

Go Green Software



Ctrl+S(ave) the planet:

Make sustainable software choices





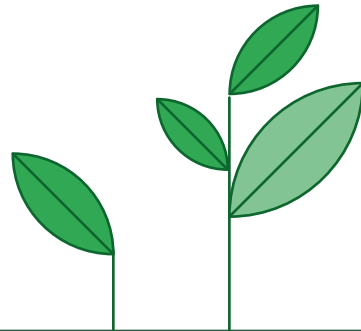
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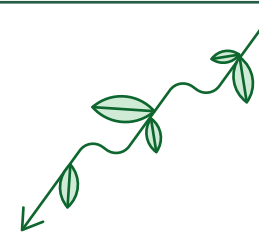


Introduction



The software industry plays a significant role in consuming energy and resources. That's why green software development was created. **It's an approach to software engineering that focuses on energy efficiency and being environmentally sustainable.**

It involves designing, developing, and deploying software that consumes less energy and resources, and has a smaller environmental impact.



This book provides an overview of green software development principles and covers:



The environmental impact of software



The principles of green software development



Tools and techniques for green software development



Green software development project case studies

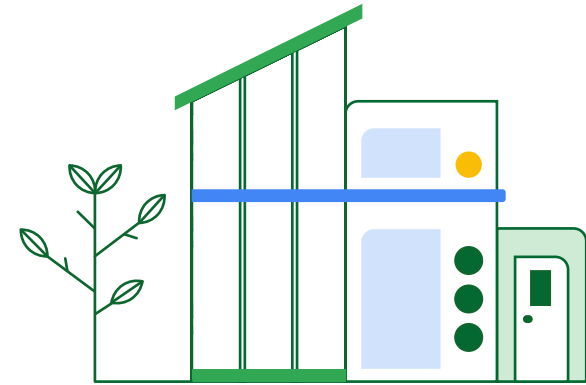
This book is intended for technology users, developers and engineers who are interested in learning more about green software development. It provides the information you need to design, develop, and deploy software that is more sustainable.

By following these **practical and actionable steps, you can help to develop software with the planet in mind.**





Why should businesses care about sustainable development



Businesses who produce physical products have been adopting **Environment Science and Pollution Research (ESPR)** since the first publication in 1995. The five ESPR, **Durable, Reusable, Repairable, Recyclable** and **Upgradable**, approach can be applied to physical and software based solutions. Below outlines the five ESPR for a software engineer or software developer.



Durable: Software can be made more durable when you use open-source code. It's owned by a community, hence the chance of it becoming outdated or unsupported is low. **Choose open source for a more durable solution.**



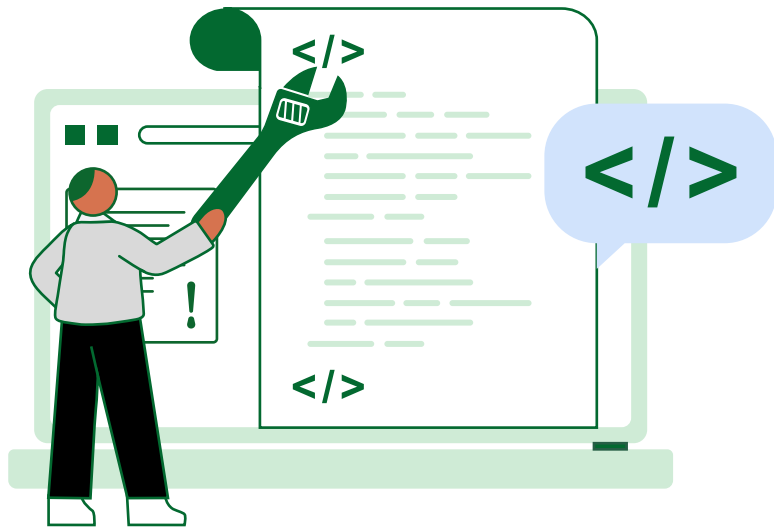
Reusable: Software can be made more reusable through common APIs, micro services or data as a product. **Companies that invest in platform services can guide users to a small number of reusable services.**



Repairable: Software can be made more repairable by using modular design (e.g. microservices). **Modular design allows developers to create software that can be easily updated or repaired.** This means there is no need to replace the entire software system when a problem occurs.



Recyclable: Software can be made more recyclable by **considering the CO₂e impact through CI/CD processes.** Imagine if every developer, devops, MLops team considered the reduction CO₂e each time a component is changed.



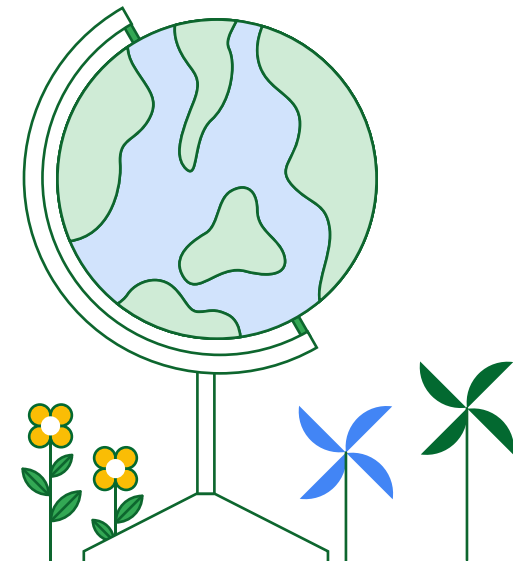
Upgradeable: Using managed services from cloud provides the ability to be part of a large community of users meaning upgradable is considered for everyone and does not get missed. Tech debt or legacy out of date software is a big aspect of increased emission. Imagine someone else refactoring for your organization within the cost of a managed service.

It is possible to align with the physical world. Using aspects from this guide will help reduce your carbon emissions.

Currently large organizations need to report their carbon emissions using global frameworks e.g. “Greenhouse gas emissions protocol”. Software and applications contribute to these carbon emissions. Taking proactive steps can reduce greenhouse emissions and this set of principles have been created to enable the process to accelerate; a secondary factor exists which is reducing energy consumption especially in Europe.

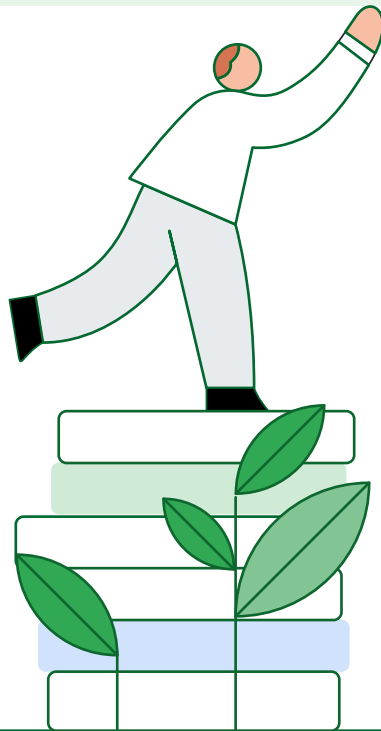
Green technology has been used for a number of years (e.g. TPU that was invented in 2015 to reduce compute time) as a key capability within Google and for our customers.

On average, a Google-owned and -operated data center is more than 1.5 times as energy efficient as a typical enterprise data center and, compared with five years ago, we now deliver approximately three times as much computing power with the same amount of electrical power ([Google’s Environmental report](#)).



What is Google's sustainability strategy

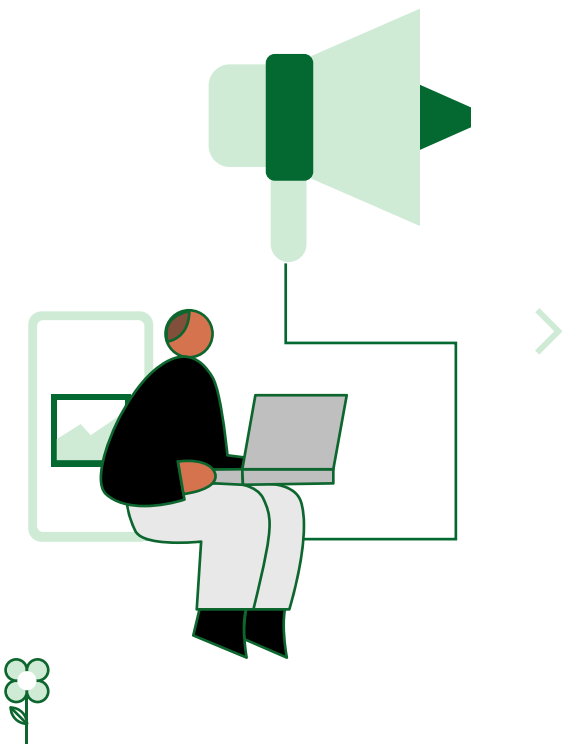
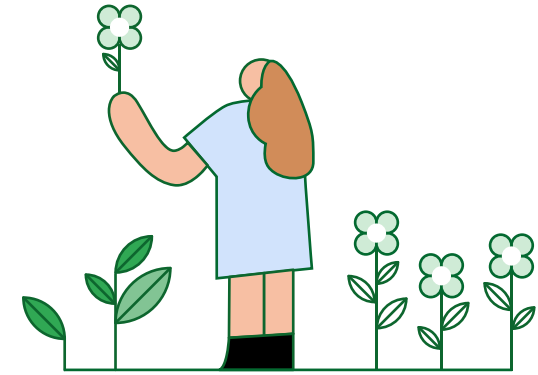
At Google, we remain committed to sustainability and continue to lead and encourage others to join us in improving the health of our planet. **We are committed to achieving Net Zero by 2030** and the way we structure our sustainability work is in 3 pillars:



Operating our business sustainably: We always start with how we can operate our business more sustainably. It's our responsibility — and it's also the best way to **innovate, iterate, and share best practices with others**. We have committed to operating on **carbon-free energy 24/7 by 2030** and we're constantly pursuing new carbon-free energy generation and storage technologies while working with governments, utilities, and policymakers to deploy those technologies and drive system-level change. By supporting public policies that advance robust global climate action, we create **pathways to a carbon-free economy**.

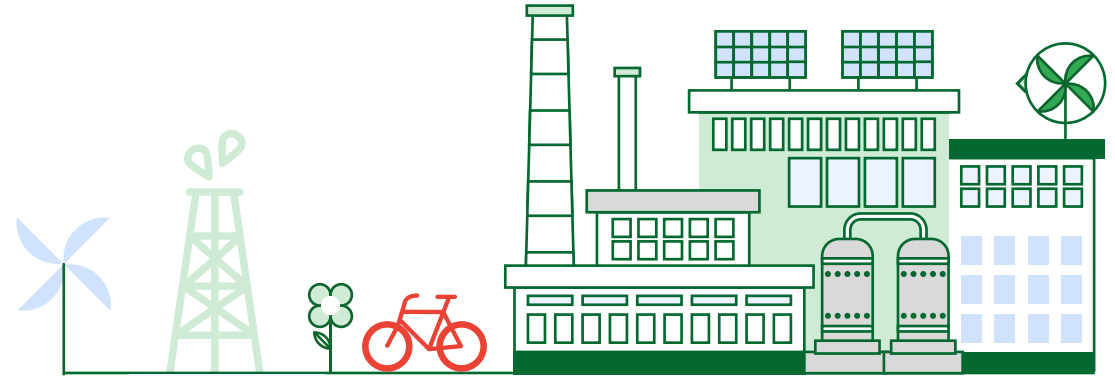
Working together with our partners and customers:

Empower partners (nonprofits, researchers, policymakers, enterprise customers etc.) with **the tech they need to scale up carbon solutions**. Our impact is far greater when we share technology, methods, and funding to help organizations everywhere transition to resilient, carbon-free systems.



Empowering individuals to take action: Through our products (core products, consumer hardware), we offer helpful ways for everyone to be part of the solution. **Collectively, individual actions can make a big difference.** At Google, we're continuously developing products and technology that help support everyone on their journey to a more sustainable life. In addition, **sharing knowledge, experiences, and lessons learned on the path to sustainability**, is always a great way to improve people's collective intelligence. This involves the **rapid adoption of existing climate solutions to reduce risks and adapt to climate effects everywhere.**

Linking sustainable development to corporate strategy



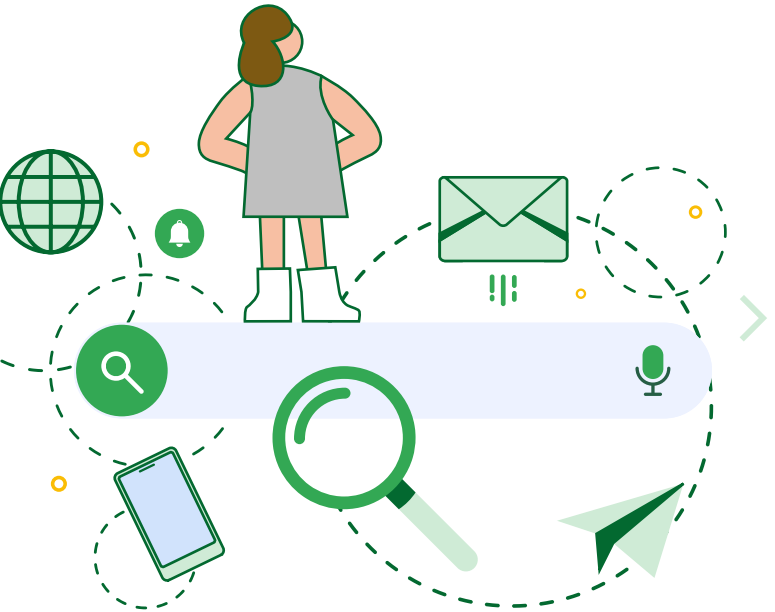
Although sustainability is not a new topic, there has been a dramatic shift in attention and focus over the last 20 years from businesses, consumers and governments. Climate change and the continued failure³ to meet carbon reduction policy targets has led to **growing concern about irreversible environmental damage for generations to come.**

Over that 20 year period, businesses have increasingly taken on responsibility for their environmental impact. Corporate sustainability has become imperative if organizations seek consumer and brand approval, and want to remain competitive.

In turn, corporations are slowly understanding the critical relationship between a sustainable business strategy and long-term stakeholder value. If businesses operate sustainably, these establish foundations for long-term corporate success⁴.

So where do we stand today? A 2022 publication by the World Economic Forum⁵ estimated only 60% of organizations have a sustainability strategy plan in place. While this is an all-time high, there is still room for improvement.

Below are some of the reasons why organizations have already seen the value of a sustainability strategy, or their motivations to consider one soon:



Brand image and changing consumer attitudes: Around 75% Gen Z consumers, who are increasingly the dominant addressable market, have eco-conscious buying habits. **To stay relevant, businesses are embedding sustainability into their corporate strategy through public tracking commitments of carbon emissions.** Hence educated IT teams are critical in developing software that’s natively green or migrating to green. Businesses have seen a competitive advantage and growth opportunities in publicly sharing with their customers their sustainability practices.



Investor pressure: Sustainability topics are making it to board rooms due to investor pressure as ESG (environmental, social and governance) factors are being incorporated into investment strategies. Companies with inadequate sustainability measurement and reporting are seen as risky investments. **Over 90% of S&P 500 companies publish ESG reports.**

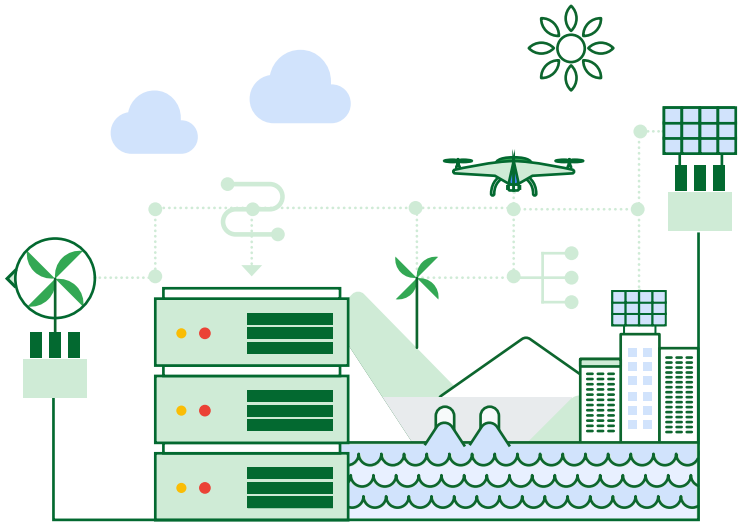


Regulations and legal risk: There has been a more than **38-fold increase in environmental regulations around the world since 1972.** Businesses need to be informed of different regulations around the world to operate such as the EU Taxonomy Regulation.



Increase efficiency and innovation: There is a correlation between an efficient company's resources management and cost reduction which is often fueled by innovation. A **McKinsey study** found that businesses that focus on green operating practices, increase operating profits by 60%.

When it comes to the technology industry, we are predominantly in **phase one - Greening of IT**. This means that most businesses are currently focused on reducing the immediate impact of IT operations and lowering associated emissions.



We believe **phase two is Greening by IT** which means using IT innovation to reimagine solutions and business models to be more sustainable which has been already demonstrated successful by some companies.

It is in the **Greening By IT** phase that we see green software development principles coming to the forefront. Where there is a choice to engineer in a more sustainable way, we expect that technology leaders will look at this more deeply to consider how they can meet their business sustainability strategies.





Software development goals

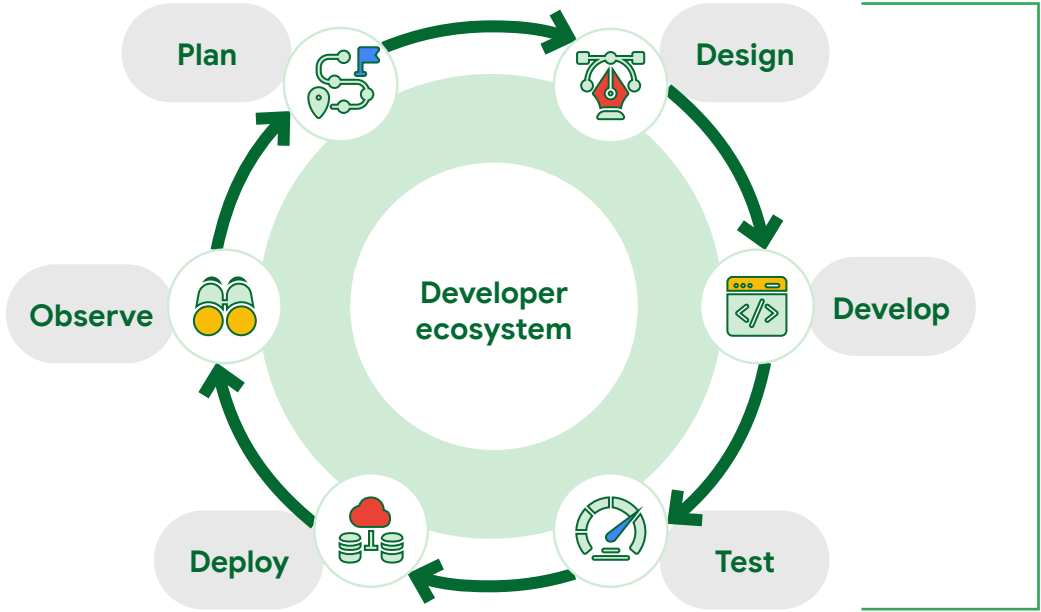


The software development process requires complex, cross-functional collaboration while continuously improving products and services. The overarching goal of sustainable software development is to bring sustainability into the technology delivery by making software products as carbon-efficient and carbon-aware as possible while reducing energy needs of technology.

Carbon-efficiency covers all aspects of the technology ecosystem to optimize the carbon footprint. Carbon-awareness has the goal to change the behavior of the software, its engineers and users to reduce the emitted carbon. In a recent article⁶ by Gartner, **environmental sustainability increased in 2021 to 2022 by 292% to become one of the top 10 focuses.** Both carbon-efficiency and carbon-awareness have various factors and drivers that are typically influenced by different software development lifecycle methodologies and the personas working on delivering IT capabilities.

The World Economic Forum believes digital technologies⁷ could **reduce emissions by 20% by 2050** within energy, materials and mobility sectors.

Consider in parallel we developed green software that was optimized through the lifespan of a solution. Customers have already started re-architecting cloud solutions with some adoption of green tech principles, measuring carbon emissions before and at the end of the transformation process. These metrics show a **reduction in cost optimization and CO₂ emissions of up to 30%** (the percentage could be higher for those architectures migrated from on-premise data centers to the cloud).



We see the typical end to end CI/CD pipeline and within each area there is 3 focus areas:

- Reducing carbon emissions
- Use techniques and tools to identify positive or negative impacts
- Aligning carbon reduction approaches to development lifecycle

Carbon-efficiency

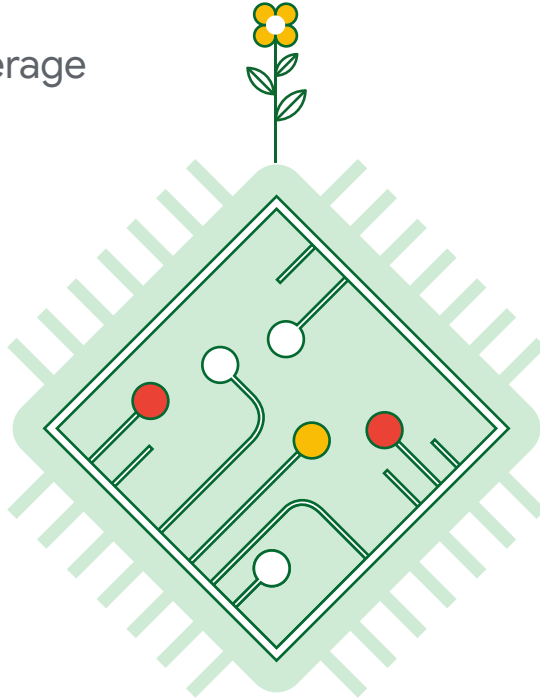
Carbon-efficiency is determined by many factors. Generally speaking: Software has **four key areas** that impact the carbon footprint; over the course of the subsequent sections we will go through the impact these have.

- CPU utilization
- Grid carbon intensity (gCO₂eq/kWh): This metric indicates the average operational gross emissions per unit of energy from the grid
- Resource consumption itself
- Network emissions

Carbon-awareness

Carbon-awareness is broken into **three approaches** that provide clear awareness of the impacts of efficiency.

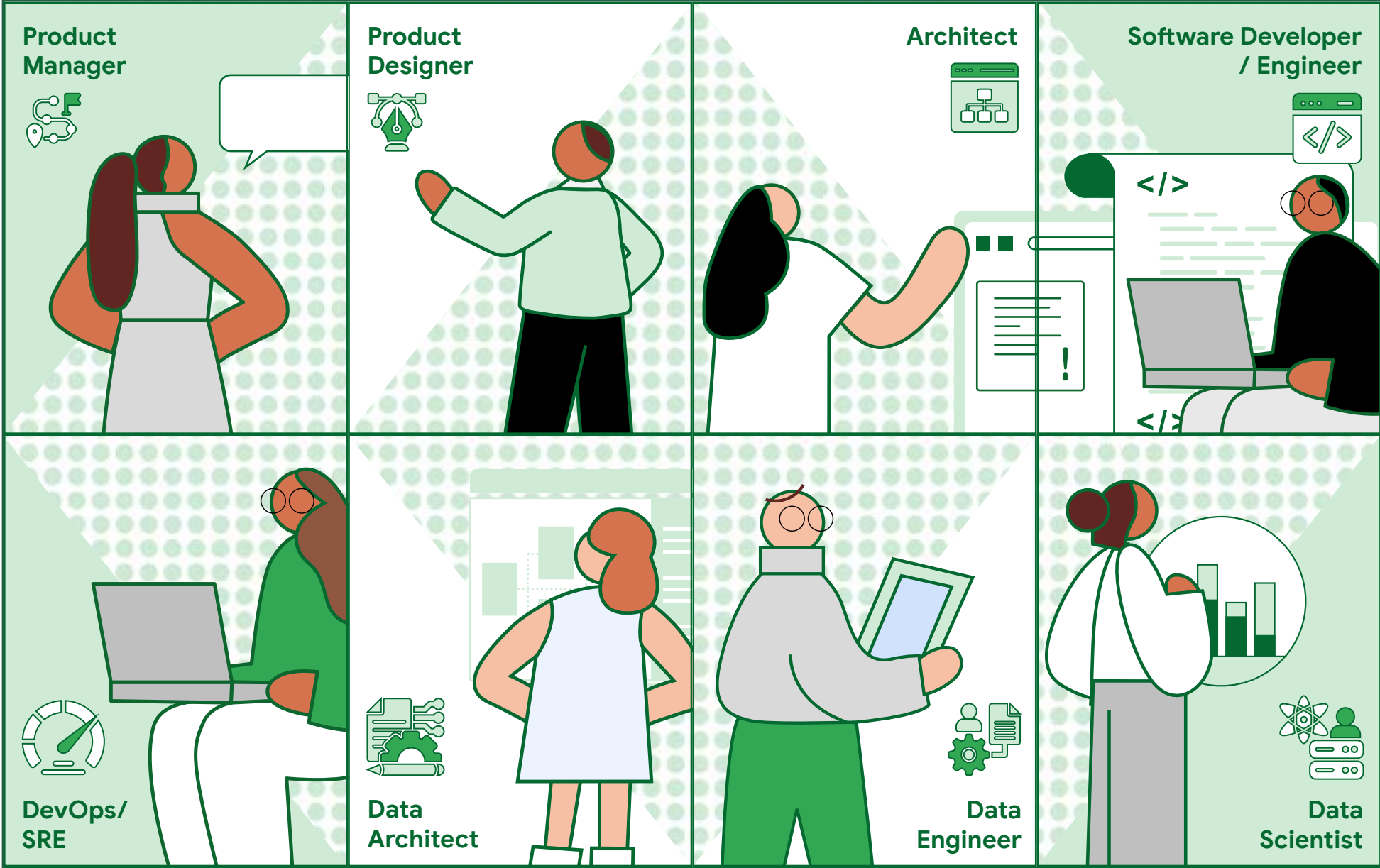
- Educate through Carbon Equivalence⁸ to real world information
- Inform using data on usage of technology
- Observe the impact and reduction impact



Introduction to approaches and personas

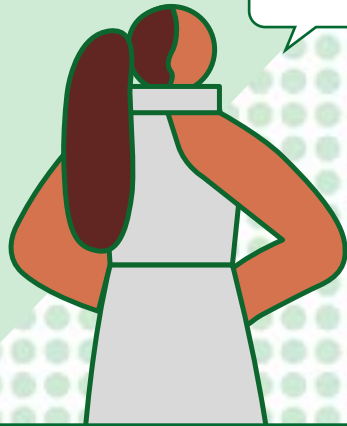
When considering green software approaches this breaks into two domains the first being the system/application life cycle or the specific technology personas. Through discussion with various teams, customers and individuals it was clear to focus on the persona. So this section is broken down into **common personas in the technology space and public cloud focus.**







Product Manager



During the life of a product the emissions and energy usage changes, especially with roadmap changes. **Product Managers should consider the carbon emissions during the life of a solution and validate the expected emission changes like any other change.**



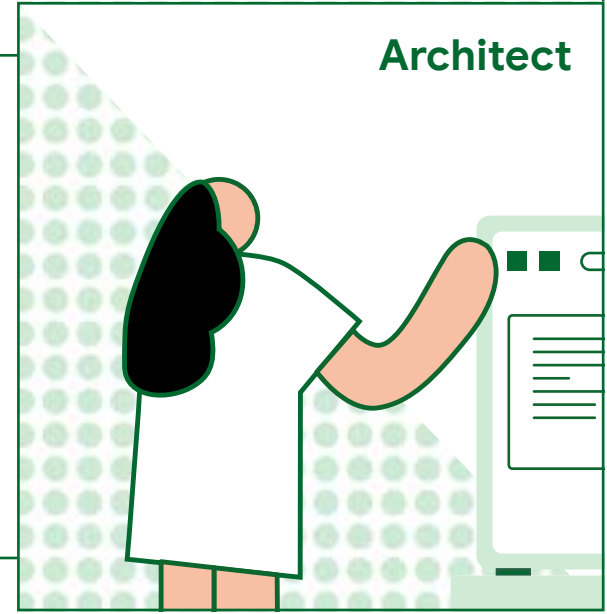
Product Designer

Product designers can reduce digital products' carbon footprint by implementing green design practices such as using system fonts, choosing darker colors, creating reusable design components, and serving only essential content. By optimizing content strategy, minimizing energy usage, and reducing loading times, **designers can create user-friendly and environmentally conscious products.**



Architect

An Architect of a solution considers high availability, disaster recovery, scalability and performance. **But it is equally key to define the architect goals of emissions and energy usage.**



Software Developer / Engineer

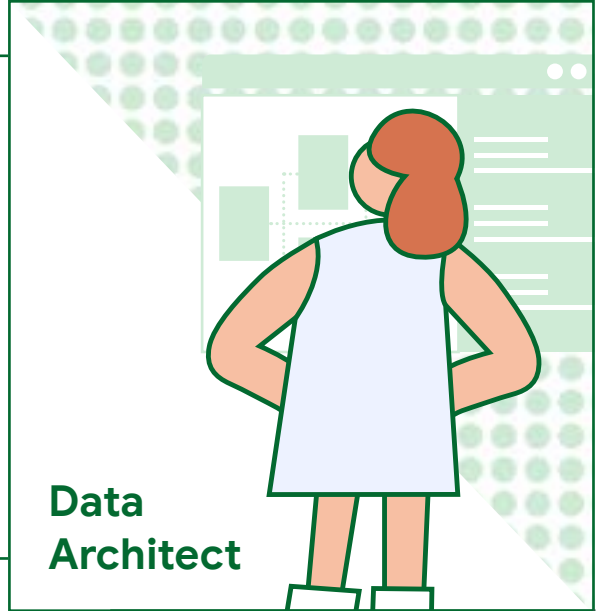
Every code or system aspect impacts the emissions or energy usage. Every developer needs to write optimized code that uses the most efficient approach. Each modification or change can have a dramatic impact, one of the core Google approaches is reducing code or complexity removes risk, maintenance cost and now emissions.





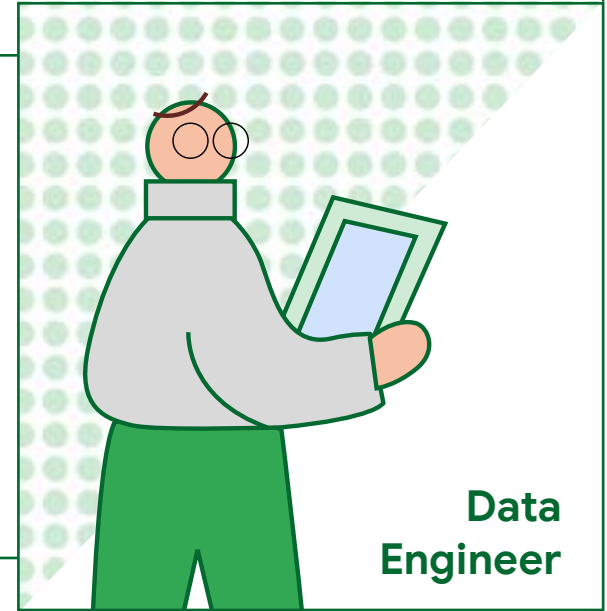
Within the operational environment, there is a responsibility to reduce emissions. As the system grows, it is essential to have sustainability targets for the system. **Especially important is setting observability targets for emissions as now it is possible to view using carbon footprint data.**

Data platforms often have high energy consumption, especially monoliths that store large amounts of data, due to inadequate governance and strong coupling between storage and computational layers. **The Data Architect plays a key role** in designing and modernizing data platforms to make them sustainable, reduced energy demand and emissions impact.

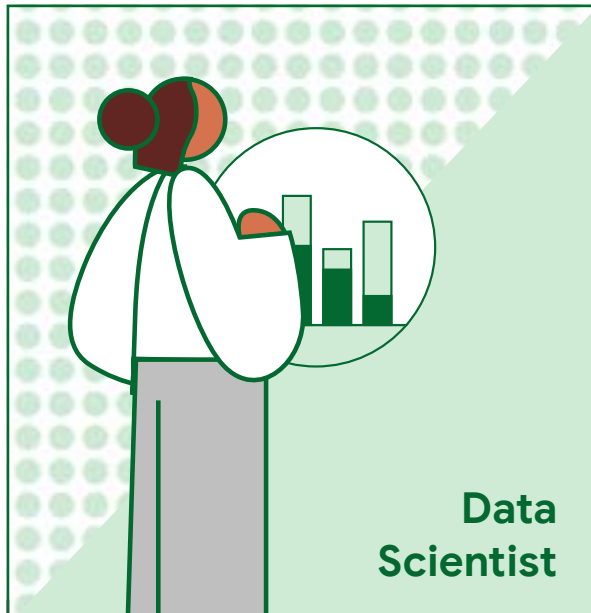




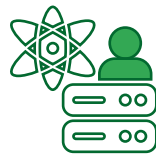
Data and data life cycle management has a big impact on companies' emissions. The Data Engineer can use different storage techniques to remove the emissions for example moving from high performance to high density storage.



Data Engineer



Data Scientist



Every piece of data research has emissions and the Data Scientist needs to consider this in any research, data exploitation that is performed within the system. Every machine learning process has emissions, the choice of where, when and how they are executed can have an impact.



As can be seen in every role, there is a consideration around sustainability, emissions and energy usage; no one role is exempt from emissions. **Even if your role is missing, there are aspects of all the roles that can be applied to everyone who has a direct or indirect connection with technology.**



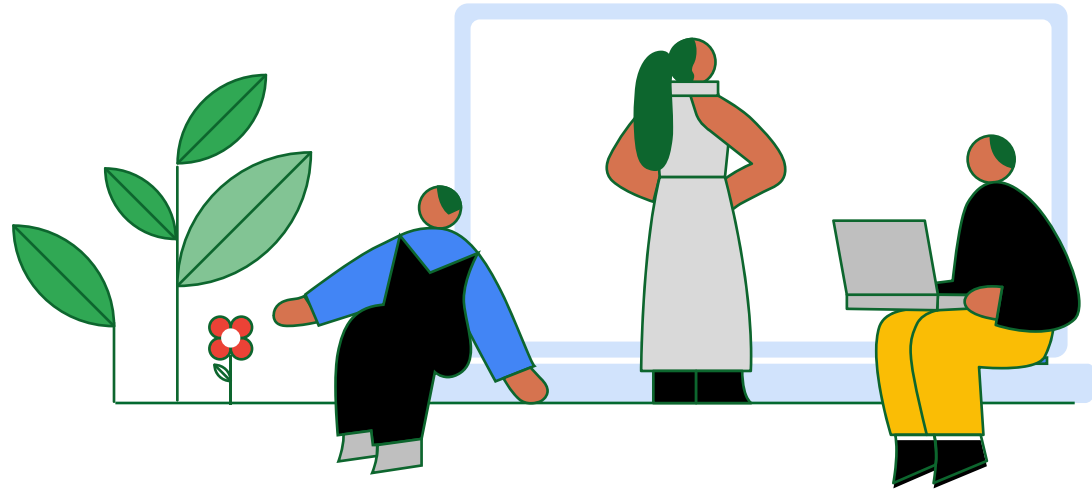
Sustainability is top of mind for executives around the world requiring new approaches to all aspects of business. CTOs, CIOs and engineering leaders play a significant role in identifying and deploying the digital technologies necessary for the sustainability transformation, while ensuring the use of these technologies is itself sustainable. Modern developers must have the tools and data necessary to follow green software principles and build sustainably.

Jen Bennett

Senior Director, CTO office, Sustainability, Google Cloud



How can you get started now



This document was created to enable everybody in software-related roles to improve the sustainability of the entire lifecycle of tech products. It is far from being complete and some introduced best practices might not lead to a short-term improvement. Nevertheless, **the most important aspect is awareness and education. Change is driven by people,** and as more people know about such practices, more will start to execute on it.

But, after all these practices and principles, the biggest question remains unanswered: **Where to start as an organization?** The practices above demonstrate many concrete starting points, but beyond these there are other pillars where organizations can accelerate their sustainability transformation journey.



Strategy: Sustainability needs to be part of every company's strategy, not only for the ones with a high scope 1 or 2 emissions. Strategy doesn't have to follow a top-down approach. Especially for sustainability, the push to adapt or shift strategies often comes from the bottom.

Start by brainstorming how your strategy needs to change to become more sustainable.



Sustainable product design: In the early chapters of this document the five principles of sustainable product design were introduced that are coming from a circular economy way of thinking: **Durable, Reusable, Repairable, Recyclable and Upgradeable**. Often, people in the software business don't consider these principles as relevant, but there are many examples where they perfectly connect (e.g. building code that is reusable, using hardware that is upgradeable). Every SW product team should think about these principles and how the greenest version of their product could look like.

Start by brainstorming how your product could adopt the five principles.



Culture: Every organization has people that deeply care about climate change and the long-term effects and challenges. These people are the catalyst for opening up a deep cultural push to make sustainability part of a company's DNA. A great starting point is Employee Resource Groups (ERGs) for sustainability. In these groups, like-minded people can share their thoughts, gain more knowledge and insights about green topics and discuss how the company as a whole can evolve.

Start by founding an sustainability employee resource group.

Adopt *Sustainability by Design* approach meaning that any product, small or large workload, cloud architecture, data platform must be designed or optimized with the impact of emissions on the environment in mind.



Education: Tech professionals are able to impact a significant amount of energy, which is used day by day during their jobs. That is where everybody in an organization, independent of their role, needs to get familiar with what they can do in their job to become more sustainable.

Start by setting up training sessions to educate people about green software practices.

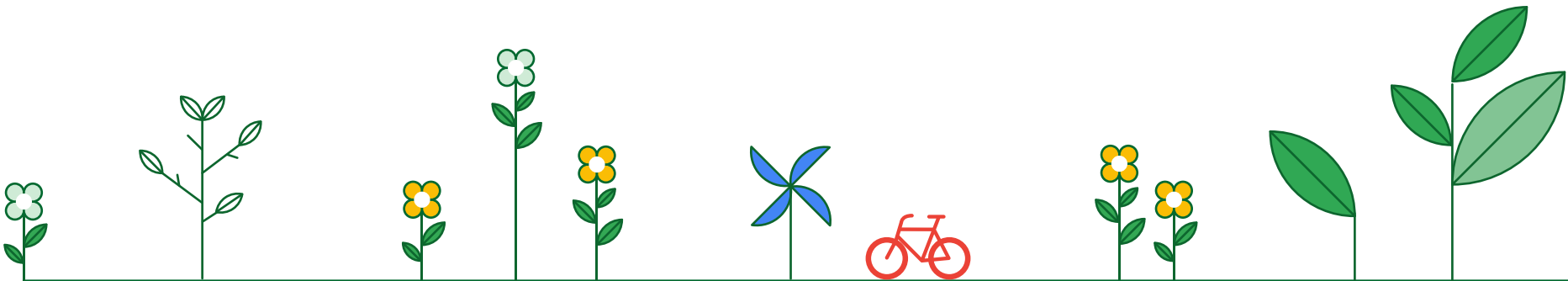


Data foundation: Any journey of optimization starts with a baseline. In terms of sustainability, a data foundation containing insights into current emissions provides this. Often this data needs first to be collected and organized at an accessible point.

Start by organizing a data foundation with sustainability data for the company.

Measure is key, start by measuring the carbon footprint of what you have already implemented and track all the changes applied during the sustainable transformation journey, to get real data of your actions' impact.

The essential answer to the question where to start is: “**start somewhere**”. Even if the first step is tiny, it is a step into the right direction to a livable and more sustainable future, because all actions matter, all contribute to achieving a major change mindset.



Footnotes

- 1 [Greenhouse Gas Protocol](#)
- 2 [Google: Our data centers are now twice as energy-efficient as a typical enterprise facility](#), siliconANGLE, February 2020
- 3 [Sixth Assessment Report](#), IPCC, March 2023
- 4 [ESG and Sustainability: Your 101 Guide for Understanding Corporate Sustainability](#), Green House Bureau, November 2021
- 5 [Why sustainability is crucial for corporate strategy](#), World Economic Forum, June 2022
- 6 [CEOs Turn a Sharp Eye to Workforce Issues and Sustainability in 2022-23](#), Gartner, April 2022
- 7 [Digital solutions can reduce global emissions by up to 20%. Here's how](#), World Economic Forum, May 2022
- 8 [Greenhouse Gas Equivalencies Calculator](#), United States Environmental Protection Agency

Acknowledgements

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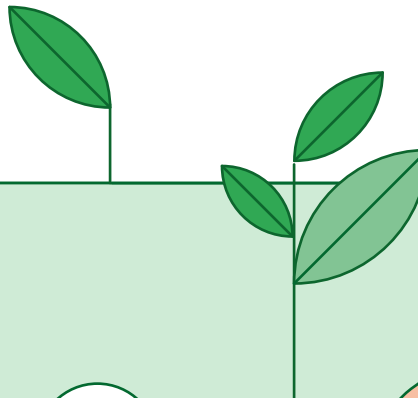
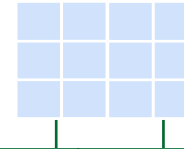
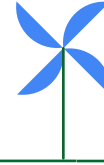
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