

The Tech Professional's Guide to Sustainable Computing

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Introduction: A Call to Action

The world's online computing is straining power and water supplies and generating outsized greenhouse gas emissions. Data centers demand enormous amounts of electricity from fossil fuel power plants that in turn emit carbon dioxide, and the cooling systems for their IT equipment deplete fresh water. Moreover, data transmission networks and laptops, phones, and workstations double the resource and emissions impacts of online computing while adding to e-waste.

Many decisions about applications, cloud usage, and other online computing do not take environmental resource impacts into account. But each cloud migration, application design, and configuration decision either compounds our problems or reduces them. The skyrocketing growth of GenAI only intensifies the impacts on our environment because its resource demands are as much as 10 times higher than for other applications.

If technology professionals don't make changes to their business as usual, online computing's growth will continue to accelerate climate change, deplete water and power resources, and damage life in our communities—making business operations and environmental restoration more difficult.



Making the transition to sustainable computing requires time and resources, but it also brings down costs, lengthens workforce tenure, and creates profitable customer relationships. There is another reason to do it: runaway demands on data centers and power are outpacing the construction of new facilities, leaving organizations facing higher bills and potential service limitations. Forward-thinking organizations with efficient and energy-aware technology operations will avert expensive last-minute problems.

Information technology professionals need to embed sustainability considerations into every application, decision, and work process. **We need to assume responsibility for the impacts of our work on our community and environment.** Sustainable computing is ultimately about a shared vision and it is up to us to take action.

The Problem: Resources and Environmental Impacts

The Vast Impact of the World's Data Centers

The importance of reining in the growth and environmental impact of online computing stems from its excessive power and water consumption, greenhouse gas emissions, pollution, and community impact.



Power Consumption

Online computing uses enormous amounts of electricity: from users' laptops and workstations, to data transmission, to the data centers that power the applications and storage we call the cloud. Data center power demand is growing much faster than new power can be supplied. Globally, electric utilities are racing to expand supply by extending and building fossil fuel plants—increasing the carbon intensity of our electricity supply.

Water Consumption

Data centers draw enormous and unquantified amounts of drinking water for equipment cooling systems. They also use water indirectly from electricity use, since power plants also cool with water. Many data centers are located in water-stressed regions where solar power is plentiful and land is affordable, causing strain on limited drinking water supplies.

Carbon Emissions

The worldwide computing infrastructure generates enormous amounts of greenhouse gas emissions from power and water use. As data centers and cloud usage expand, their atmospheric pollution grows, with chemicals that are unhealthy to breathe and cause harmful climate impacts.

Pollution and Communities

Only 22% of the laptops, computers, servers, and networking equipment used in cloud computing are recycled, and 43% of data centres have no e-waste handling policy.²³ Equipment turnover increases heavy metals in soil and water from dumping, and missed opportunities to reclaim gold, copper, and lithium. At the same time, data centers make communities less livable by adding noise, unsightly development, and uncertain supplies and bills for water and power.

Our Responsibility

Our industry does have positive environmental actions to be proud of. Large technology companies are the world's largest purchasers of clean energy, many manufacturers take back and refurbish their products, and much of the economic transformation our industry created has replaced polluting business activities. But the fact remains that online computing is driving an unignorable worsening of our environment and communities. It is our responsibility to adopt sustainable computing.



A Sustainable Computing Example: Before and After

Before

Here is a fictional company called InsuranceCo. They have an underwriting application that runs on a data center, with tech teams and underwriters working with it. To serve one user for one day, their cloud-based application generates carbon emissions totaling 1,200 lbs—the same weight as a grizzly bear. If the team that designed and operated this app made sustainability adjustments, they could drop carbon emissions total by up to 70%. This level of impact represents a tremendous opportunity to make a difference.



After

Let's return to the invented example of InsuranceCo and their underwriting application. There are some sustainability changes they could make in just a few months with vauluable results.⁴

Rescheduling Workloads

- The electricity grid in the location where the InsuranceCo app runs on a data center has the most clean energy at 2pm.
- Changing flexible computing activity to 2pm instead of 6pm reduces carbon emissions by 11%.
- Electricity Maps gives information on the carbon intensity of grids. (<u>app.electricitymaps.com/map/</u> <u>all/monthly</u>)

Moving Data Center Location

• The grid in some locations is cleaner. Moving the app from Virginia to Oregon reduced emissions by 17%.

Carbon–Aware Scheduling

- Using a scheduler that tracks clean grid time windows, more of the apps runs with lower emissions.
- Computing jobs running at cleaner times brought another 12% reduction in carbon emissions.
- Green software tools including carbon–aware schedulers are on <u>https://cloud.sustainability.</u> <u>watch</u>



Green AI Design

- Plans for AI features can be adjusted to minimize power consumption by using a smaller model in place of a large, general purpose model.
- Balancing resource demands as a consideration can lead to only using Al for 2 features instead of 7.
- Other AI sustainability choices are designing for minimum data storage, frequent dark data removal, service architecture, among other things.



Practitioner's Tip: "Remember: every optimization counts, and collective small actions lead to significant environmental impact. Start today with whatever resources you have available, and build from there."

Guide to Sustainable Computing

Tech professionals are transitioning their organizations to sustainable computing. The process combines organizational change guidance with technical implementation steps to reduce environmental impact while improving business outcomes. The mission is to build a "business as usual" sustainability focus in a motivated and committed IT organization.

This guide is the reference that tech professionals need to succeed in transitioning their organizations to sustainable computing practices. The commitment and leadership to make that happen are the X factor that determines success.

Sustainable Computing Guide	1	Light the Spark Create an understanding of sustainable computing and build interest in the mission
	2	Start Simple Make measurable improvements quickly and easily
	3	Build a Complete Approach Build sustainability into the organization and the computing environment.

Light the Spark

To light the spark of adopting sustainable computing, start by learning and sharing important information about green software practices. Once a small group of interested people understand the principles of green software design, green IT, and green devops, they can discuss what might work for them. And being able to share reasons why sustainable computing is good business and how everyone can play a role in it makes brainstorming about a "new normal" more engaging. Here are four introductory topics to help get the conversation started:



Practitioner's Tip: "It doesn't need to be perfect. Begin with whatever data you can access and build from there"

Business Benefits

What are the benefits of sustainable computing to the bottom line? Companies with recognized sustainability practices benefit from more revenue opportunities, cost reductions, and organizational improvements. It can be useful to share some of this information with colleagues in discussions of how much time and money to devote to sustainable computing.

Cloud Hosting Expense Reduction	There are enduring savings from buying less computing and storage services from your cloud provider. This is the biggest financial benefit of sustainable computing.	
Meaningful for Tech Professionals – Especially Early Career	Survey results show that the majority of global tech professionals prioritize sustainability and are shifting toward environmental values. They respond more to personal commitment than to costs or company metrics. ⁵ Research demonstrates the importance of values alignment and sustainability are even more pronounced for the generation just starting their careers. ⁶	
Premium Pricing Opportunities	Demonstrating sustainability offers premium pricing opportunities. Surveys show that 80% of consumers will pay a 10% premium for products with minimal environmental impact. ^{7 8}	
Customer Loyalty	yalty Research confirms that the public are more likely to do business with companies with a credible sustainability reputation because they see those firms as ethical and reliable. ^{9 10}	
Cost-Effective Preparation for ESG Reporting	Companies with verifiably green computing operations have lower carbon emissions and improved emissions reporting, making them better partners for customers that prioritize ESG. In addition, a demonstrated commitment to sustainability forges stronger partnerships across the value chain.	

Green Computing Practices 😰

Green computing practices minimize the negative environmental impact of computing operations by conserving water and power, minimizing carbon emissions, and avoiding pollution and e-waste. There are organizations publishing and teaching on green information technology principles for software design, devops, data center management, and more. The principles are:



Learn More:

Linux Foundation's free 2-hour Green Software Class

(https://training.linuxfoundation.org/training/green-software-for-practitioners-lfc131) Green Software Foundation's free practitioner class (https://learn.greensoftware.foundation) Inco Academy's free Green Digital Certificate (https://greendigitalcertificate.inco-group.co)



Every function plays a role in reducing carbon emissions and resource consumption. Here are the ways the team succeeds as a whole:



DevOps

Optimize cloud set-up and operations and enable carbon awareness



Developers

Write energy-aware and resource-conserving applications that minimize carbon emissions end-to-end



Architects Define goals of reduced resource consumption and carbon emissions



Database engineers Implement storage optimization and reduce the high energy consumption of data storage



QA Teams Streamline testing procedures and evaluate sustainability implementation



Senior leadership Commits resources and sets targets to prioritize sustainable digital services.

Learn More:

Sustainable IT, Green Software Foundation, Green Web Foundation, Sustainable DevOps, The Green Grid

Common Hesitations

Asking people to change their work process raises concerns and presents challenges. The study of how to inspire people to change is a large field that identifies some predictable hurdles. Knowing what problems might arise allows for some advance planning and reflection that can make the change process more comfortable.





Technical professionals who have succeeded in leading their colleagues through a transition to sustainable computing recommend building some simple metrics and sharing the results, which will gather attention. They also suggest community-building actions to create a committed group of supporters. In addition, there are opportunities for simple climate action.



Here are the areas we recommend considering as starting points:

Build a Cohort 🛄

What are the benefits of sustainable computing to the bottom line? Sustainable computing success brings revenue opportunities, cost reductions, and organizational improvements. It can be useful to share some of this information with colleagues in discussions of what time or resources are worth devoting to sustainable computing.

Find a way to informally engage colleagues who are interested in the environmental impact of their work. There will be quite a few. There is increasing press coverage of problems with data centers, while for years groups like the Green Software Foundation have been developing principles of sustainable information technology. Try these small steps to build a cohort that will eventually lead change:

- Talk with engineers and managers interested in green software design and engage them in brainstorming and feedback sessions to build momentum
- Start a thread on discussion platforms such as Slack or a company wiki
- Share articles and ideas to prompt discussion about how to implement green principals
- Invite participants to share lunch or set up a regular meetup to informally share learning
- Encourage interested colleagues to take a class in green computing and even offer seminars

Create Simple Metrics **2**

Seeing real numbers motivates tech professionals to learn more and do more. Power consumption and carbon emissions from computing operations are measurable with existing data sources or with the assistance of simple tools. Here are some ideas:

- Estimate carbon emissions using Green Algorithms (<u>https://calculator.green-algorithms.org</u>)
- Add a lightweight carbon tracking tool such as Carbon Aware (<u>https://carbon-aware-sdk.greensoftware.foundation</u>) or Green Metrics (<u>https://metrics.green-coding.io</u>)
- Use carbon emissions reports from cloud hosting providers based on past usage
- Make the data relevant for colleagues by including an equivalence such as "same as driving X miles in a gas car." The EPA Equivalency Calculator provides useful benchmarks (<u>https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator</u>)
- Organize a sustainability hackathon for building simple metrics. Leverage green software tools that estimate power consumption of hardware, or emissions of public cloud usage, or predict energy consumption of model training.

With a core group of people building and talking about sustainable computing, it can be useful to adopt the Software Carbon Intensity (SCI) metric, standardized at the W₃c in 2024.

	1	A metric for tracking and measuring the rate of carbon emissions from a software system.
Software Carbon Intensity Metric:	2	A framework for enabling power and carbon awareness in systems
	3	A definition for how to calculate and track the GHG emissions from design, development, and use

Learn more:

Cloud Sustainability Watch listing of green coding tools (<u>https://cloud.sustainability.watch</u>)

Select a Cleaner Cloud Location 👪

Cloud services run nonstop, and over time even small cloud operations can emit large amounts of carbon and consume excessive amounts of power and water. Moving a cloud instance to a cleaner and more efficient data center can make a big difference.



Every data center uses the electricity that comes from the local power grid–carefully evaluate claims of 100% renewable or low-carbon power. Find a location with a clean electrical grid by checking it on Electricity Maps (https://app.electricitymaps.com/map/all/monthly)

Learn more:

Cloud Sustainability Watch's Cloud Hosting Selection advice at https://cloud.sustainability.watch

Practitioner's Tip: "Start a green software Slack channel to share articles and promote discussion. Run learning sessions to introduce green software and encourage people to do the Linux Foundation's Green Software course. It's free and takes two hours!"

Reschedule Flexible Workloads 🍊

There are opportunities for simple climate action in making adjustments to your applications in the cloud. Jobs that are not time sensitive can run at times when the electricity is clean. Find out the location of the data center where your flexible jobs run, and look up the grid carbon intensity on Electricity Maps (<u>https://app.electricitymaps.com/map/all/monthly</u>). Is there a time of day when the power is cleanest? Reschedule the jobs to run at that time.

"Green" a New Project Plan 🚺

Study Green IT principles or take the free Linux Foundation green software course to gain ideas about changes that might apply to a project that is in the planning phase. Make suggestions that will improve the sustainability characteristics of the application. Try an emissions modeling tool such as <u>Green Metrics Tool</u> that enables predictive comparisons of the emissions and power consumption for one software application versus another.

Practitioner's Tip: "Including sustainability metrics in upcoming projects is a good approach to trying out green software development without disrupting an organization."

Make the Wins Visible 6

Build momentum for sustainable computing by sharing data regularly. The more people see real–world data, the more they think of ways to make their work more sustainable. Here are some ways to do that.



Build a Complete Approach

The transformation to sustainable computing extends to every function, and there are green principles for every role. There is also an essential shift in organizational culture when sustainability becomes a consideration on par with reliability and delivery deadlines.



Make Sustainability Reviews Routine

Make sustainability a routine part of work processes and planning by making it part of the standing agenda at regular meetings. Projects could all have a Software Carbon Intensity (SCI) score included. Add a few questions, such as:

- What was the SCI for this application before and after this revision?
- What is the carbon awareness built into this code?
- Are we using hardware most efficiently, and can we extend the life of the hardware we are using?

Adopt Green Software Design 😰

Integrate sustainability into the software development life cycle:

Development Practices

- Review and optimize CPU-intensive operations
- Eliminate redundant code, computations, and API calls
- Minimize data transfers with compression, caching, and CDNs
- Eliminate unnecessary data creation and storage
- Choose lightweight libraries and energy-efficient frameworks and languages
- Shut down inactive dev systems to eliminate idling

Testing and Deployment Strategies

- Test sparingly and eliminate redundant test steps
- Use energy-efficient testing environments
- Parallelize tests to reduce pipeline runtime
- Shut down inactive test systems to eliminate idling
- Track efficiency metrics

Green Software Design Culture

- Add power and carbon emissions metrics to development dashboards
- Establish end-to-end sustainability targets for all technical functions
- Share green patterns and information on internal repositories
- Eliminate excess workstation purchases and shut down idling equipment
- Evaluate new features by how much their compute and storage will cost
- Include efficiency criteria in code reviews

Practitioner's Tip: "Once engineers realize how their software components affect carbon emissions, they look more closely at what their team is doing."

Adopt Green DevOps and Cloud Ops 🖪

Make your organization's data center use cheaper and greener with optimized resource management:

Resource Optimization

- Right-size VMs, containers, and databases
- Compress stored data and transmitted data
- Vary service levels according to business needs

Workload Management

- Set up tools to shift workload according to carbon intensity and high-demand periods
- Enable auto-scaling and load-balancing

Idle Resource Reduction

- Minimize idling with managed services, serverless environments, and virtualization
- Implement automated shutdown schedules for non-production environments during nonwork hours
- Regularly decommission unused resources

Performance Monitoring and Resource Consumption Measurement

- Track work done per watt and processor utilization rates
- Implement dashboards tracking power usage and carbon emissions metrics
- Monitor grid carbon intensity per compute hour across different workloads

Practitioner's Tip: "Give a few basic metrics to visualize cloud GHG emissions, even just using your cloud provider's carbon tool, and provide an equivalent such as driving distance or phone charges. It doesn't need to be perfect - begin with whatever data you can access, and build from there."

Make Green AI Decisions 🙆

While these software design principles apply to all applications, GenAl's significant impact on the environment requires additional considerations:

Think Carefully About Using GenAl

- Question whether a GenAl application is necessary for your use case
- A different technology may fulfill requirements with lower resource consumption and greenhouse gas emissions
- Consider financial and sustainability costs—they may exceed the benefits
- If it is the only solution, focus on efficient design and deployment

Smaller Open-Source Models

- Select smaller models trained on a data set targeting your required capability or subject matter
- Use pre-trained open-source models when possible—green software groups like Hugging Face offer a range of options
- Look for or add climate impact data on model cards (HuggingFace has instructions)

Optimized Model Training

- Set low accuracy criteria and generous retraining thresholds to minimize testing and retraining
- Consider stopping model training at 20% completion and using accuracy forecasting to find the optimal point (mixed-quality model)
- Optimize training data pipelines with pruning and quantization

Applications Designed for Efficiency

- Design applications for power conservation which lowers directly software carbon intensity
- Remove unnecessary GenAl features to reduce inferences and data storage
- Limit inference runs in user interactions with well-design user experience
- Eliminate unnecessary data creation to curtail data storage growth

Edge Locations to Curtail Data Transmission

- Large data transmission volumes from GenAI apps drive carbon emissions from networking equipment operations
- Locating models and processing on edge locations brings down software carbon intensity, if edge computing is suitable

Plan the Way Forward 5

Your organization's adoption of sustainable computing is part of a broader transformation. Extend your impact by getting involved at a policy and industry level:

- Support advocacy campaigns to contest utilities expanding gas power plants
- Advocate for tighter data center emissions rules such as EU CSRD
- Question the rapid adoption of resource-intensive technologies like billion-dollar GenAI models
- Join advocacy campaigns for green computing and cloud sustainability

By recognizing and reducing the environmental impact of online computing in your organization and in the broader industry, you are positioning your organization as a sustainability leader.

Practitioner's Tip: "Implementing sustainable practices doesn't require a complete system overhaul—it starts with small, actionable steps that create lasting change."

A Practitioner's Case Study

Integrating Green Software Practices: A Journey of Small Steps and Big Impact

Annie Freeman, Public Speaker | Engineer at Xero | Green Software Advocate

Starting the Journey

The journey began with a simple realization: while climate change might seem like someone else's problem, it requires every industry to transform how they operate. As someone passionate about making an impact, I wanted to connect my full-time software engineering role with environmental action.

When you work in a large software company, adding another initiative to an already packed roadmap can feel overwhelming. This was exactly the challenge we faced when considering how to integrate sustainable computing practices into our ways of working. **Without a direct feature benefit to customers, these initiatives often risk falling to the bottom of priority lists.** However, with 99% of our employees expressing deep concern about sustainability in our company survey, we knew we had to find a way forward.

Finding the Data

We started with a hackathon project that would eventually transform our approach to software sustainability. **We focused on what matters most: data.**

Cloud providers' emissions data, while improving, often lacks the granularity needed to drive real change. We needed to make this personal—to show engineers exactly how the software components they own impacted our carbon footprint. To develop a proof of concept, we worked with Climatiq to get emissions factors data, and leveraged internal AWS billing data to generate granular data. This would eventually evolve into Footprint, our internal measurement tool.

The impact of having concrete data was immediate and powerful. A perfect example came when one of our team members examined their emissions data and discovered that their choice of using AWS CodeBuild for remote code execution was having an outsized impact on carbon footprint and costs. This revelation prompted them to redesign their architecture around Kubernetes, significantly improving both environmental impact and operational efficiency.

Building the Momentum

Building on this momentum, we established a community of practice that grew to over 70 members within a few months. We ran educational sessions, shared insights about data center efficiency, and encouraged participation in the Linux Foundation's Green Software Practitioner training. Our internally built Footprint tool became increasingly sophisticated, providing teams with component-level emissions data that spoke directly to their work, including a breakdown of which cloud services contributed to the emissions output of each component.

The current phase of our journey focuses on normalization—making carbon emissions just another "boring" metric that teams routinely consider alongside performance, reliability, and cost. **Engineers now roll emissions data into their technical decisions and sprint reviews.**

Looking Ahead

Looking ahead, we are partnering with our sustainability team to create a comprehensive engagement plan. Our future plans include developing a self– assessment tool that evaluates software sustainability maturity, organizing competitions and hackathons, and integrating green software practices into our engineering standards.

Key Lesson

The key lesson from our journey? Sometimes, the most effective approach to transformation isn't a dramatic overhaul but rather a series of small, data-driven steps that gradually reshape how we think about and build software. By making sustainability tangible and personal to each engineer's daily work, we're seeing real change take root in our engineering culture.

Conclusion

The growing environmental impact of cloud computing is significantly affecting our resource supplies, communities, and climate future.

The top cloud providers operate their infrastructure at the highest efficiency level while making enormous investments in sustainability improvements, but their environmental harm is still growing. As drivers of cloud industry demand and growth, those who create the technology capabilities of our organizations are central to broadening the adoption of sustainable practices.

A sustainable digital future starts with addressing the challenges posed by our online computing infrastructure. Cloud providers, tech leaders, and policymakers must work together to ensure the benefits outweigh the costs. **When we all understand the impact of our world's computing, we can steer the future of technology toward a more sustainable and responsible path.**



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About Cloud Sustainability Watch

Cloud Sustainability Watch is a nonprofit volunteer campaign to reduce the environmental toll of cloud computing, AI, and data centers. We enable tech professionals with information and support for sustainable computing. **Our mission is to advocate for and enable IT leaders to improve business results and organizational strength by adopting sustainable cloud computing practices and technologies.** To get involved, <u>email info[at]cloud.sustainability.watch</u> or follow us on LinkedIn

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