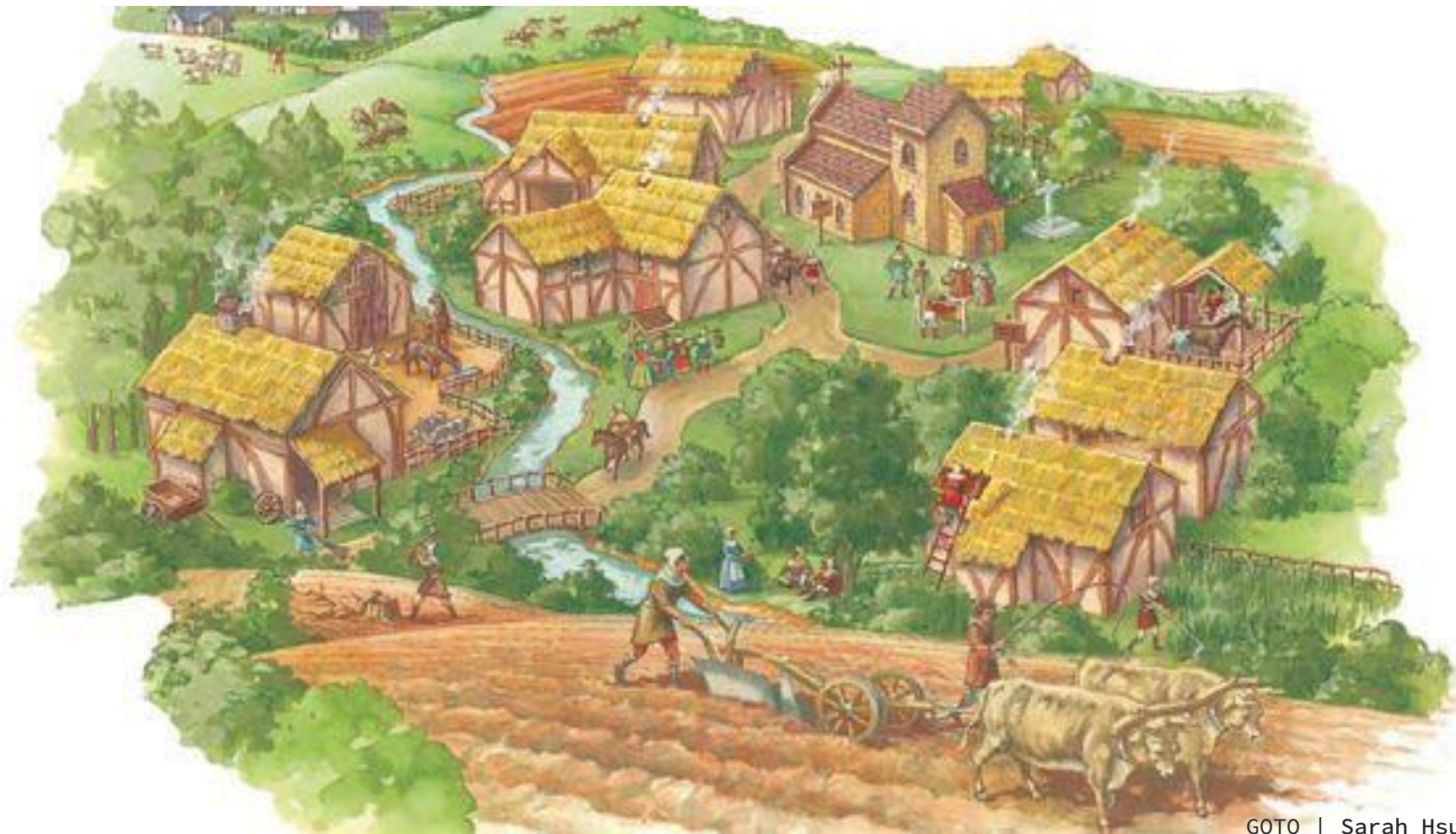
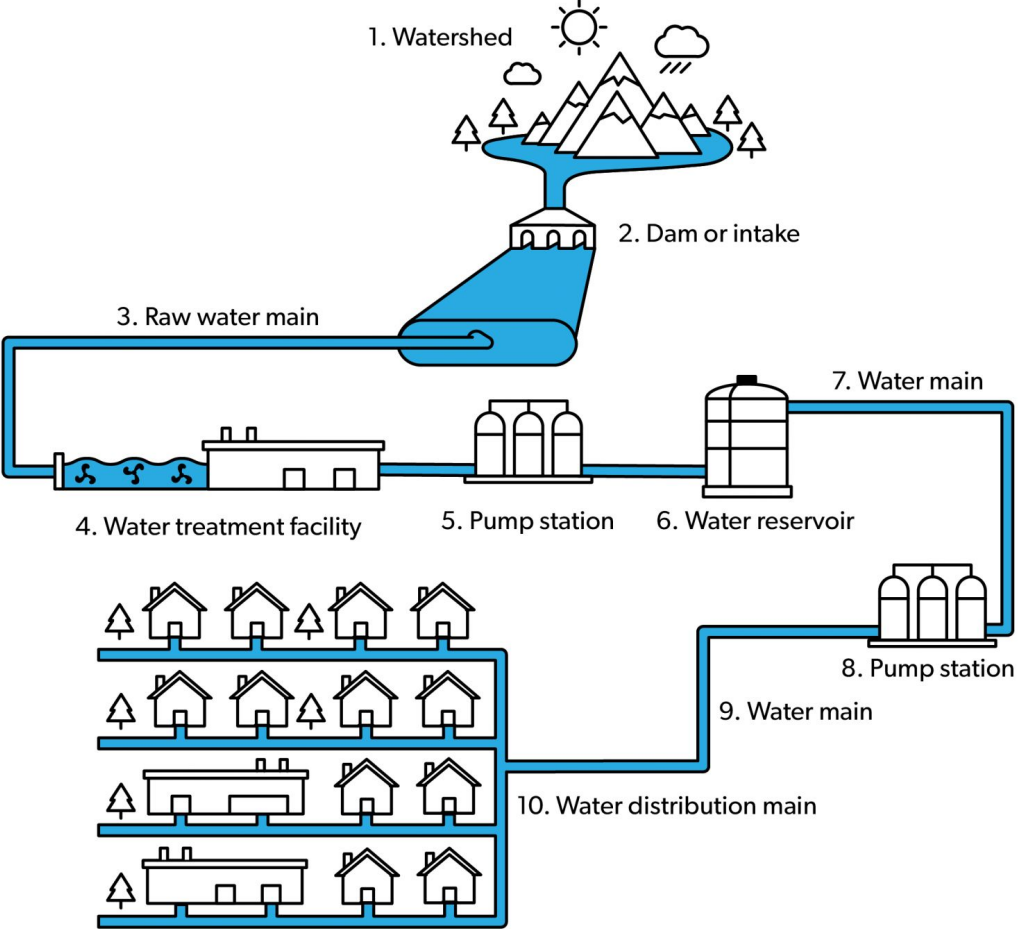


We're about to start...

A little journey back  
in time ...

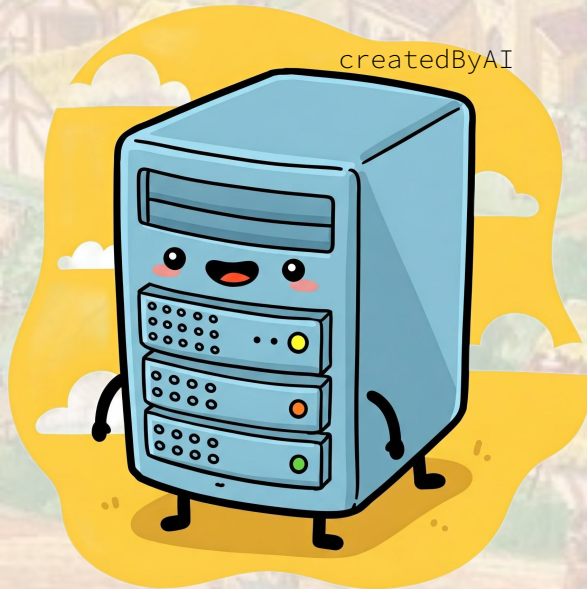


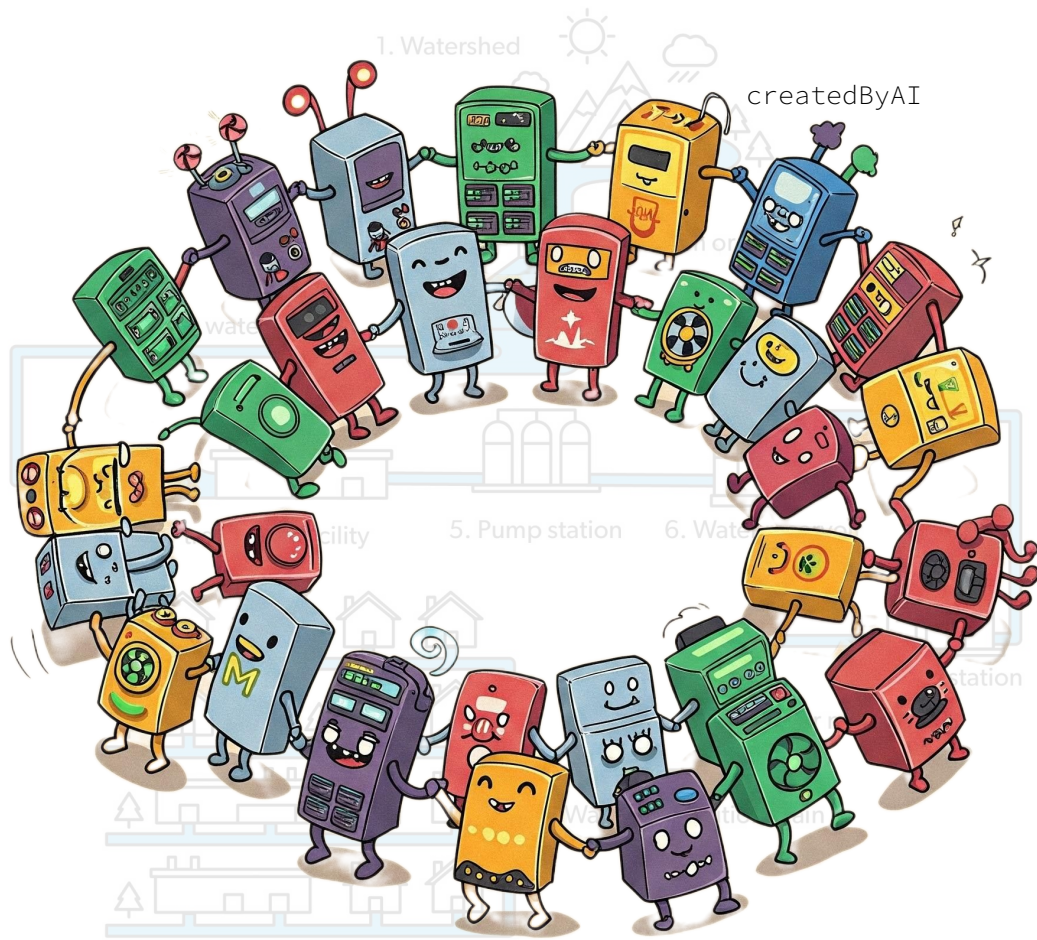


11. Water main connects to plumbing inside your home

# Beyond Uptime: What the '*Metric*' Is Going On with Green Software?

Sarah Hsu @ GOTO Copenhagen '25





11. Water main connects to plumbing inside your home

How do we accurately  
monitor the  
environmental impact  
of these intricate  
software systems?

# Sarah Hsu

Site Reliability Engineer

Green Software Course  
Lead @ Green Software  
Foundation

Co-author of O'Reilly  
Book “Building Green  
Software”

Linkedin: *greenhsu123*



# Agenda

- Introduction
- The Evolution of Metrics
- Bringing in the Environment
- Monitoring the Green Dimension
- Working with Imperfect Data
- The Limits of Proxies
- Green Observability
- Where We Go From Here

# Is it working?



# Yes, but?



<https://grafana.com/blog/2023/10/10/how-to-embed-grafana-dashboards-into-web-applications/>



# The Four Horsemen of Metrics

*Error budgets enable teams to innovate while maintaining reliability.*

*For every SLO, there is an error budget.*

*As a team's error budget becomes depleted, an error budget policy codifies how a team will respond.*

$$SLI = \left[ \frac{\text{Good events}}{\text{Valid events}} \right] \times 100\%$$

**SLO**  
99.9%

is equal to.....

**Error Budget**  
.1%

$$.001 \times \frac{30 \text{ days}}{\text{Month}} \times \frac{24 \text{ Hours}}{\text{Day}} \times \frac{60 \text{ Mins}}{\text{Hours}} = \frac{43 \text{ Mins}}{\text{Months}}$$



Q Search or jump to...

cmd+k



Home > Dashboards > Grafana SLO > 75% Mythical Correctness and Latency qtfy846t0w1kbbkh89m1m



Add



Last 6 hours



job

All

namespace

All

# 75% Mythical Correctness and Latency SLO

Time Window

28d

SLO

75%

Critical alert

OK

Warning alert

OK

Burn Rate Alerts

SLI



Current SLI Value

62.3%

Error Budget Trend



Remaining Error Budget

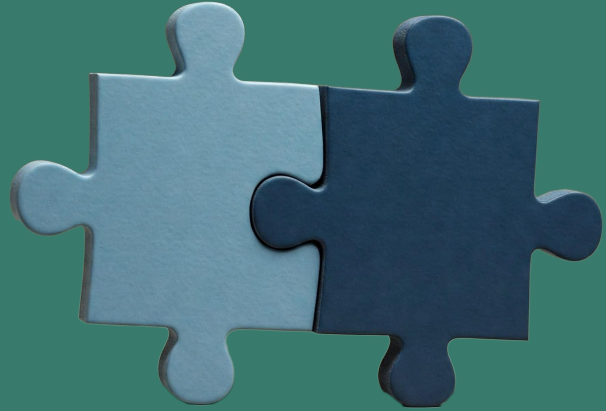
60.9%

GOTO | Sarah Hsu | 15

No alerts matching filters

<https://grafana.com/products/cloud/slo/>

The missing  
piece?





Q Search or jump to...

cmd+k



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Add



Last 6 hours



job All namespace All

## 75% Mythical Correctness and Latency SLO

Time Window

28d

SLO

75%

Critical alert

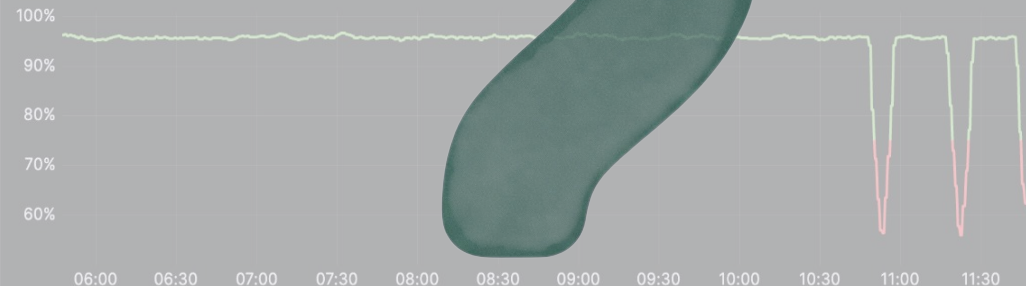
OK

Warning alert

OK

Burn Rate Alerts

SLI



Current SLI Value

62.3%

Error Budget Trend



Remaining Error Budget

60.9%

GOTO | Sarah Hsu | 17

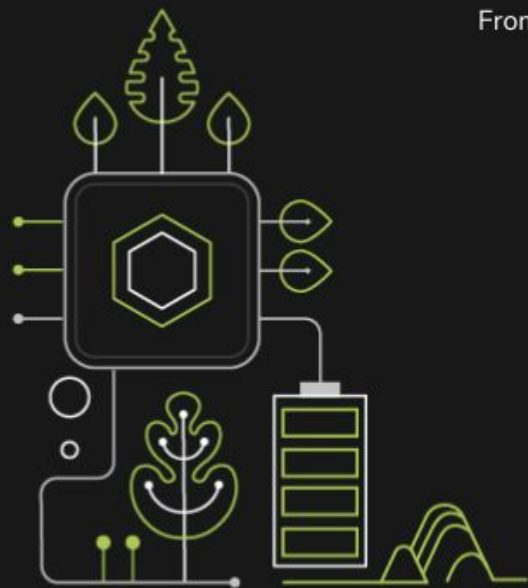
<https://grafana.com/products/cloud/slo/>

No alerts matching filters



From the 2023 State of Green Software report by Green Software Foundation  
Find out more at [stateof.greensoftware.org](https://stateof.greensoftware.org)

# Developers want to have a positive impact



Green  
Software  
Foundation



# What is Green Software?

Green Software =  
Carbon-Efficient Software

# Carbon Efficiency



**Energy  
Efficiency**



**Hardware  
Efficiency**



**Carbon  
Awareness**

# gCO<sub>2</sub>e / kWh

How clean or dirty is electricity

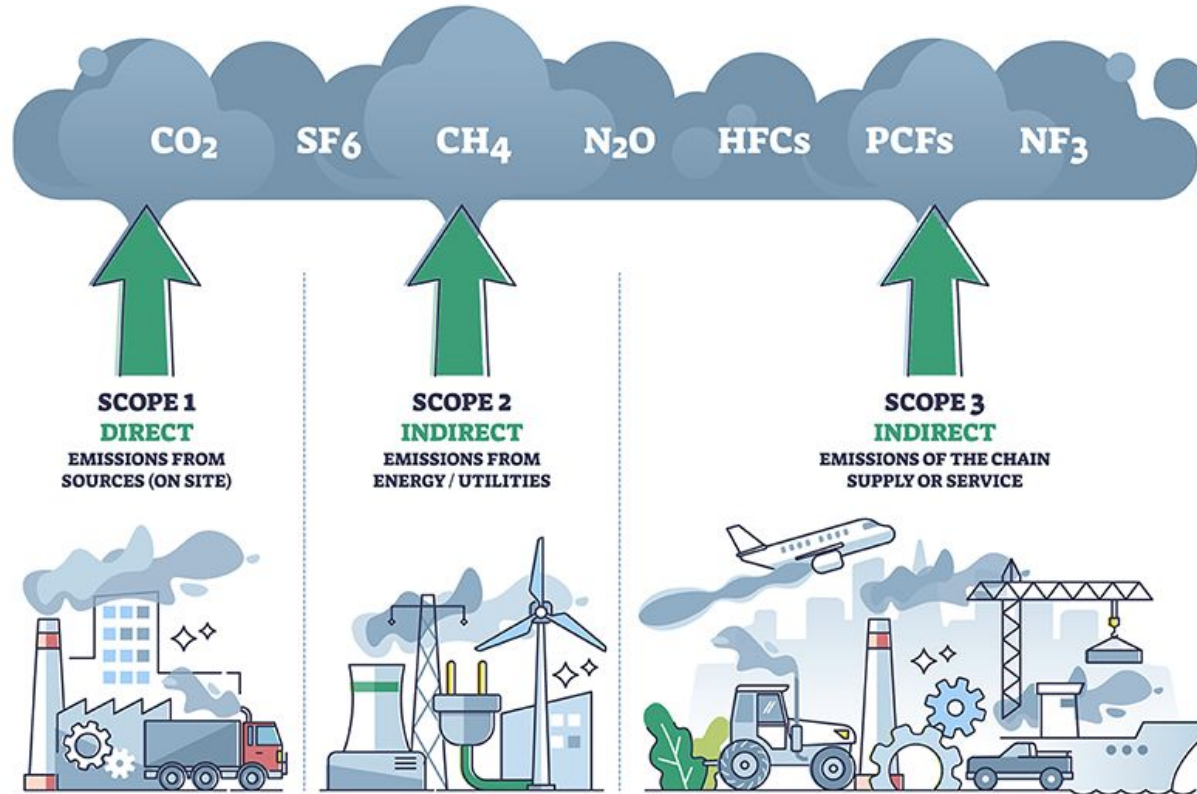
How do we  
accurately monitor the  
environmental impact  
of these intricate  
software systems?

**carbon = CO<sub>2</sub>e**

How do we  
accurately ~~measure~~ the  
~~environmental~~ **carbon** impact  
of these intricate  
software systems?

Why is it so hard?

# SCOPES OF EMISSIONS



| GHG Scope     | 2            | 3                                 |
|---------------|--------------|-----------------------------------|
| Private cloud | Energy       | Embodied Carbon                   |
| Public cloud  |              | Energy +<br>Embodied Carbon       |
| Hybrid cloud  | Some energy  | Some Energy +<br>Embodied Carbon  |
| Open source   | Some energy? | Some Energy +<br>Embodied Carbon? |



Carbon emitted per kWh  
of energy, gCO2/kWh

Carbon emitted through  
the hardware that the  
software is running on

$$SCI = ((E * I) + M) \text{ per } R$$

Energy consumed by  
software in kWh

Functional Unit; this is how  
software scales, for example  
per user or per device

$\text{CO}_2\text{e}$

Carbon Dioxide Equivalent

$\text{gCO}_2\text{e}/\text{R}$

Software Carbon Intensity

$\text{kWh}$

Energy Consumption

$\text{gCO}_2\text{e}/\text{kWh}$

Carbon Intensity of Electricity

$\text{kgCO}_2\text{e}$

Embodied Carbon

$\text{CPU } \%$

CPU Utilisation

$\text{Memory } \%$

Memory Utilisation

$\text{Network } \%$

Network Utilisation

Ratio

Power Usage Effectiveness

\$

Cost



# Cost

(\$)

## Pros:

- Easy to track and understand
- Potential for real-time
- Boosts incentives

## Cons:

- Doesn't directly link to carbon
- Can be misleading

# Energy Consumption (kWh)

## Pros:

- Direct link to carbon
- Relatively easy to understand
- Potential for real-time

## Cons:

- Hard to measure precisely
- Doesn't account for carbon intensity

# Carbon Intensity

(gCO<sub>2</sub>e/kWh)

## Pros:

- Provides essential carbon context
- Enables carbon-aware design
- Potential for real-time

## Cons:

- Availability is patchy
- Coarse granularity

# Resource Utilisation (%)

## Pros:

- Readily-available and familiar
- Infers energy use trends
- More granular and real-time

## Cons:

- Doesn't account for carbon intensity
- Doesn't capture idle energy use
- Varies across hardware

# Embodied Carbon (kgCO<sub>2</sub>e)

## Pros:

- Accounts for the full lifecycle
- Encourages hardware efficiency
- Incentivizes shared infrastructure

## Cons:

- Data is not readily-available
- Hard to measure per workload

# Power Usage Effectiveness (Ratio)

## Pros:

- Indicates data center efficiency
- Helps assess overhead energy consumption
- Useful for evaluating cloud provider sustainability

## Cons:

- Not software-specific
- No visibility or control for most developers
- Methodology may vary between data centers

# What, now?



<https://stock.adobe.com/>

Cost

Resource  
Utilisation

Energy  
Usage

Carbon  
Intensity

SCI

More  
Practical

More  
Precise

# Comparing common carbon-monitoring proxies

| Proxy Metric         | Precision | Practicality | Real-Time | Carbon Context | Granularity |
|----------------------|-----------|--------------|-----------|----------------|-------------|
| SCI                  | ✔ High    | ⚠ Medium     | ⚠ Depends | ✔              | ⚠ Depends   |
| Carbon Intensity     | ✔ High    | ⚠ Medium     | ✔         | ✔              | ⚠ Limited   |
| Energy Usage         | ✔ Medium  | ⚠ Medium     | ⚠ Depends | ✖              | ⚠ Varies    |
| Resource Utilization | ✖ Low     | ✔ High       | ✔         | ✖              | ✔ Yes       |
| Cost                 | ✖ Low     | ✔ High       | ✔         | ✖              | ✔ Yes       |
| PUE                  | ✖ Low     | ⚠ Low        | ✖         | ✖              | ✖ Coarse    |
| Embodied Carbon      | ✔ High    | ⚠ Low        | ✖         | ✔              | ✖ None      |

# Comparing common tooling

| Tooling                   | Uses Energy | Uses Cost | Uses Carbon Intensity | Infra-Aware | Open Source |
|---------------------------|-------------|-----------|-----------------------|-------------|-------------|
| Cloud Carbon Footprint    | ✔ Yes       | ✔ Yes     | ✗ No                  | ✔ Yes       | ✔ Yes       |
| Scaphandre                | ✔ Yes       | ✗ No      | ✗ No                  | ✔ Yes       | ✔ Yes       |
| Kepler                    | ✔ Yes       | ✗ No      | ✗ No                  | ✔ Yes       | ✔ Yes       |
| Green Metrics Tool        | ✔ Yes       | ✗ No      | ✗ No                  | ⚠ Partial   | ✔ Yes       |
| WattTime / ElectricityMap | ✗ No        | ✗ No      | ✔ Yes                 | ✗ No        | ⚠ Mixed     |

**ARE YOU NOT ENTERTAINED?**



What  
can we do?



iStock™  
Credit: jeffbergen

# WE ARE ALL IN THIS TOGETHER



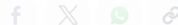
Home > Cloud Computing > Overprovisioning & Always-On Resources Lead to \$26.6 Billion in Public Cloud Waste Expected in 2021

# Overprovisioning & Always-On Resources Lead to \$26.6 Billion in Public Cloud Waste Expected in 2021



Katy Stalcup  
Contributor

Disclosure



Last updated January 21, 2021

Overprovisioning and leaving cloud resources on are two enormous sources of wasted spend.

Wasted spend drags down IT budgets – of particular importance as we enter 2021. The [Flexera 2021 State of Tech Spend report](#) found that the biggest change in key IT initiatives from 2020 to 2021 was in cost savings, with the percent of respondents ranking cost savings as a top initiative *tripling* year-over-year.

It's important that this is being recognized. Based on data collected by Gartner, we estimate that wasted spend will exceed **\$26.6 billion** this year.

## Where the Wasted Cloud Spend is Coming From

Gartner [estimates](#) a total market spend of \$304 billion on public cloud services end-user spending in 2021, as broken out in the table below. Their estimate for the proportion of that spent on Infrastructure as a Service (IaaS) is \$65.3 billion. While wasted spend can be found in any area of cloud spend, customers tend to see the largest amount in these two areas, as well as SaaS.

|                                                  | 2019    | 2020    | 2021    | 2022    |
|--------------------------------------------------|---------|---------|---------|---------|
| Cloud Business Process Services (BPaaS)          | 45,212  | 44,741  | 47,521  | 50,336  |
| Cloud Application Infrastructure Services (PaaS) | 31,510  | 43,823  | 55,466  | 68,964  |
| Cloud Application Services (SaaS)                | 102,064 | 101,480 | 117,775 | 138,261 |
| Cloud Management and Security Services           | 12,936  | 14,880  | 17,001  | 19,934  |
| Cloud System Infrastructure Services (IaaS)      | 44,457  | 51,421  | 65,264  | 82,226  |
| Desktop as a Service (DaaS)                      | 616     | 1,204   | 1,945   | 2,542   |

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## Trending News



GO TO

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# CPU and memory utilization

The average CPU utilization across clusters remained low at 10% (-23% YoY), while average memory utilization was marginally better at 23% (+15% YoY), indicating no significant year-over-year improvement in resource efficiency across cloud platforms compared to our previous report from 2024.

10%

AVERAGE CPU UTILIZATION

23%

AVERAGE MEMORY UTILIZATION

| Cloud provider                                                   |  |  |  |
|------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| CPU utilization<br>(resources used vs. provisioned)              | 10%                                                                                 | 12%                                                                                 | 8%                                                                                  |
| Memory utilization<br>(resources used vs. provisioned)           | 24%                                                                                 | 23%                                                                                 | 21%                                                                                 |
| CPU overprovisioning<br>(resources requested vs. provisioned)    | 39%                                                                                 | 39%                                                                                 | 41%                                                                                 |
| Memory overprovisioning<br>(resources requested vs. provisioned) | 58%                                                                                 | 53%                                                                                 | 65%                                                                                 |

# A really SIMPLE example

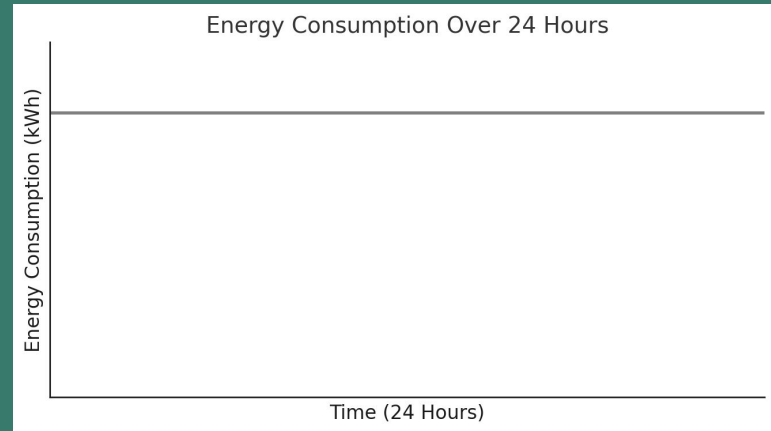
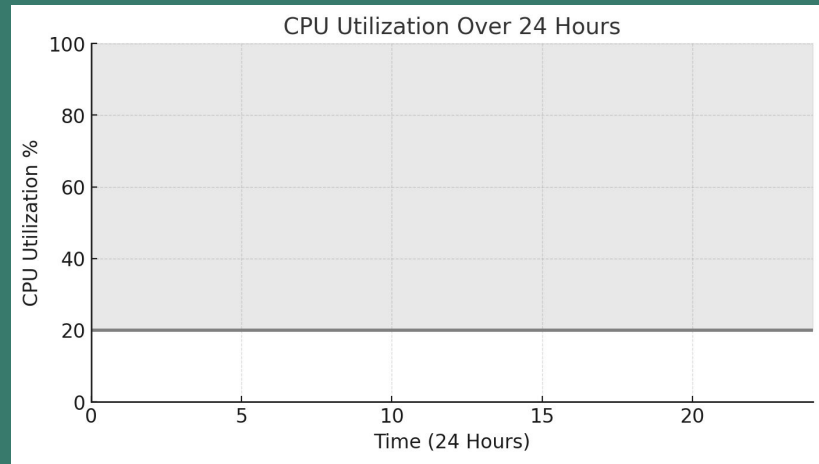
5 static replicas



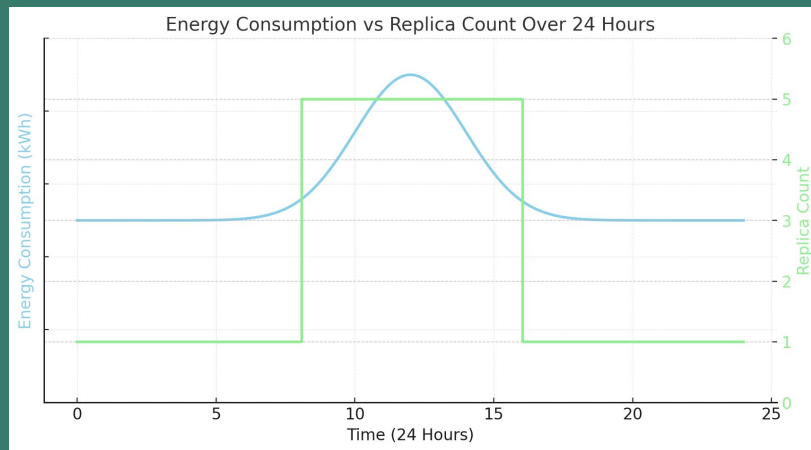
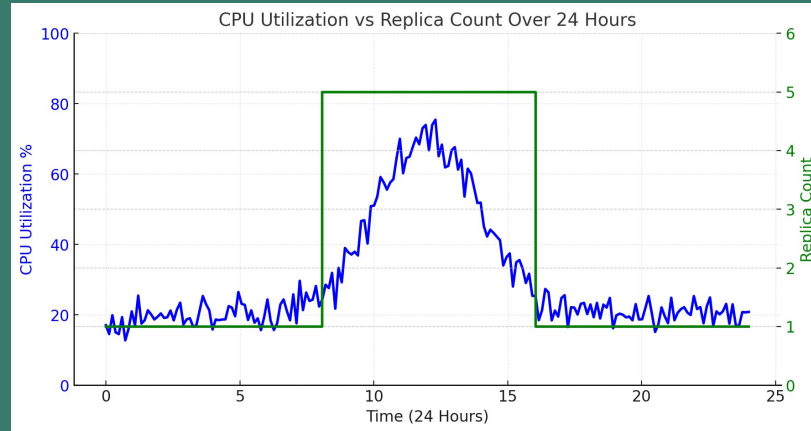
5 dynamic replicas



5 static  
replicas



# 5 dynamic replicas



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DEVOPS

Microsoft Virtual Event (April 29-30): Unleash AI innovation with an API-first strategy

# Automating Platform Upgrades at eBay

JUN 11, 2023 • 2 MIN READ



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Aditya Kulkarni

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Product Manager at Secure Privacy |  
Senior Editor at InfoQ

eBay recently provided insights into their adoption of a pipeline-driven automation solution, enabling them to achieve continuous updates to their framework and infrastructure. The solution architecture has the potential to become more versatile as it adopts a pluggable and loosely coupled approach, allowing for easier extensibility.

eBay's platform comprises two key components: the framework serving as the foundation for the application code, and the cloud-based infrastructure responsible for hosting the application. By leveraging [the automation solution](#), eBay streamlines the preparation, execution, and validation of jobs, resulting in a notable boost in productivity.

Within the expansive and intricate marketplace, there exist various types of upgrades, such as framework upgrades, framework migrations, and cloud migrations. Due to the scale and intricacy of the platform, these upgrades occur in a continuous manner, reflecting the ongoing evolution and enhancement of eBay's systems.

For example, let's consider a specific case of cloud migration. This process entails transitioning the cloud infrastructure from openstratus, which relies on virtual machines, to Kubernetes, which operates with container-based technology. This migration has an impact on the application development lifecycle, as it involves transitioning from a library-based manifest approach to an image-based manifest approach. Accomplishing this type of migration typically follows a defined sequence of tasks, including metadata collection, configuring workloads, migrating network topology and traffic, creating new instances, implementing monitoring, and finally decommissioning the previous virtual machine-based state.

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GOTO | Sarah Hsu | 50



You Can't Optimize What  
You Can't See —

*But* You Don't Need to See  
Everything to Start

## 5 Golden Signals

- Latency
- Traffic
- Error
- Saturation
- **!!CARBON!!**

What does  
it mean for SREs?

ARCHITECTURE & DESIGN

InfoQ Dev Summit Munich (Oct 15-16): Explore proven strategies for optimizing your software dev approach.

# Applying Chaos Engineering in Healthcare: Getting Started with Sensitive Workloads

SEP 28, 2020 • 10 MIN READ

by



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reviewed by



Charles Humble

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Techie, podcaster, editor, author and consultant

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## Key Takeaways

- While chaos engineering is a proven technique for improving the resilience of systems, there is often a reluctance amongst stakeholders to introduce the practice when a system is viewed as critical.
- With critical systems, it can be a good idea to first run experiments in your dev/test type environments to minimize both actual and perceived risk. As you learn new things from these early experiments, you can explain to stakeholders that production is a larger and more complex environment which would further benefit from this practice.
- Using real production traffic, as opposed to a synthetic workload, can improve the usefulness of the experiments in these early stages.
- A good chaos engineering practice helps you to improve both the resilience of the system, and its observability when incidents do occur.

...

Chaos engineering is a discipline that has seen growing interest over recent years. It provides a definition to a valuable practice of improving the reliability of your systems by embracing the fact that systems will fail. While literature and talks abound on how this approach can be applied, there is often hesitation when systems are viewed as

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Uptime Institute's 2022 Outage Analysis Finds Downtime Costs and Consequences Worsening as Industry Efforts to Curb Outage Frequency Fall Short

# Uptime Institute's 2022 Outage Analysis Finds Downtime Costs and Consequences Worsening as Industry Efforts to Curb Outage Frequency Fall Short

*New research details latest digital infrastructure failure rates, increasing outage costs and impacts, top downtime causes, and more*

NEW YORK, NY – June 8, 2022 – The digital infrastructure sector is struggling to achieve a measurable reduction in outage rates and severity, and the financial consequences and overall disruption from outages are steadily increasing, according to [Uptime Institute](#), which today released the findings of its 2022 annual Outage Analysis report.

"Digital infrastructure operators are still struggling to meet the high standards that customers expect and service level agreements demand – despite improving technologies and the industry's strong investment in resiliency and downtime prevention," said Andy Lawrence, founding member and executive director, [Uptime Institute Intelligence](#).

"The lack of improvement in overall outage rates is partly the result of the immensity of recent investment in digital infrastructure, and all the associated complexity that operators face as they transition to hybrid, distributed architectures" said Lawrence. "In time, both the technology and operational practices will improve

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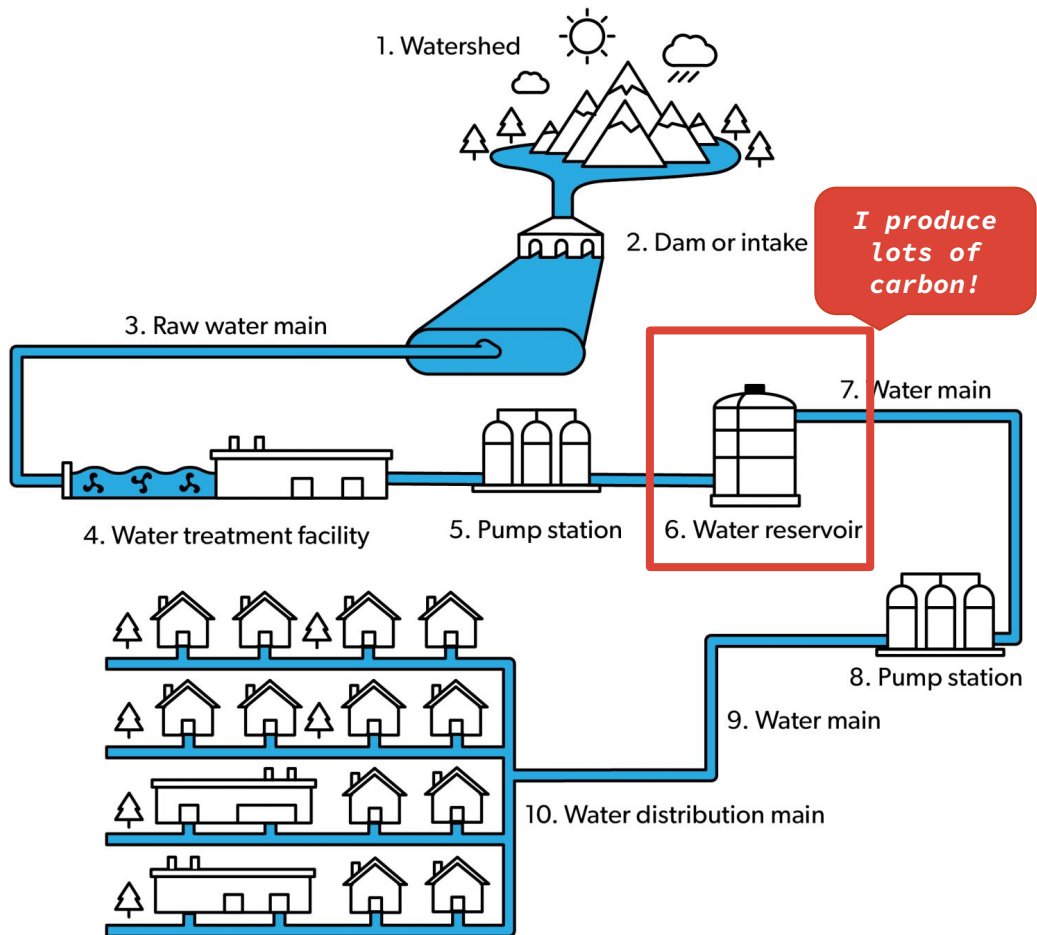
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Should we add **green** to  
observability?



11. Water main connects to plumbing inside your home



# So, what's next?

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8 - > 68

We represent the  
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# Green Software for Practitioners (LFC131)

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This is an introductory course designed for software practitioners.



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This course provides a framework to educate software practitioners in topics related to green software.

# So, what's next?

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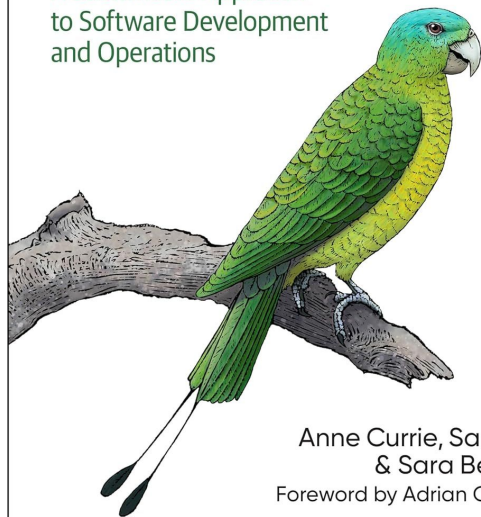
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Read Building Green Software

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A Sustainable Approach  
to Software Development  
and Operations

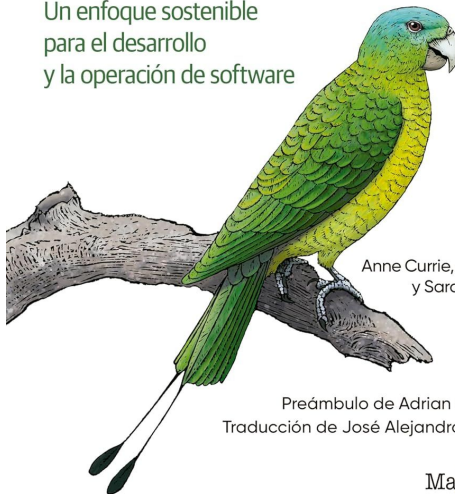


Anne Currie, Sarah Hsu  
& Sara Bergman  
Foreword by Adrian Cockcroft

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# Construir software verde

Un enfoque sostenible  
para el desarrollo  
y la operación de software



Anne Currie, Sarah Hsu  
y Sara Bergman

Preámbulo de Adrian Cockcroft  
Traducción de José Alejandro Sánchez

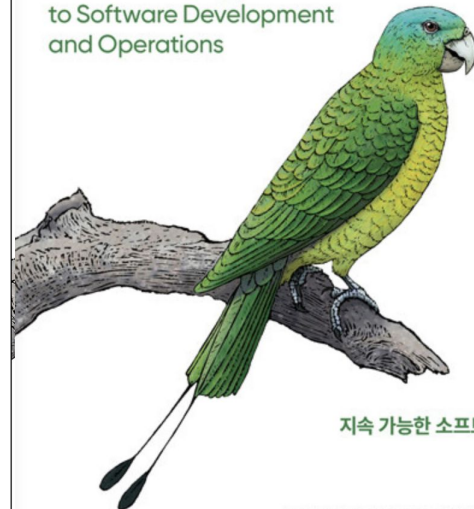
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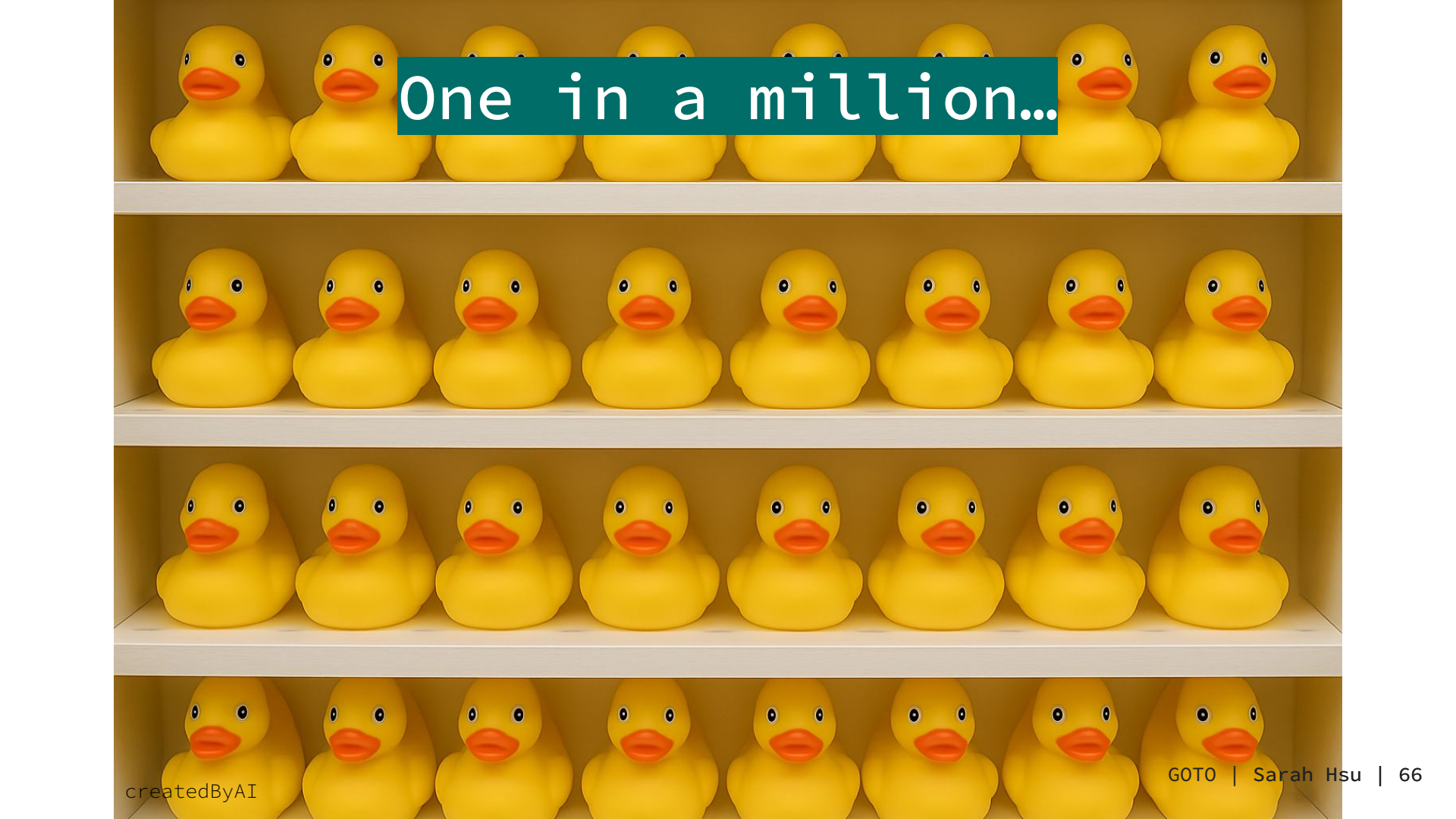
A Sustainable Approach  
to Software Development  
and Operations



지속 가능한 소프트웨어 개발과  
운영 가이드

앤 커리, 세라 수, 사라 베리만 지음 / 차건희 옮김

Jpub  
제이퍼블

The image consists of a 4x8 grid of yellow rubber ducks. A teal rectangular box with white text is positioned over the top row of ducks. The text reads "One in a million..".

One in a million..

- Sustainability is a software concern

# The End

- Sustainability is a software concern
- Proxies aren't perfect, but they work

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- Green software isn't new work
- SRE practices already align with sustainability

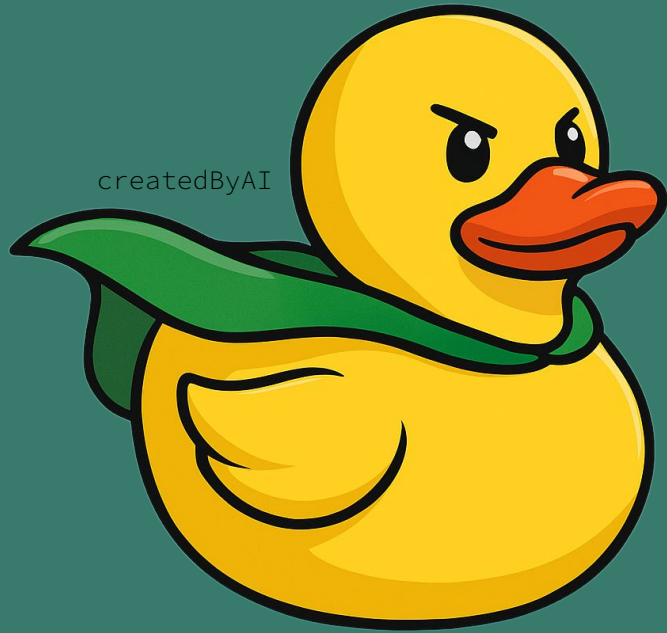
# The End

- Sustainability is a software concern
- Proxies aren't perfect, but they work
- Imperfect data  $\neq$  inaction
- Green software isn't new work
- SRE practices already align with sustainability
- Green belongs in observability



One in a million..

Still makes bathtime better!



createdByAI

***“We can do it”***

(Yes, we can! Thank you!)