion, and one of these has also reached Zero Waste to Landfill.[15] In 2016, we diverted 86% of waste from our global data center operations away from landfills.

Google has saved more than $1 billion through our energy-efficiency initiatives and hundreds of millions more through resource efficiency. By sharing our best practices and supporting research and collaboration, we hope to help other companies realize their own savings and promote ever-greater data center sustainability worldwide.

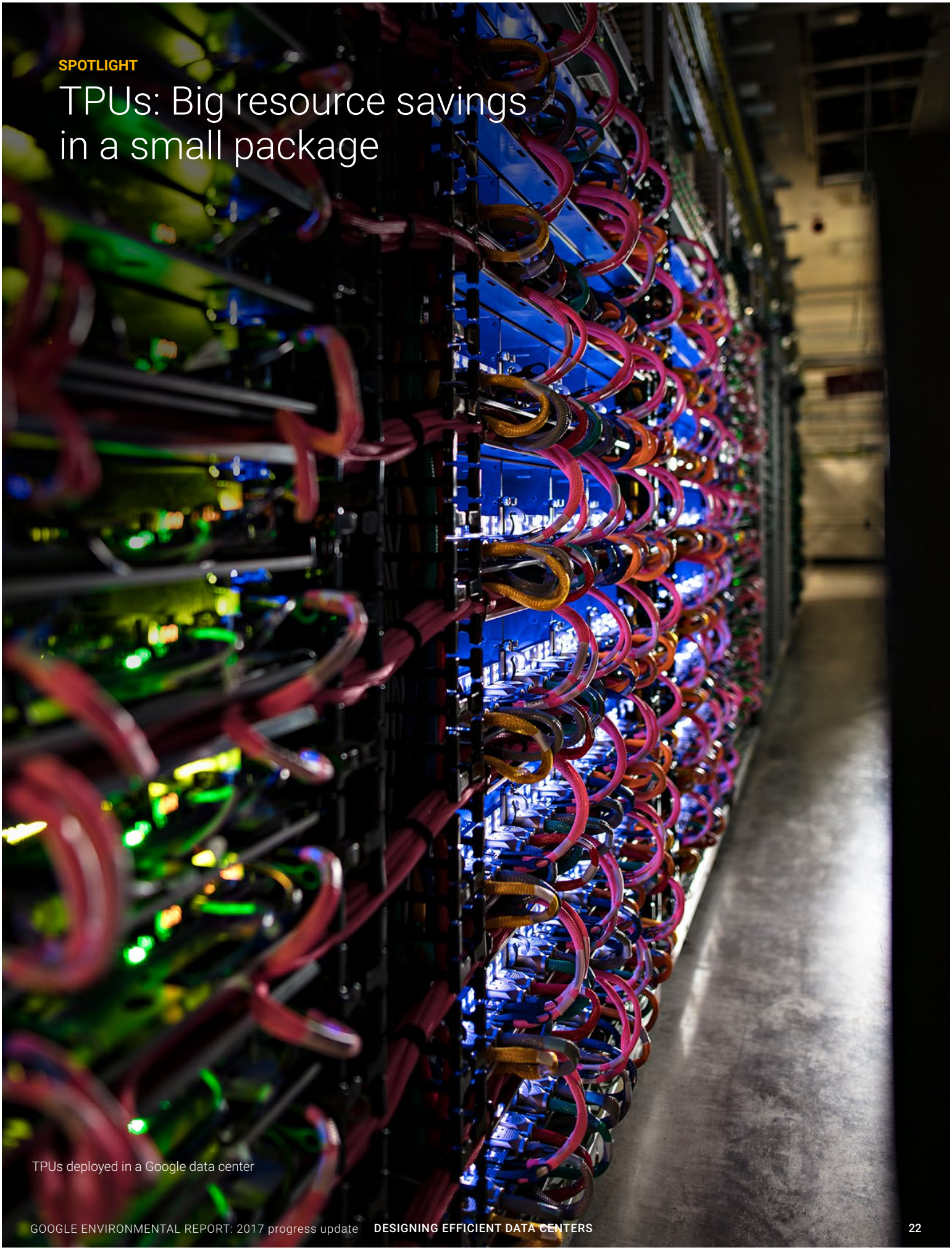
LEARN MORE

2011 case study: Google's Green Computing: Efficiency at Scale
2011 case study: Google's Green Data Centers: Network POP Case Study
2016 case study: Circular Economy at Work in Google Data Centers
Google Data Centers website: Efficiency: How We Do It

An employee works atop a storage tank at Google's data center in Douglas County, Georgia.

SPOTLIGHT

TPUs: Big resource savings in a small package



TPUs deployed in a Google data center

15x–30x

TPUS ARE 15 TO 30 TIMES FASTER FOR MACHINE LEARNING APPLICATIONS THAN CONVENTIONAL CHIPS ARE.

Machine learning puts the oomph in many of Google's popular applications, from Street View to voice recognition to Smart Reply in Inbox by Gmail. It involves deep neural networks and complex mathematical systems that can analyze large amounts of data in order to learn specific tasks. Machine learning thus requires a lot of compute power, which puts more pressure on Google engineers to find ways to save power as we use this tool more broadly throughout our products.

About five years ago, when we started using machine learning to enhance Google Voice Search, we realized that, given the processing units we were currently using, if every person in the world with an Android phone used voice search for just three minutes a day, we would need twice as many data centers. Rather than double our data center fleet and our environmental footprint, we set out to create a computer chip designed specifically for machine learning applications like speech recognition.

The result is the Tensor Processing Unit (TPU), an entirely new class of application-specific integrated circuit that has been running machine learning applications in our data centers since 2015. TPUs are designed to use sophisticated machine learning models and apply them more quickly, so users get more intelligent results more quickly as well. TPUs are much faster for machine learning applications than are conventional chips—15 to 30 times faster than their contemporary graphics processing units (GPUs) and central processing units (CPUs)[16]—and they allow us to make predictions, and enable products to respond, in fractions of a second.

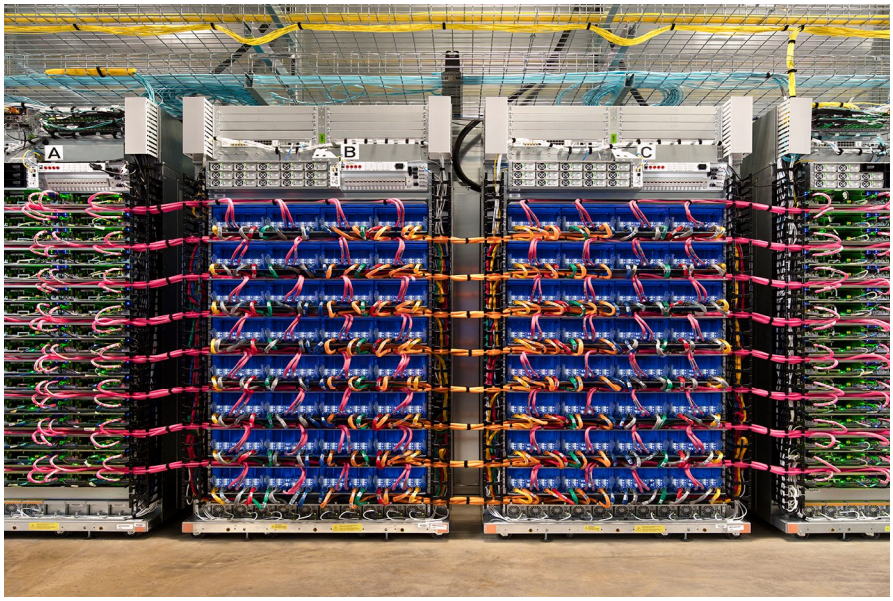
These custom chips are behind every Google search query, powering the vision models that underlie products like Google Image Search, Google Photos, and the Google Cloud Vision API. When AlphaGo won its famous 2016 match against Lee Sedol to become the first computer to defeat a world champion in the ancient game of Go, it was TPUs that enabled it to "think" much more quickly and look farther ahead between moves.

TPUs are also much more energy efficient for machine learning by an order of magnitude, outperforming standard processors by 30 to 80 times in the TOPS/Watt efficiency measure.[17] This is roughly equivalent to fast-forwarding technology seven years into the future (more than three generations of Moore's Law).

More than 100 teams at Google are using machine learning today, and TPUs will enable huge resource savings for all of them. By dramatically reducing the need to expand our data center fleet, this new technology has brought us immense savings in land, materials, energy, and water, not to mention money. We can in turn pass on these savings to our customers. While we'll continue pushing our data centers to make them as sustainable as possible, the most sustainable data center is one that doesn't have to be built.

LEARN MORE

2014 research paper: Machine Learning Applications for Data Center Optimization
2017 research paper: In-Datacenter Performance Analysis of a Tensor Processing Unit



A "TPU pod" built with 64 second-generation TPUs delivers up to 11.5 petaflops of machine learning acceleration.

Advancing renewable energy

El Romero solar farm in Chile
(80 MW for Google)

Overview

Running our business requires us to consume energy—primarily electricity—to power our data centers, offices, and other infrastructure. And combating climate change requires the world to transition to a clean energy economy. So we've made it a top priority not only to become more energy efficient but also to ensure that the energy we purchase comes from clean sources such as renewables. Our support for clean energy goes hand in hand with reducing our carbon footprint. By improving the efficiency of our operations and buying both renewable power and high-quality carbon offsets, we've been carbon neutral since 2007.

Google is the world's largest corporate purchaser of renewable energy.[18] Since 2010, we've signed 20 agreements to purchase a total of 2.6 gigawatts (GW) of renewable energy that is new to the grid—generating emissions savings that are equivalent to taking more than 1.2 million cars off the road. And in 2012, we set a long-term goal to reach 100% renewable energy for our operations.

This year, we're going to achieve it. In 2016, our energy deals produced enough renewable electricity to cover 57% of our operations. These efforts earned Google a 2016 Green Power Leadership Award in Direct Project Engagement from the U.S. Environmental Protection Agency. And given our signed contracts for projects that will come online in 2017, we'll reach 100% renewable energy for our global operations this year. While we'll still be drawing power from the grid, some of which will be from fossil fuel resources, we'll purchase enough wind and solar energy to account for every megawatt-hour (MWh) of electricity our data center and office operations consume annually.

RENEWABLE ENERGY: BY THE NUMBERS

100%
RENEWABLE ENERGY

We will achieve 100% renewable energy for our operations in 2017.

2.6 GW
TOTAL OF RENEWABLE ENERGY

Google is the world's largest corporate purchaser of renewable energy. We've signed 20 agreements totaling 2.6 GW of renewable energy—generating emissions savings equivalent to taking more than 1.2 million cars off the road.

598 MW
OF ADDITIONAL RENEWABLE ENERGY

In 2016, we increased our total purchases of renewable energy by entering into five new PPAs totaling 598 MW.

$2.5 BILLION
IN INVESTMENT COMMITMENTS

Since 2010, we've committed to invest nearly $2.5 billion in renewable energy projects with a total combined capacity of 3.7 GW.

We achieved our 100% renewable energy target much faster and at much greater scale than we thought possible when we set this goal five years ago. We met it primarily by buying renewable electricity directly from new wind and solar farms via long-term power purchase agreements (PPAs), as well as by buying renewable power through utilities via renewable energy purchasing models that we helped create. In addition, a small portion of our utility energy purchases include renewable sources as part of the utility's grid mix.[19]

By pioneering new energy purchasing models that others can follow, we've helped drive wide-scale adoption of clean energy. We're also helping to green the power grid through our advocacy of clean energy policies and our support for renewable energy procurement programs. For example, we provided a seed grant to the Center for Resource Solutions to explore the creation of renewable energy certification systems in Asia. These efforts earned Google a second 2016 Green Power Leadership Award in International Green Power Market Development.

Along with being the world's largest corporate purchaser of renewable energy, Google is also one of the world's largest corporate investors in renewable energy. Since 2010, we've committed to invest nearly $2.5 billion in large-scale renewable energy projects and residential solar rooftop funds with a combined capacity of 3.7 GW. These targeted investments go beyond our own operational footprint,

Interior of turbine at Golden Hills wind farm in California (43 MW for Google)

Golden Hills wind farm in California
(43 MW for Google)

enabling renewable energy deployment at a larger scale while generating attractive risk-adjusted returns.

The cost of renewable power has dropped precipitously, while its scale has grown dramatically. Over the past seven years, wind and solar energy costs have decreased by 66% and 85%, respectively.[20] In 2015, wind and solar energy became the world's largest source of newly installed power capacity,[21] and in 2016, almost two-thirds of net new power capacity globally came from renewable energy.[22] Renewables have become a mainstream source of affordable electricity for millions of people.

Increasing the share of renewables on the grid would bring many positive impacts. For example, doubling renewables by 2030 is expected to increase global gross domestic product (GDP) by as much as 1.1%, improve global welfare by 3.7%, and employ more than 24 million people in the renewable energy sector.[23] At Google, we'll continue doing our best to help accelerate the transition to clean energy and a more prosperous future.

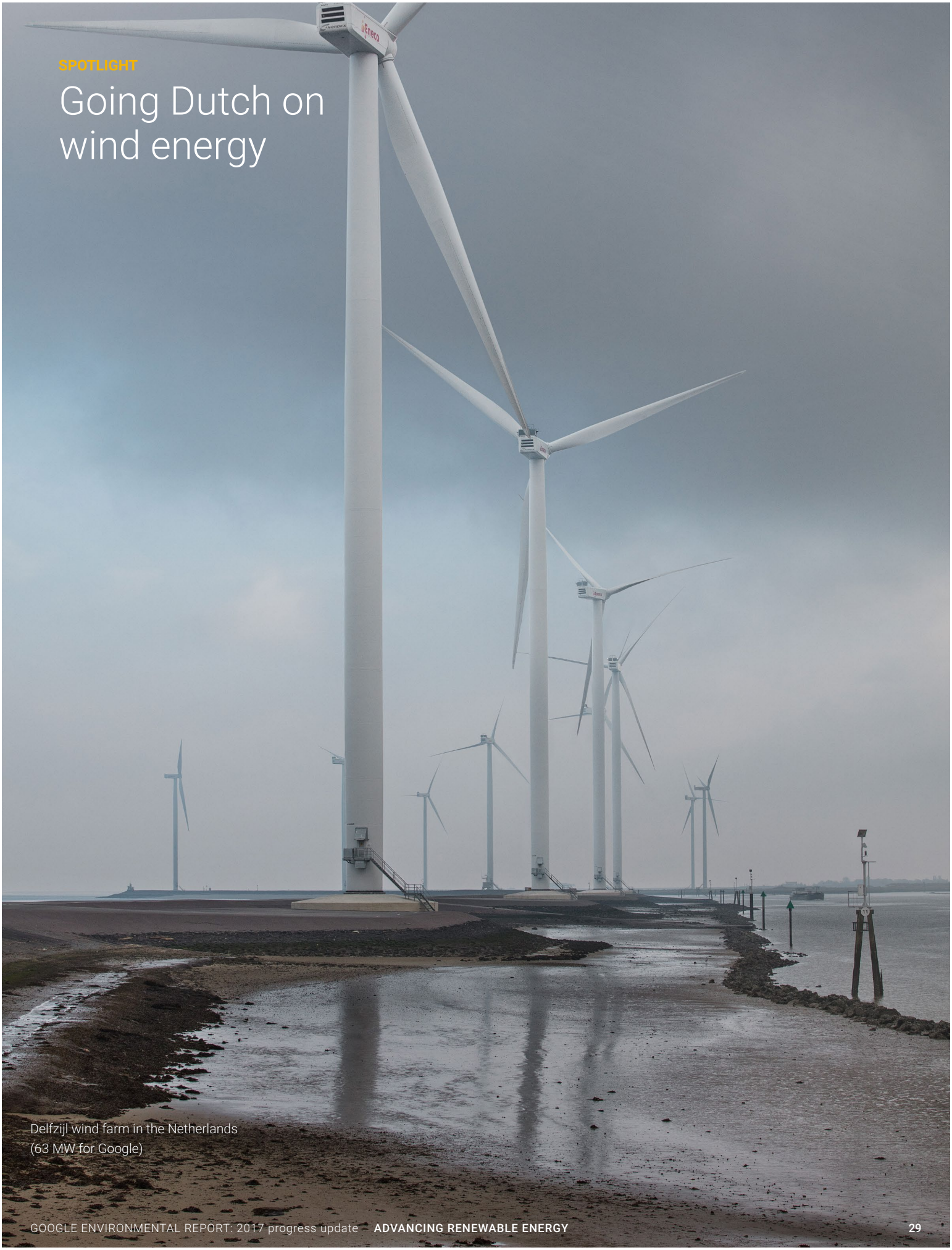
LEARN MORE

2013 white paper: Expanding Renewable Energy Options for Companies through Utility-Offered Renewable Energy Tariffs

2016 white paper: Achieving Our 100% Renewable Energy Purchasing Goal and Going Beyond

SPOTLIGHT

Going Dutch on wind energy



Delfzijl wind farm in the Netherlands
(63 MW for Google)

Delfzijl wind farm in the Netherlands
(63 MW for Google)

136 MW

OF RENEWABLE ENERGY

THE KRAMMER AND BOUWDOKKEN WIND PROJECTS COMBINED WILL ADD 136 MW OF NEW RENEWABLE CAPACITY TO THE DUTCH ELECTRICITY GRID.

Making a clean energy future a reality will require corporations, communities, and governments to work together. That's why we were excited to join forces with three leading Dutch companies—AkzoNobel, DSM, and Philips—to source power from two new wind projects in the Netherlands. Our long-term collaboration offers a successful and replicable model for how companies can achieve time and cost savings and meet ever-growing sustainability targets in a scalable way by jointly sourcing renewable power.

Acting as a group offered big advantages. Combining our collective power needs into one agreement gave the consortium access to better pricing by allowing it to buy power from a larger project than most members could have pursued individually, while letting each partner share risk and build a more diversified energy portfolio. Using PPA contracts with identical terms between each buyer and the project developer reduced negotiation costs. Creating a replicable structure let us negotiate subsequent deals in a fraction of the time. Including the time it took to negotiate the terms of the consortium, the first PPA transaction took 36 months from inception to closing, and the second took only 7 months. Finally, drawing from each company's expertise let the group share best practices and market knowledge.

The first agreement, executed in October 2016, was for the consortium to purchase the entire power production —102 MW—of Windpark Krammer, a wind farm established by two community-owned cooperatives in the Dutch province of Zeeland. Once the Krammer wind farm becomes fully operational in 2019, the consortium will buy a total of 350 gigawatt hours (GWh) per year—equivalent to the annual power

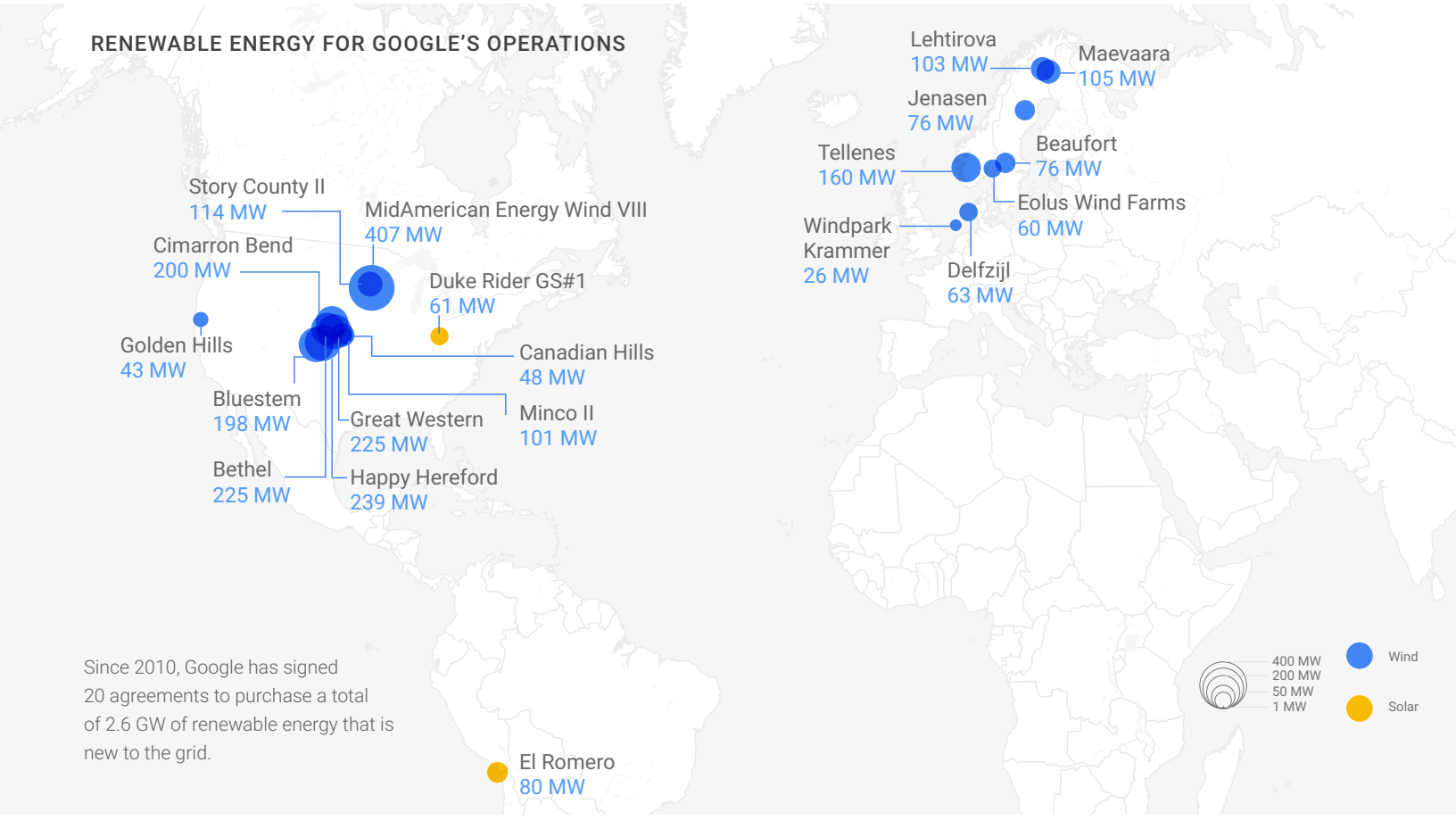
consumption of 100,000 households. Our purchase agreement is for a 15-year period, a crucial element for the project to secure financing. This is also the first time Google has teamed up with a community on a consumer-to-business energy partnership. We'll be buying wind power directly from 4,000 landowners, mostly farmers, who collectively own the land on which the wind turbines will be built. Some of these landowners will also be direct, albeit modest, investors in the wind farm.

The consortium's second PPA, signed in January 2017, will enable development of the 34 MW Windpark Bouwdokken. When both are operational, the Krammer and the Bouwdokken wind projects combined will add 136 MW of new renewable capacity to the Dutch grid.

These deals weren't Google's first renewable energy agreements in the Netherlands. In 2014, we announced that we would independently purchase the entire energy output (63 MW) of a new wind farm in Delfzijl. Thanks to that contract, 18 new wind turbines have been built, and our data center in Eemshaven has had renewable energy from day one. Together these three deals have enabled us to significantly contribute to the Netherlands' national target of 14% renewable energy by 2020.

As the world's largest corporate purchaser of renewable energy, we were thrilled to work with other companies to jointly pursue our sustainability goals and help realize a clean energy future faster than ever.

RENEWABLE ENERGY FOR GOOGLE'S OPERATIONS



Since 2010, Google has signed 20 agreements to purchase a total of 2.6 GW of renewable energy that is new to the grid.

Creating sustainable workplaces

Central staircase in Google's Fulton Market office in Chicago, Illinois

Overview

Americans spend roughly 90% of their time indoors,[24] and much of that time is spent at work. At Google, just as we try to focus on the user in designing our products, we try to focus on our employees in creating the healthiest possible workplaces, from our Bay Area headquarters to Google offices at diverse sites in more than 150 cities around the world. To do so we look for innovative ideas that deliver measurable results and can be implemented at scale.

We start by applying industry-leading green building standards wherever possible and by using tools like our own Portico to source nontoxic materials that are easy to cycle. As of the end of 2016, 865,000 square meters (9.3 million square feet) of Google office facilities had achieved LEED (Leadership in Energy and Environmental Design) certification, with 34% of our LEED-certified square footage achieving a Platinum rating and 54% a Gold rating.

We take a science- and community-driven approach to managing our campuses, with the aim of strengthening the ecosystem while improving access to the outdoors for Google employees and the surrounding community. We also look for opportunities to install renewable energy like solar panels and ground source heat pumps.

We reduce our water footprint by installing water-saving technologies and using reclaimed water wherever possible. From 2013 to 2016, we reduced potable liters of water consumed per Googler by 40% at our Bay Area headquarters. We reduce waste wherever we can and look for diversion pathways that keep the waste we do generate out of landfills. From 2015 to 2016, we reduced total waste per Googler by 2% at our Bay Area headquarters, and in 2016, we reached an 85% landfill diversion rate in the Bay Area and 78% for our offices globally. We are now working to set regional water- and waste-reduction targets across our portfolio.

SUSTAINABLE WORKPLACES: BY THE NUMBERS

9.3 MILLION
SQUARE FEET LEED CERTIFIED

As of the end of 2016, 865,494 square meters (9.3 million square feet) of Google office facilities have achieved LEED certification.

40%
REDUCTION IN POTABLE WATER USE

From 2013 to 2016, we reduced potable liters of water used per Googler by 40% at our Bay Area headquarters.

85%
LANDFILL DIVERSION

In 2016, we reached an 85% landfill diversion rate in the Bay Area and 78% for our offices globally.

152 MILLION
VEHICLE KILOMETERS AVOIDED

By using Google shuttles and corporate electric vehicles in the Bay Area in 2016, we saved 33,000 metric tons of carbon dioxide emissions—equivalent to taking 6,500 cars off the road.

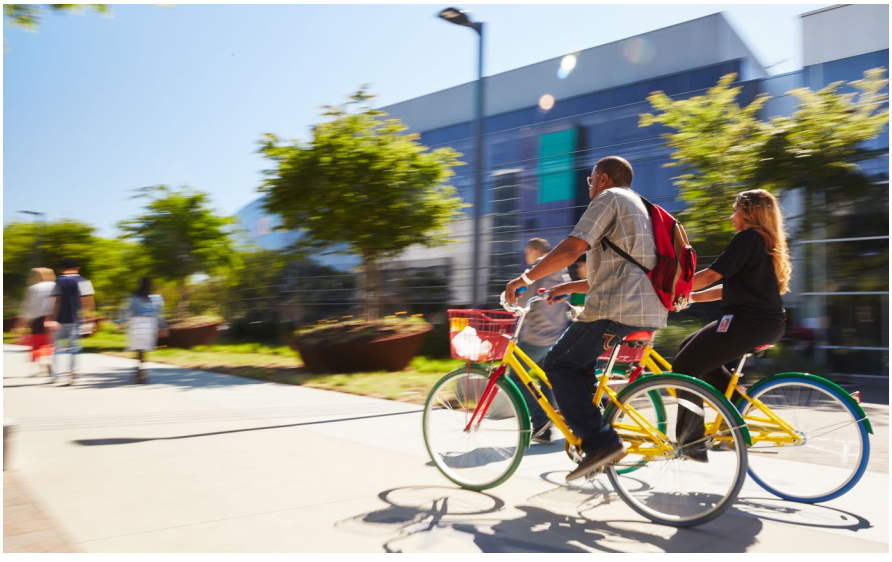
Our cafés and MicroKitchens offer nutritious, responsibly sourced meals, snacks, and beverages. We try to make thoughtful choices in the products we buy and the suppliers we buy them from. Our food program also focuses on reducing waste throughout our operations, composting where we can and donating leftover food when we're legally able to do so. But we've learned that the best way to reduce food waste is to prevent it in the first place by tracking data and making adjustments. In 2016 this sort of data-driven optimization helped Google avoid 700,000 kilograms (1.5 million pounds) of food waste in our cafés around the world.

Our Transportation team works to make commuting and campus mobility a stress-free part of every employee's day. We set ambitious goals for helping Googlers transition to shuttles, carpooling, public transit, biking, and walking. In 2016, initial results indicate that for the Mountain View portion of our Bay Area headquarters, we exceeded our long-term goal to reduce single-occupancy vehicle commuting to 45%. We also achieved a design standard of providing approximately 10% of parking with electric vehicle charging stations for new construction and tenant improvement projects in the Sunnyvale portion of our Bay Area headquarters. In 2016, our Google shuttle buses and corporate electric vehicles in the Bay Area produced savings of more than 33,000 metric tons of carbon dioxide emissions—the equivalent of taking 6,500 cars off the road every day for a year or avoiding 152 million vehicle kilometers (95 million vehicle miles) per year.

Finally, as we explore these sustainability strategies, we're committed to sharing what we learn with other companies in order to help foster the growth of a new generation of more productive, environmentally friendly businesses.

LEARN MORE

2015 report: Vision for a Resilient Silicon Valley Landscape
2016 report: Google Bay Area Waste Case Study



Employees ride shared GBikes to get around Google's Mountain View, California, campus.

SPOTLIGHT

Fulton Market: Building a workplace that works

Google's Fulton Market office in Chicago, Illinois, is the largest Living Building Challenge–certified project in the world.

Google's Fulton Market office in Chicago, Illinois

100%

RED LIST–FREE MATERIALS

ALL BUILDING MATERIALS USED IN THE FULTON MARKET OFFICE ARE FREE OF THE WORST-IN-CLASS CHEMICALS FOUND IN CONSTRUCTION PRODUCTS.

Google Chicago, also known as Fulton Market and as Google's new home in the Windy City, is a 30,000-square-meter (350,000-square-foot) space spanning seven floors. The building, built in 1923 in Chicago's historic West Loop neighborhood, was originally a cold-storage warehouse. Today this industrial concrete structure has been transformed into a warm, inviting workplace and the first Google office to receive the Living Building Challenge (LBC) Materials Petal Certification.[25] In fact, Fulton Market is currently the largest LBC-certified project in the world.

When the project began, our team set ambitious goals for improving Googler wellness, happiness, and productivity through the use of design factors like lighting, materials, and biophilia (connecting people to nature). This was also the first time we explored utilizing multiple green rating systems, including LEED v4, LBC Certification, and WELL Building Certification. Pursuing these certifications led us to focus on four key initiatives: 100% Red List–free materials, circadian rhythm lighting design, sustainably sourced wood, and biophilic design.

The LBC Materials Petal is the leading healthy materials certification for green buildings. To meet it while also meeting Google's own healthy materials requirements, the team used our online application Portico. Developed in partnership with the Healthy Building Network, Portico combines a product database and collaborative workflow tools to offer an in-depth focus on healthy materials. At the moment, this tool is available internally at Google and to our project partners, but we're working to expand access to Portico in the future. In a similar spirit of driving industry-wide change, the Google Chicago design team also used the project to

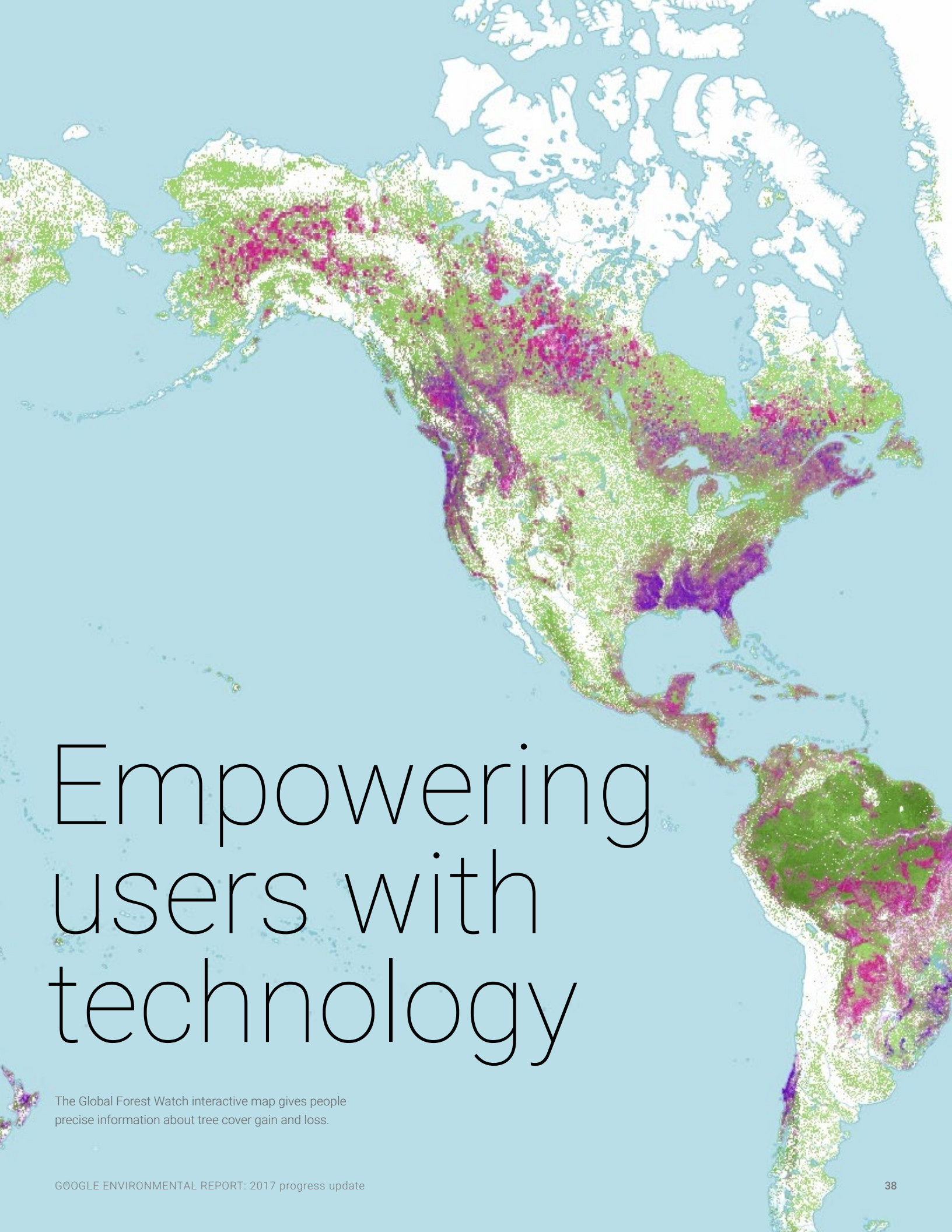
encourage broader market transformation by writing to manufacturers to argue for greater product transparency and request full ingredient lists.

Our lighting strategy focused on improving Googler productivity and stress levels by aligning with the body's natural circadian rhythm through careful integration of daylight and electric light. Open offices along the building's outer edges maximize access to natural daylight, and we make sure that spaces lacking daylight access still benefit from the full spectrum of light.

Our team tried to avoid using new wood, first exhausting all feasible reclaimed wood sources (the aerobics room floor, for example, had a previous life in a local high school gym). When new wood was necessary, we worked with local millworkers to identify nearby sources of Forest Stewardship Council wood from sustainably managed and harvested forests.

Each floor has a Chicago-centric theme, including the city's L System, Loop, and famous parks. But the whole building integrates biophilia with a sense of place, taking inspiration from nature through touches like edible plants, wall textures, and dynamic video walls. We'll look to use our learnings from Chicago in future projects.

Google's Fulton Market office in Chicago, Illinois



Empowering users with technology

The Global Forest Watch interactive map gives people precise information about tree cover gain and loss.

Overview

A global challenge requires a global response. We strive to meet the vast challenge posed by climate change by working to empower everyone—from individuals and communities to nonprofit organizations, businesses, and governments—to use Google technology to help create a more sustainable and resource-efficient world.

Google Cloud Platform and G Suite applications like Gmail, Docs, and Drive are enabling millions of businesses to switch from locally hosted solutions to Google Cloud's highly efficient, renewable energy–based computing infrastructure. This infrastructure is so efficient that providing an active user one month of Google services creates about the same amount of GHG emissions as driving a car one mile.[26] Businesses that switch to cloud-based products like G Suite have reported reductions in IT energy use and carbon emissions up to 85%,[27] and a business using Gmail can reduce the GHG emissions impact of its email service by up to 98%, compared with running email on local servers.[28] In addition, Google Maps now provides more than 1 billion kilometers' worth of transit results per day, helping limit carbon emissions by giving people access to mass transit options, bike routes, and traffic information.

We also put Google technology to work helping others study and respond to environmental challenges. Our Geo team is working with numerous research and environmental organizations to map the world's forests, oceans, and watersheds, and then getting that information into the hands of decision-makers by working with partners to build services like Global Forest Watch, Global Fishing Watch, Project Sunroof, and the DiSARM platform for malaria risk mapping. These tools, representing 10 petabytes' worth of freely available geospatial data, can provide invaluable information to scientists, environmental organizations, and communities

TECHNOLOGY: BY THE NUMBERS

85%
POTENTIAL ENERGY SAVINGS

Businesses that switch to G Suite products like Gmail, Calendar, Docs, Drive, and Meet have reported reductions in IT energy use and carbon emissions from 65% to 85%.

1 BILLION
KILOMETERS OF TRANSIT RESULTS

Google Maps provides more than 1 billion kilometers' worth of transit results per day, helping limit carbon emissions by giving people access to mass transit options, bike routes, and traffic information.

10
PETABYTES

Global Forest Watch, Global Fishing Watch, Project Sunroof, and the DiSARM platform for malaria risk mapping have enabled tens of thousands of scientists around the world to easily analyze 10 petabytes of geospatial information, resulting in a deeper understanding of the planet.

UL110
GOOGLE PIXEL PHONES

Google Pixel phones are UL 110 certified for sustainability in categories like energy use, health and environment, and end-of-life management.

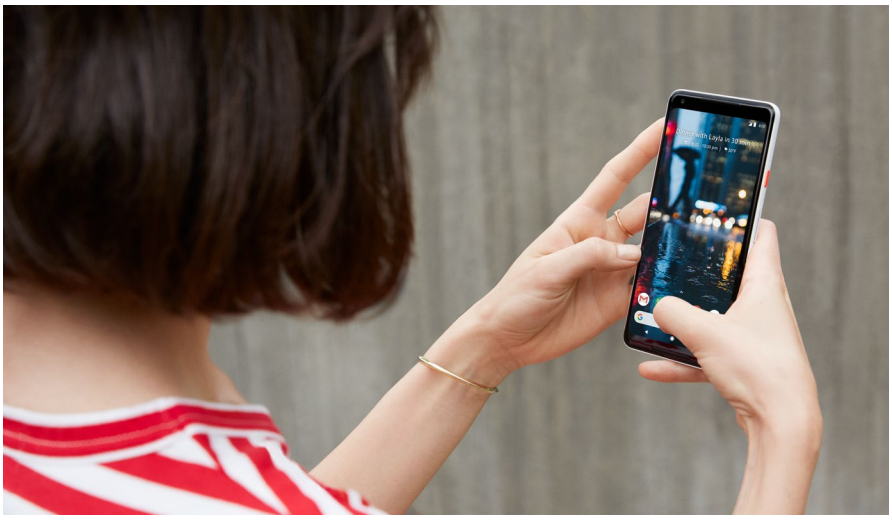
that are trying to devise more informed solutions to challenges like deforestation, overfishing, and air pollution.

We also hold ourselves to a rigorous set of environmental standards throughout the life cycle of Google-branded consumer electronics, from design and manufacturing through packaging and recycling. Google Pixel phones are UL 110 certified for sustainability in categories like energy use, health and environment, and end-of-life management. A portion of the plastic content in products like Google Home and Chromecast is recycled, and we make it easy for customers to recycle their electronics for free via take-back programs.

The Nest Learning Thermostat, a product of the Alphabet company, uses learning algorithms and smart control of residential heating and cooling systems to reduce home energy consumption. Many people leave traditional thermostats at one temperature or forget to change them when they leave home for extended times, wasting energy and costing more money. The Nest Thermostat learns your occupancy patterns and temperature preferences and detects environmental characteristics to customize a schedule that can keep you comfortable while saving energy. It can also be controlled from your phone. Multiple studies conducted by Nest and third parties show that, on average, the Nest Thermostat saves U.S. customers about 10%–12% on their heating bills and about 15% on their cooling bills.[29] Our team takes special pride in the collective savings our thermostats deliver. In fact, as of December 31, 2016, we've saved more than 10 billion kWh combined, based on the average savings studies above—enough energy to power all of San Francisco for more than 21 months.

LEARN MORE

2011 case study: Google's Green Computing: Efficiency at Scale
Project Sunroof: United Nations Momentum for Change award



Google Pixel smartphones offer built-in features like Google Assistant and are UL 110 certified for several sustainability categories.

SPOTLIGHT

Project Air View: Making the invisible visible

A Google Street View camera fitted with air quality equipment

A Google Street View car fitted with air pollution measurement equipment

Every day we make decisions with the help of data from the world around us. By making the invisible visible, air pollution maps are helping us understand how clean (or unclean) our air is so that we can make changes in order to live healthier lives, build more sustainable cities, and reduce climate-changing GHGs.

Project Air View began in 2011, when the Environmental Defense Fund (EDF) asked Google to help it map thousands of methane leaks from natural gas pipelines under select U.S. city streets, using Street View cars equipped with methane analyzers.[30] For years we've been measuring indoor environmental quality across Google offices in partnership with Aclima, which builds environmental sensor networks. So in 2014, we equipped several Street View cars with Aclima's Environmental Intelligence mobile platform, including scientific-grade analyzers and arrays of small-scale, low-cost sensors to measure particulate matter, nitric oxide, nitrogen dioxide, carbon dioxide, black carbon, and other pollutants.

In 2016, PSE&G, one of the largest U.S. utilities, announced that as part of its approved multimillion-dollar pipeline replacement program, it had used data and maps from our Street View mapping effort to prioritize the replacement of gas mains.[31] This enabled PSE&G to replace 35% fewer miles of pipe than if it hadn't used the data and thus reduce methane emissions from targeted areas by 83%.

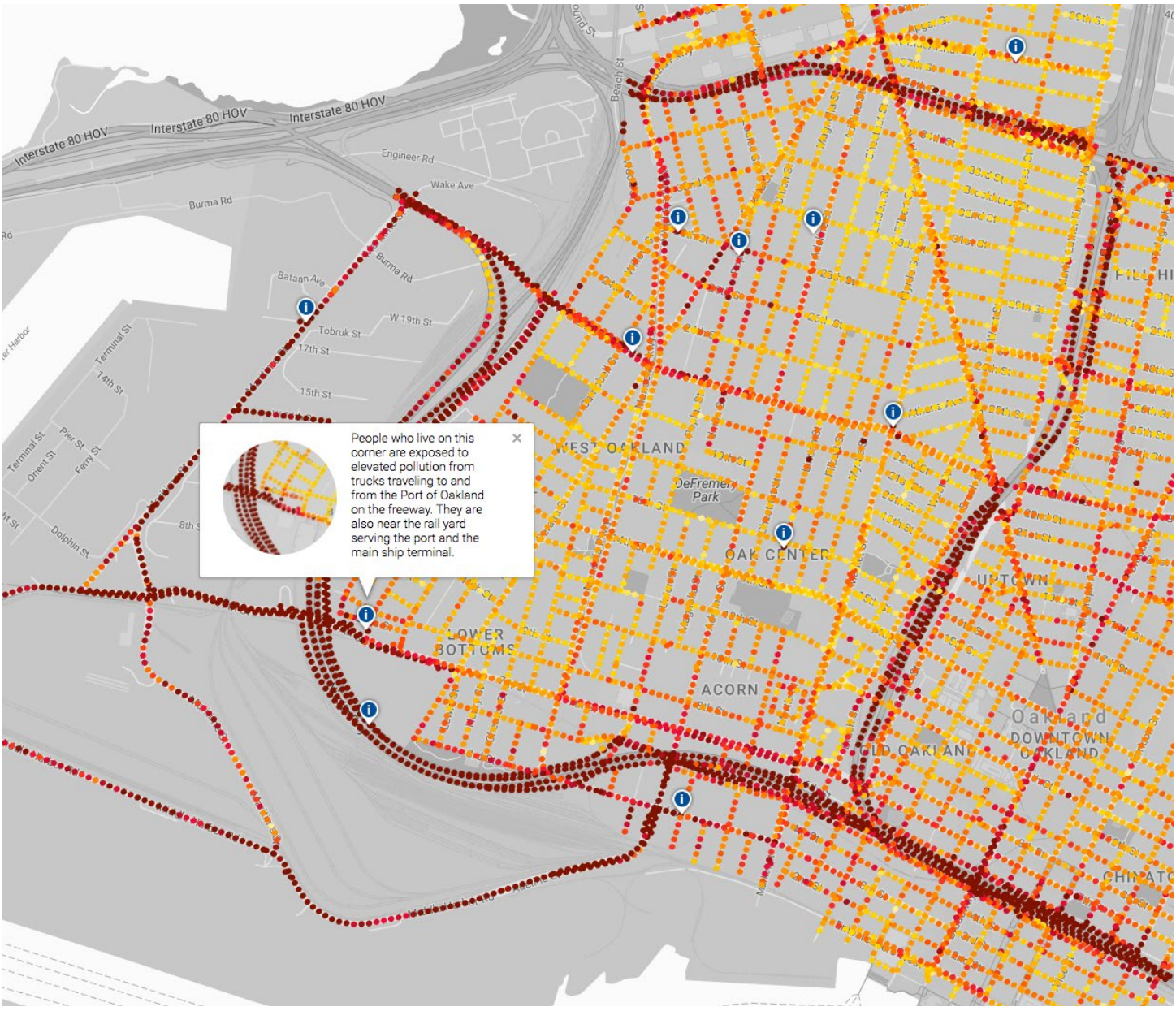
Today, Project Air View is active in three California regions in partnership with Aclima and EDF. Our results for Oakland, California, released by EDF in June 2017, show in street-level detail how pollution emitted from cars, trucks, and other sources

3 MILLION
MEASUREMENTS

PROJECT AIR VIEW'S OAKLAND SURVEY IS ONE OF THE LARGEST AIR QUALITY DATA SETS PUBLISHED TO DATE.

can change block by block.[32, 33] The freeway where the Bay Bridge meets Interstate 80, for example, has higher sustained pollution levels due to vehicles accelerating under I-80 and merging onto the bridge.

With nearly 3 million measurements in the course of a year, Air View's Oakland survey is one of the largest air quality data sets yet published, and it demonstrates how neighborhood-level environmental data can help local groups better understand their communities and help regulators find ways to improve them. The learnings can also be applied to other cities that are trying to understand local patterns and improve their own air quality.



An Environmental Defense Fund map shows analysis with Google/Aclima data of black carbon particles that come from burning fuel, especially diesel, wood, and coal. High exposure is associated with heart attacks, stroke, and some forms of cancer.

Appendix

Environmental data

The following table provides an overview of our performance over time and includes environmental data for our global operations, including our data centers, offices, and other facilities.

Data for GHG emissions and energy use covers Alphabet Inc. and all of its subsidiaries, including Google Inc. The exceptions are data center energy efficiency and renewable energy figures, which cover Google only. All other data applies only to Google. Unless otherwise specified, all data is global.

For more information on our energy use and GHG emissions data and initiatives, see our 2017 CDP climate change report.

		FISCAL YEAR[34]					
KEY PERFORMANCE INDICATOR	UNIT	2011	2012	2013	2014	2015	2016
GHG emissions[35]							
Scope 1*,†	tCO_2e	29,563	37,187	41,373	51,802	66,991	66,218
Scope 2 (market-based)*,†,[36]	tCO_2e	1,439,703	1,149,988	1,245,253	1,460,762	1,384,427[37]	1,518,643
Scope 2 (location-based)*,†	tCO_2e	1,439,703	1,654,645	1,831,142	2,198,821	2,450,438[38]	2,902,554
Scope 3*,†	tCO_2e	208,157	332,612	479,388	980,783	1,234,683	1,292,267
Total (Scope 1, 2 [market-based], and 3)	tCO_2e	1,677,423	1,519,787	1,766,014	2,493,347	2,686,101	2,877,128
Emissions neutralized by carbon offset projects	tCO_2e	−1,677,423	−1,519,787	−1,766,014	−2,493,347	−2,686,101	−1,898,889
Net operational carbon emissions[39]	tCO_2e	0	0	0	0	0	0
Carbon intensity[40]							
Carbon intensity per unit of revenue	tCO_2e/million US$	38.8	25.8	23.2	22.9	19.4	17.6
Carbon intensity per full-time equivalent (FTE) employee	tCO_2e/FTE	51.9	33.8	31.9	31.0	25.0	23.4
Carbon intensity per megawatt-hour (MWh) of electricity consumed at data centers	tCO_2e/MWh	0.552	0.337	0.325	0.316	0.242	0.227

Environmental data

KEY PERFORMANCE INDICATOR	UNIT	FISCAL YEAR 2011	2012	2013	2014	2015	2016
Energy use							
Total energy consumption[41]	MWh	2,863,852	3,547,045	3,970,438	4,702,387	5,533,433	6,513,719
Electricity consumption*	MWh	2,675,898	3,324,818	3,712,865	4,434,390	5,221,476[42]	6,209,191
U.S.	MWh	-	2,326,210	2,562,688	2,985,108	3,779,280	4,522,314
International	MWh	-	998,608	1,150,177	1,449,282	1,442,196	1,686,877
Data center energy efficiency							
Trailing 12-month (TTM) power usage effectiveness (PUE)[43]	TTM PUE	1.14	1.12	1.12	1.12	1.12	1.12
Number of data center sites included in ISO 50001 certificate	#	0	0	9	9	12	12
% of data centers that met criteria for EnMS inclusion and were included in ISO 50001 certificate	%	-	-	100	100	100	92
% of IT energy use represented by data centers included in ISO 50001 certificate	%	-	-	-	-	-	98
Renewable energy							
Total cumulative renewable energy contracts, in megawatts (MW)	MW	215	263	634	1,147	2,121	2,611
% of total electricity obtained from renewable sources[44]	%	-	34	35	37	48	57[45]
Waste generation							
Total waste generated annually	t	-	-	-	-	50,050	45,705
Waste diversion							
Annual landfill diversion rate for data centers[46]	%	-	-	-	-	84	86
Annual landfill diversion rate for offices	%	-	-	-	-	78	78
Annual food waste prevented in cafés	Kilograms	-	-	-	-	229,971	702,865
Hardware refurbishment and reuse							
Servers deployed that were remanufactured machines	%	-	-	-	-	19	36
Components used for machine upgrades that were refurbished inventory	%	-	-	-	-	52	22
Components resold into the secondary market	#	-	-	-	-	2,000,000	2,100,000
Unsellable hard drives crushed and sent to recycler	%	-	-	-	-	100	100
Water consumption							
Total annual water consumption[47]	Million gallons	-	-	-	-	-	2,500

Environmental data

KEY PERFORMANCE INDICATOR	UNIT	FISCAL YEAR 2011	2012	2013	2014	2015	2016
Sustainable workplaces							
Offices							
Cumulative LEED-certified office space	Square meters	62,852	156,894	313,209	462,395	711,626	865,494
Gold	%	69	75	63	59	58	54
Platinum	%	17	19	23	26	31	34
Commuting							
Cumulative electric vehicle (EV) charging ports installed at Google offices in the U.S.[48]	Ports	147	415	601	988	1,382	1,646
Estimated annual emissions avoided due to employee EV commuting in the U.S.	tCO_2e	41	148	483	929	1,489	2,142
Total annual employee shuttle commuting trips in the Bay Area	Total trips	1,500,000	2,000,000	2,500,000	3,000,000	3,500,000	3,750,000
Peak daily employee shuttle riders in the Bay Area	Unique riders	4,000	5,000	6,000	7,500	8,500	9,000
Annual emissions avoided due to employee shuttle trips in the Bay Area	tCO_2e	4,527	7,858	10,065	18,856	28,901	33,656
Equity investments in renewable energy projects[49]							
Cumulative commitments, in gigawatts (GW)	GW	1.8	1.9	2.4	2.7	3.7	3.7

* Indicates verified data. Scope 1, 2, and part of Scope 3 emissions are verified by an independent, accredited verifier. Our electricity use is also part of our Scope 2 verification.

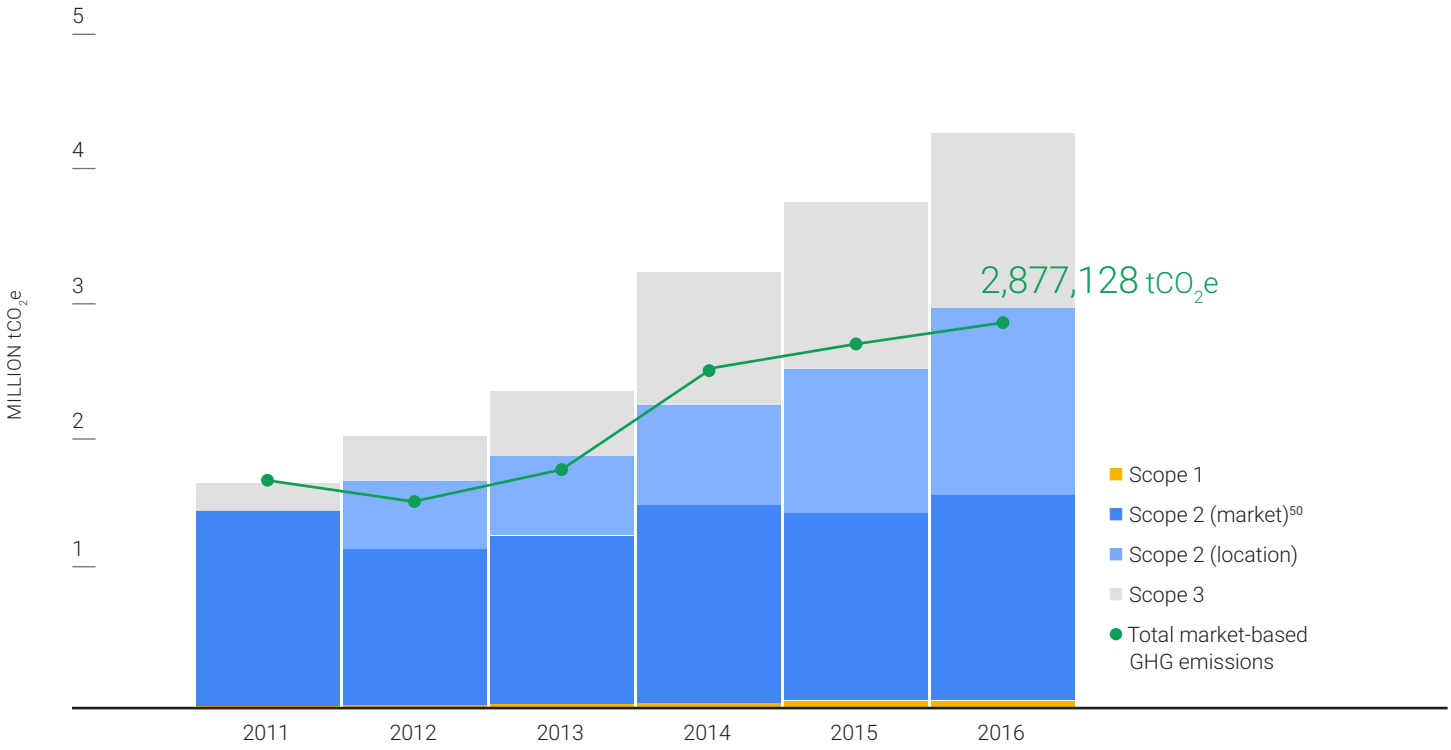
† Scope 1 emissions are direct emissions from sources we own or control, such as company vehicles or generators at Google's offices and data centers.

Scope 2 emissions are indirect emissions from the production of electricity we purchase to run our operations. The location-based category reflects the average carbon intensity of the grids where our operations are located and thus where our energy consumption occurs. The market-based category incorporates our procurement choices, i.e., our renewable energy purchases via contractual mechanisms like PPAs.

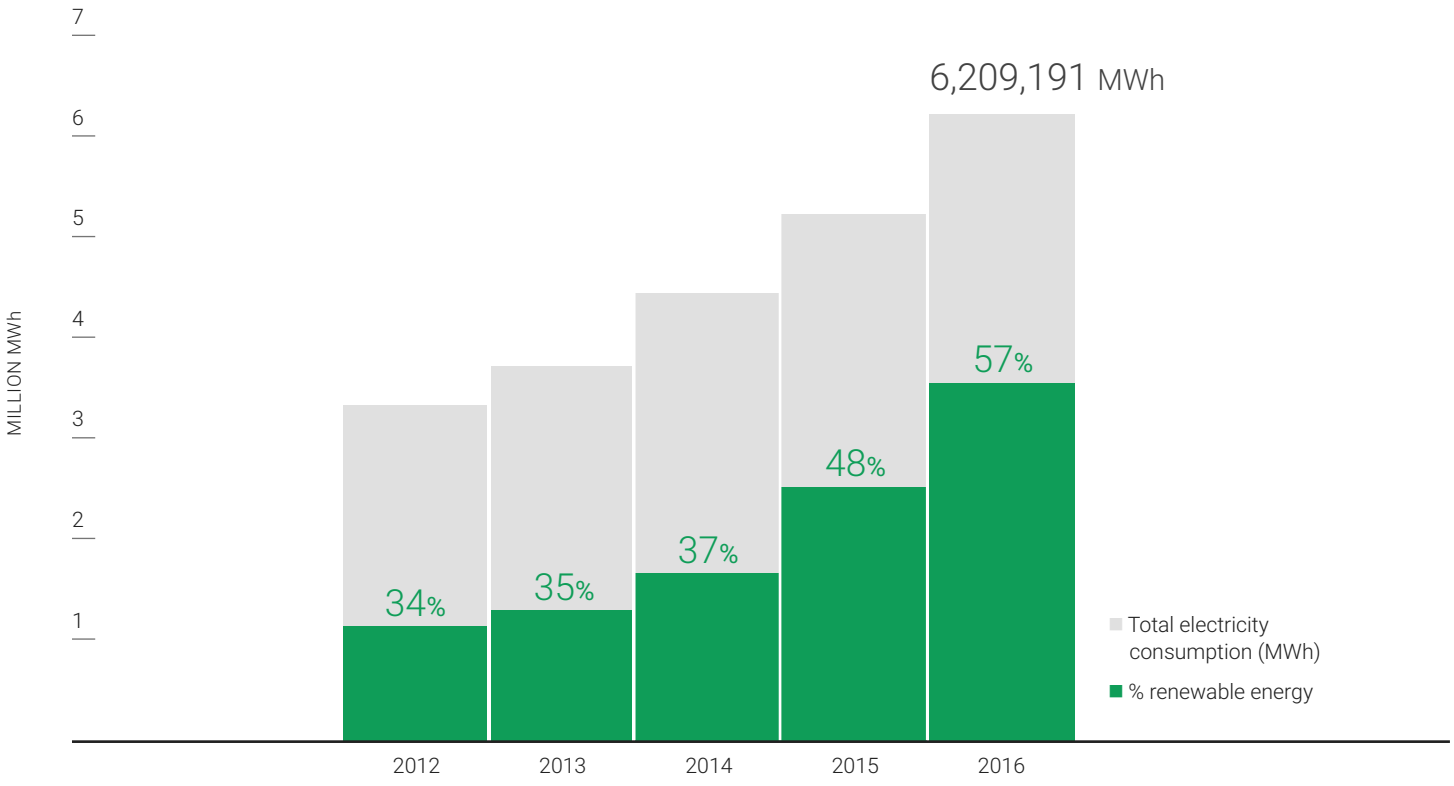
Scope 3 emissions are indirect emissions from other sources in our value chain, such as business travel or our suppliers.

Environmental data

GREENHOUSE GAS EMISSIONS

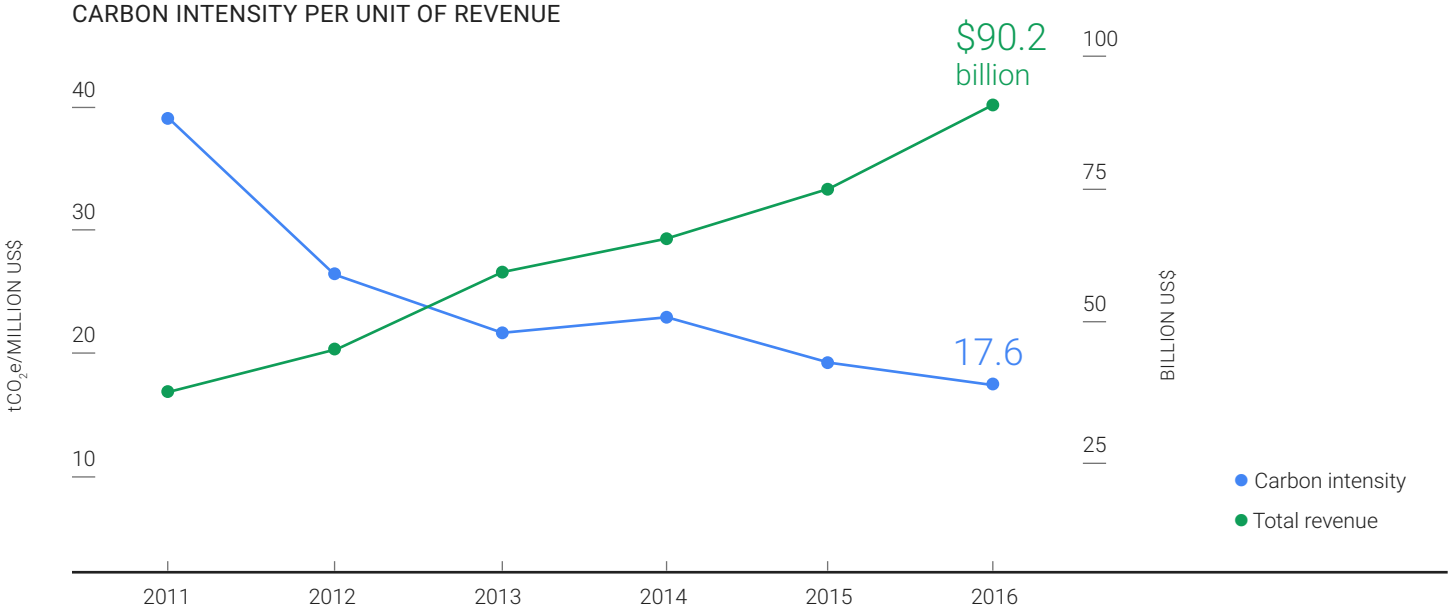


RENEWABLE ENERGY AS PERCENTAGE OF TOTAL ELECTRICITY USE

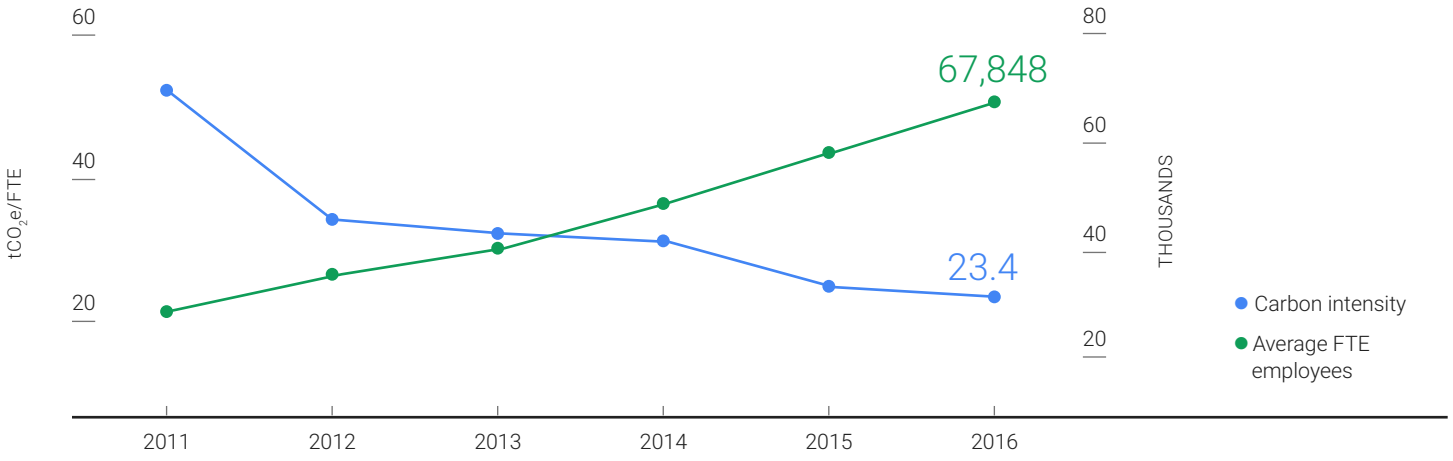


Environmental data

CARBON INTENSITY PER UNIT OF REVENUE

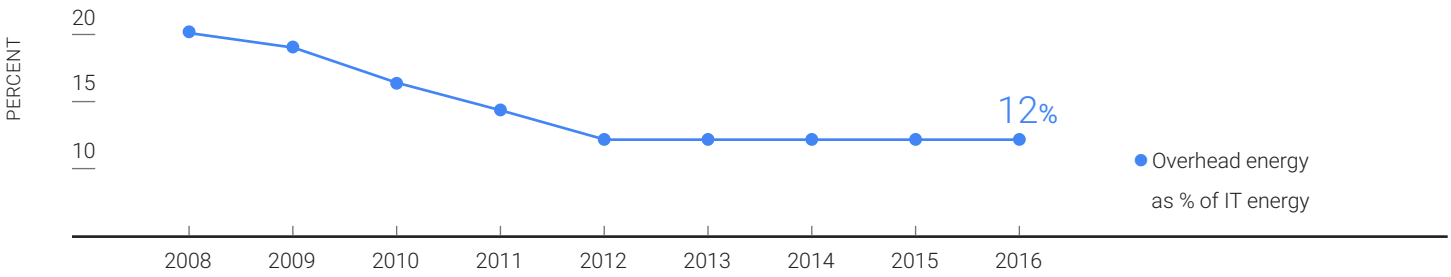


CARBON INTENSITY PER FULL-TIME EQUIVALENT (FTE) EMPLOYEE

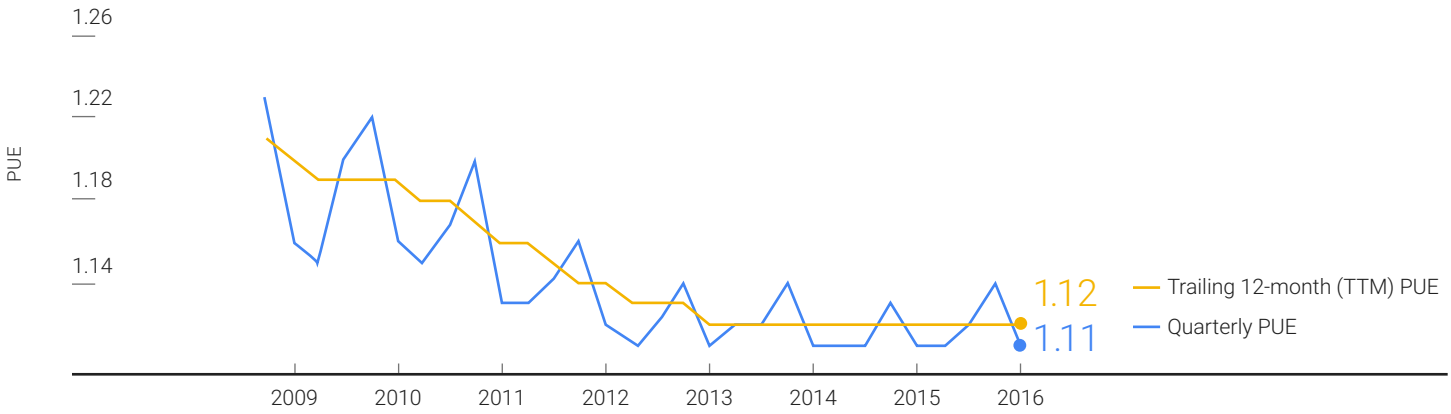


Environmental data

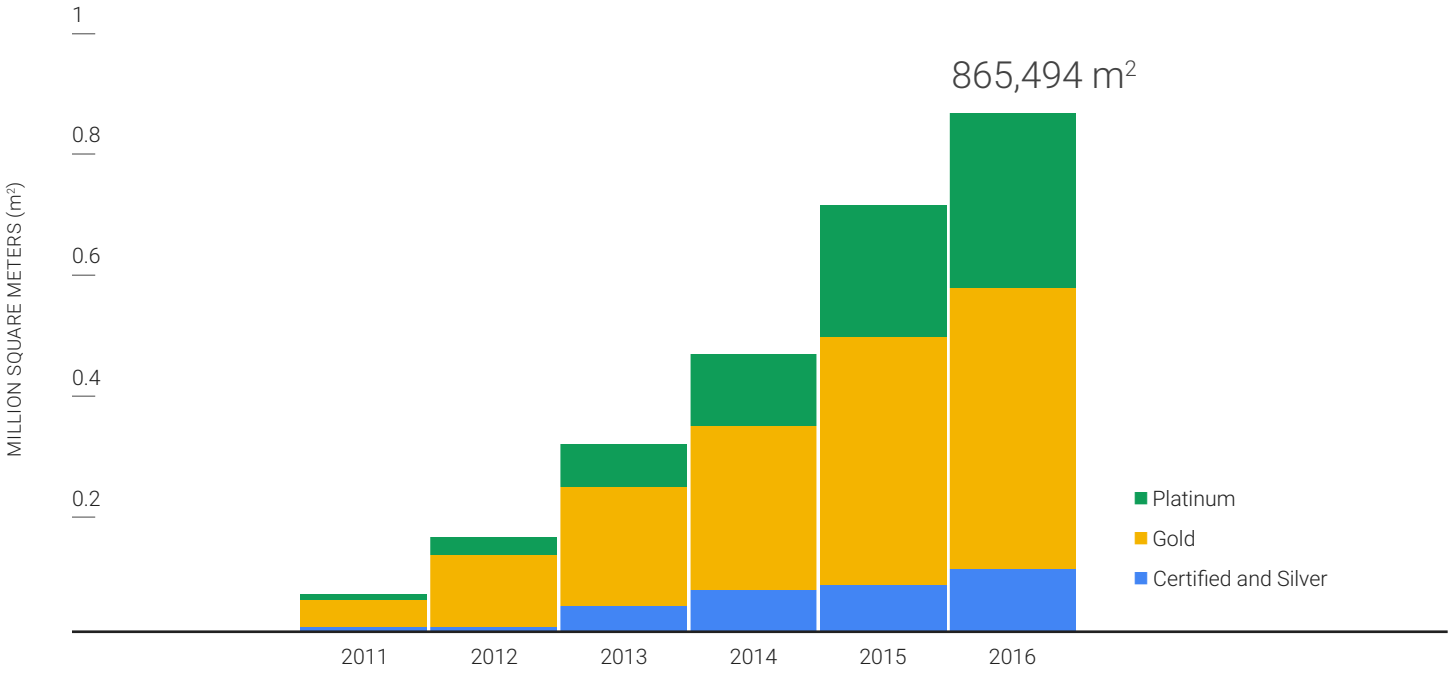
OVERHEAD ENERGY USE IN GOOGLE DATA CENTERS



AVERAGE POWER USAGE EFFECTIVENESS (PUE) FOR ALL DATA CENTERS



CUMULATIVE LEED-CERTIFIED OFFICE SPACE



Endnotes

OUR APPROACH

1. Mathy Stanislaus, "A Virtuous Circle," *The Environmental Forum*, September/October 2016 , https://www.epa.gov/sites/production/files/2016-08/documents/stainislaus_a_virtuous_circle_2016_final.pdf.
2. Global Footprint Network, accessed 2017, http://www.footprintnetwork.org.
3. Arman Shehabi et al., *United States Data Center Energy Usage Report*, Lawrence Berkeley National Laboratory, June 2016, https://eta.lbl.gov/publications/united-states-data-center-energy.
4. Eric Masanet et al., *The Energy Efficiency Potential of Cloud-Based Software: A U.S. Case Study*, Lawrence Berkeley National Laboratory, June 2013, https://www.osti.gov/scitech/servlets/purl/1171159.
5. "International Decade for Action 'Water for Life' 2005–2015," United Nations Department of Economic and Social Affairs, accessed 2016, http://www.un.org/waterforlifedecade/scarcity.shtml.
6. Read about our $6.5 million in Google.org water projects: https://www.blog.google/topics/causes-community/world-water-day.
7. A carbon offset is an investment in an activity that reduces carbon emissions. The reduction in carbon emissions is represented by a carbon credit. The credit, usually verified by a third party, signifies that GHG emissions are lower than they would have been had no one invested in the offset. One credit equals one metric ton (1,000 kilograms or 2,204 pounds) of carbon dioxide equivalent (CO_2e) prevented from being released into the atmosphere.
8. Carbon dioxide equivalent (CO_2e) is a quantity that describes, for a given mixture and amount of GHG, the amount of carbon dioxide (CO_2) that would have the same global warming potential (GWP), i.e., the ability of a gas to trap heat in the atmosphere when measured over a specified timescale (generally, 100 years). Some GHGs are more potent than others, as measured by their GWP. Carbon dioxide is the baseline and thus has a GWP of 1.
9. GWP relative to carbon dioxide (CO_2) with a 100-year time horizon and global GHGs per gas, both as per the most recent *Climate Change 2014: Synthesis Report*, Intergovernmental Panel on Climate Change, 2015, https://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full.pdf.

DESIGNING EFFICIENT DATA CENTERS

10. Five out of six of our data centers that have achieved 100% landfill diversion have a current waste-to-energy contribution greater than 10%, meaning they haven't yet achieved Zero Waste to Landfill.
11. According to Google's own analysis of our more efficient servers, power infrastructure, and cooling systems, compared with data center industry averages.
12. PUE is a standard industry ratio that compares the amount of noncomputing overhead energy (used for things like cooling and power distribution) to the amount of energy used to power IT equipment. 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.
13. According to the Uptime Institute's 2014 Data Center Industry Survey, the global average PUE of respondents' largest data centers was around 1.7.
14. At Google, Zero Waste to Landfill means that when waste leaves our operating data centers, none of it goes to a landfill—100% is diverted to more sustainable pathways, with no more than 10% going to a waste-to-energy facility, unless waste to energy can be proved more valuable than alternative diversion paths. Our approach is based on UL's Environmental Claim Validation Procedure for Zero Waste to Landfill.
15. See note 10 above.
16. Fifteen to 30 times over GPUs and CPUs made with an equivalent process technology as the TPU and became available at the same time as TPUs (i.e., in early 2015).
17. TOPS is defined as tera-operations (trillion or 10^{12} operations) per second of computation per watt of energy consumed.

ADVANCING RENEWABLE ENERGY

18. Bloomberg New Energy Finance database for wind and solar energy PPAs, as of December 31, 2016.
19. WRI's market-based Scope 2 methodology requires the use of residual grid mixes, which represent the mix of resources generating electricity in a region after accounting for those designated for specific customers via contractual instruments like PPAs.
20. *Lazard's Levelized Cost of Energy Analysis—Version 10.0*, Lazard, December 2016, https://www.lazard.com/media/438038/levelized-cost-of-energy-v100.pdf.
21. *Medium-Term Renewable Energy Market Report 2016*, International Energy Agency, October 25, 2016, https://www.iea.org/Textbase/npsum/MTrenew2016sum.pdf.
22. *Renewables 2017: Analysis and Forecasts to 2022*, International Energy Agency, October 2017, https://www.iea.org/Textbase/npsum/renew2017MRSsum.pdf.
23. *Renewable Energy Benefits: Measuring the Economics*, International Renewable Energy Agency, 2016, http://www.irena.org/DocumentDownloads/Publications/IRENA_Measuring-the-Economics_2016.pdf.

Endnotes

CREATING A SUSTAINABLE WORKPLACE

24. Neil E. Klepeis et al., "The National Human Activity Pattern Survey: A Resource for Assessing Exposure to Environmental Pollutants," *Journal of Exposure Analysis and Environmental Epidemiology*, 2001, http://www.readcube.com/articles/10.1038/sj.jea.7500165.
25. International Living Future Institute, "Living Building Challenge: Materials Petal," accessed 2017, https://living-future.org/lbc/materials-petal.

EMPOWERING USERS WITH TECHNOLOGY

26. Google emits about 8 grams of CO_2e per day to serve an active Google user—defined as someone who performs 25 searches and watches 60 minutes of YouTube a day, has a Gmail account, and uses our other key services.
27. See note 4 above.
28. The annual carbon footprint of a Gmail user is about 1/80th that of a small business with locally hosted email servers. Larger organizations show smaller, though still impressive, efficiency gains. "Google's Green Computing: Efficiency at Scale," Google, 2011.
29. *Energy Savings from the Nest Learning Thermostat: Energy Bill Analysis Results*, Nest Labs, February 2015, http://downloads.nest.com/press/documents/energy-savings-white-paper.pdf.
30. Environmental Defense Fund, "Natural Gas: Local Leaks Impact Global Climate," accessed 2017, https://www.edf.org/climate/methanemaps.
31. PSE&G, "PSE&G Teams with Google, EDF to Stop Methane Leaks," December 13, 2016.
32. Joshua S. Apte et al, "High-Resolution Air Pollution Mapping with Google Street View Cars: Exploiting Big Data," Environmental Science & Technology, June 5, 2017, http://pubs.acs.org/doi/abs/10.1021/acs.est.7b00891.
33. Environmental Defense Fund, "Mapping Air Pollution with New Mobile Sensors," accessed 2017, https://www.edf.org/airqualitymaps.

APPENDIX

34. Alphabet's fiscal year runs from January 1 to December 31. Unless otherwise specified, reported data is global.
35. GHG emissions are calculated according to WRI's Greenhouse Gas Protocol. For more information on our methodology, see our 2017 CDP climate change report.
36. Since 2010, we've procured renewable energy for our operations, and in 2012, we began publishing how this reduces our overall carbon footprint. Up until 2015, there was no guidance from WRI on how to account for these emissions reductions, so we developed our own methodology, whereby on an annual basis we assigned renewable electricity procured against electricity consumed (in MWh) in the closest data center to the renewable energy project. In 2015, WRI released new guidance for market-based Scope 2 accounting, which we adopted, starting with 2015 data. Our pre-2015 methodology differs from WRI's in the use of residual mixes, which avoid double-counting of claimed renewable energy attributes.
37. We have restated our 2015 electricity and Scope 2 emissions data due to quality assurance improvements in our data collection and calculations.
38. See note 37 above.
39. In 2016, we adopted the industry practice of including only operational emissions in our carbon neutrality commitment. Our 2016 operational emissions include Scope 1, Scope 2 (market-based), and Scope 3 (business travel and employee commuting). For more information, see our 2017 white paper *10 Years of Carbon Neutrality*.
40. Carbon intensity figures are based on our combined Scope 1 and market-based Scope 2 emissions, with the exception of electricity consumption intensity, which is calculated using only market-based Scope 2 at the data centers.
41. Total energy consumption represents total Scope 2 electricity consumption plus total Scope 1 fuel use.
42. See note 37 above.
43. Power usage effectiveness (PUE) is an industry-recognized ratio to measure data center efficiency. For more information on our PUE and how we calculate it, see "Efficiency: How We Do It" on our website.
44. Percentage of renewable energy is calculated on a calendar-year basis, comparing the volume of renewable electricity (in MWh) purchased for our operations (i.e., renewable energy procured through our PPA contracts, on-site renewable energy generation, and residual renewable electricity delivered directly through the grid) with the total volume of electricity consumed by our operations.
45. To align with the method outlined in note 44 above, starting in 2016, we adapted our methodology for calculating total electricity obtained from renewable sources. Prior to 2016, we were not accounting for the residual renewable electricity purchased through grid electricity.
46. Waste diverted to a more sustainable pathway than landfill or incineration without energy recovery.
47. Includes water consumed at offices and data centers.
48. Number of ports for ChargePoint stations in the United States only, which represent the majority of our electric vehicle charging ports in the United States. Emissions avoided are estimated using data from these ports only.
49. In addition to our renewable energy contracts, Google also invests in renewable energy projects around the world that have an attractive risk-adjusted financial return. These projects are not used to offset our carbon footprint.
50. See note 36 above.

Google

ON THE COVER:
El Romero solar farm in Chile (80 MW for Google)

GOOGLE ENVIRONMENTAL REPORT: 2017 progress update
Published October 2017