Cloud Sustainability

The internet should be a global public good
Healthy for the planet and for the people who use it.

Element 84

The internet is the world’s largest coal-powered machine.

thegreenwebfoundation.org

If the Internet was a country, it would be the 4th largest polluter

ITC's total emissions from a 2021 study by Freitag et al. compared with fossil CO2 emissions by country, using data from 2020 from the European Union's Emissions Database for Global Atmospheric Research (EDGAR

https://www.sustainablewebmanifesto.com/

Architecture decisions we make
have an impact
on our environment

There are things that software engineers can do to help

There are things that designers can do to help

There are things that data analysts can do to help

Environmental Impact of Digital Work

1. Email
2. Web trackers
3. Web site and web hosting
4. e-Waste
5. Personal Behaviours (power saving, etc)
6. Streaming
7. Get Involved

30 mins of streaming on Netflix is equivalent to driving 4 miles

The Environmental Impact of Your Digital Business

Components of Cloud Sustainability

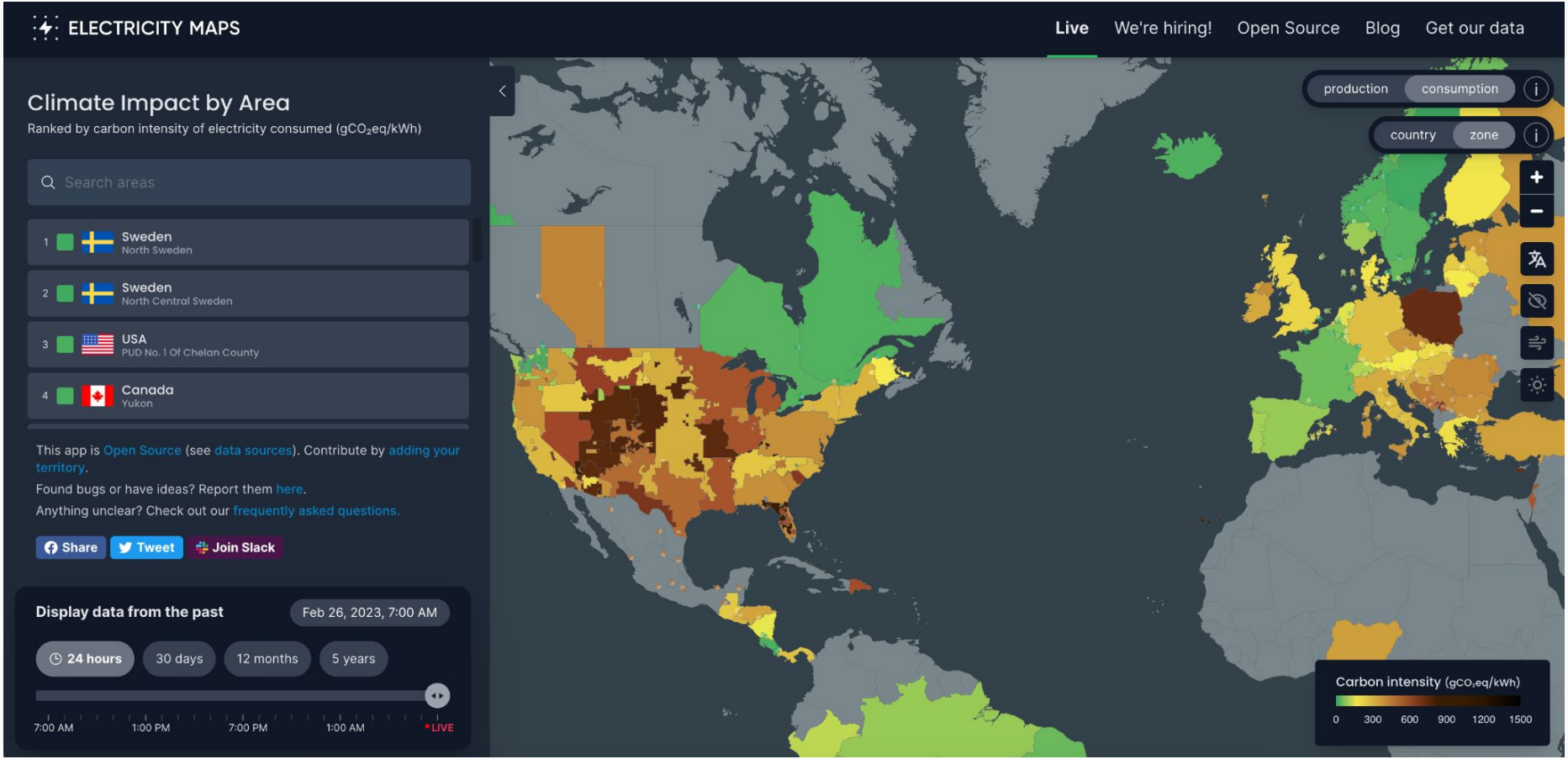
- Datacenter
  - PUE/CUE/WUE - Power, Carbon, Water Usage Efficiency
  - Resource management (e.g. lifetime or equipment, resource extraction)
  - Commitments, Reporting, Downstream programs (e.g. Amazon's Well-Architected Sustainability Pillar)
- Software Development
  - Power usage
    - Software
    - Infrastructure
  - Data transfer
- Network
  - Smart data routing, caching
  - Abuse

Data centers

Carbon intensity of hyperscalers

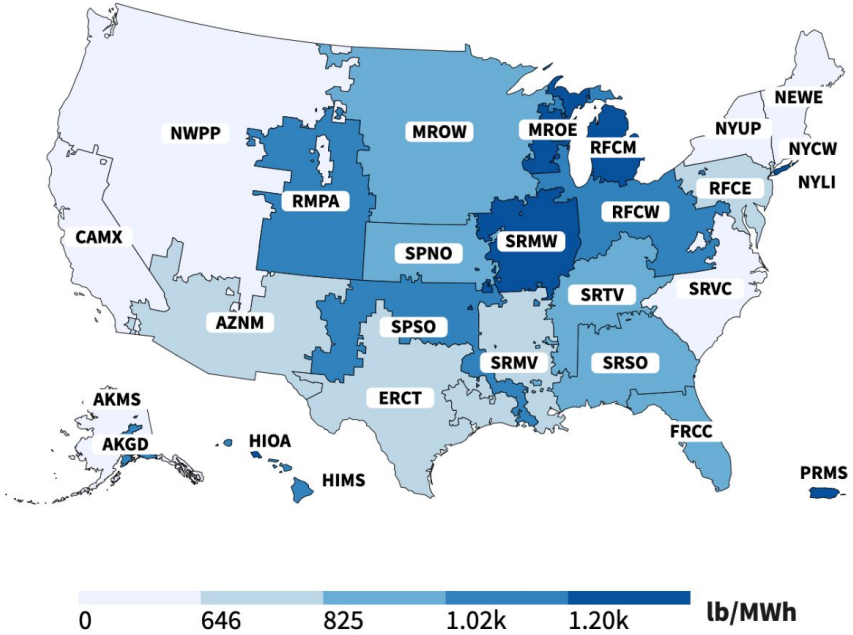
Category	Energy use (million MWh)	Computing workloads (million)	Water intensity (m^3 MWh^{-1})	Carbon intensity (ton CO_2-eq MWh^{-1})	Water intensity (m^3/workload)	Carbon intensity (ton CO_2-eq/ workload)
Internal	26.90	16	7.20	0.45	12.15	0.75
Colocation	22.40	41	7.00	0.42	3.85	0.25
Hyperscale	22.85	76	7.00	0.44	2.10	0.15

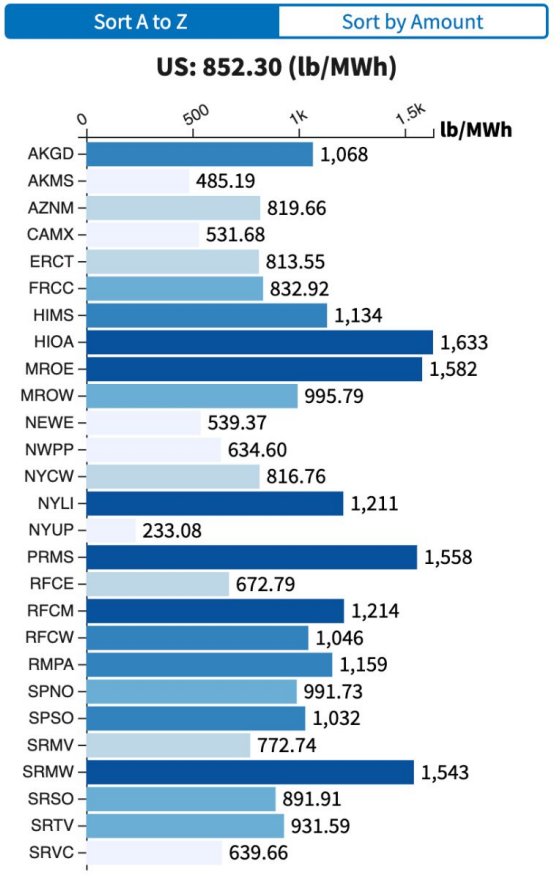
Siddik, Shabi, Marston "The environmental footprint of data centers in the United States" (2021)



https://app.electricitymaps.com/map

CO_2 total output emission rate (lb/MWh) by eGRID subregion, 2021



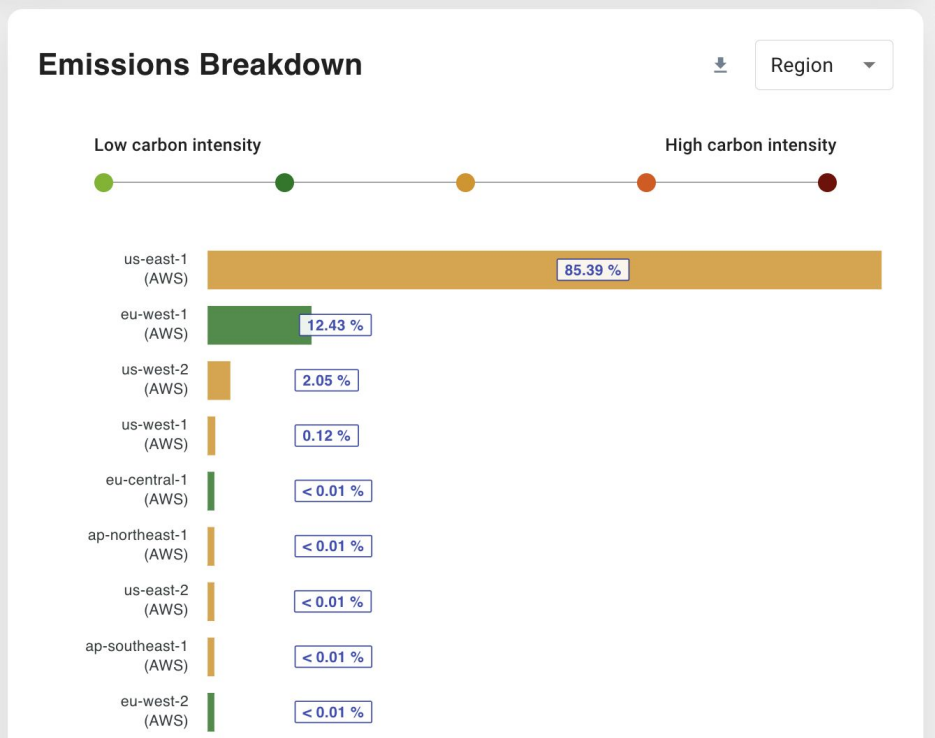


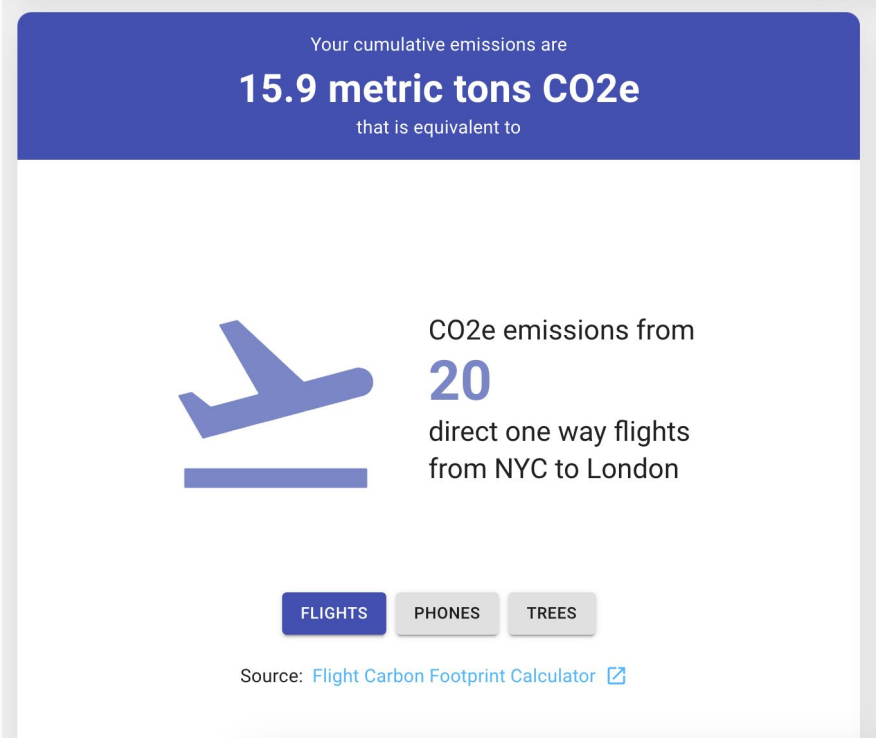
https://www.epa.gov/egrid

- Open Source Cloud Carbon Emissions Measurement and Analysis Tool
- Calculates CO2e from cloud power usage derived from billing data
- Builds upon Etsy's Cloud Jewels cloud energy conversion factors for estimating CO2e emissions for compute, storage and networking

- Instructions & Cloudformation to setup **AWS Cost Usage Reporting** and S3-Glue-Athena stack
- Transformed legacy CUR data into expected format to get data back to 2018
  - 21 accounts (azavea + client)
  - ~800GB csv CUR data
- Packaged with API, Client, CLI and library

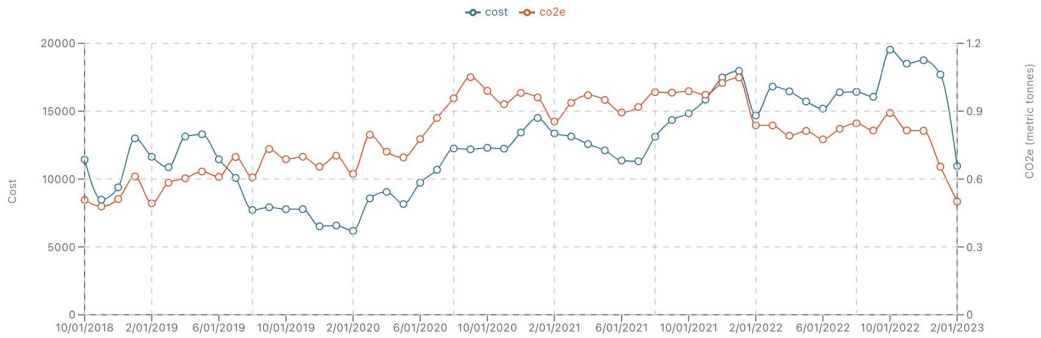
Cloud Carbon Footprint client





Cloud Carbon Footprint client

Cost and CO2e All time

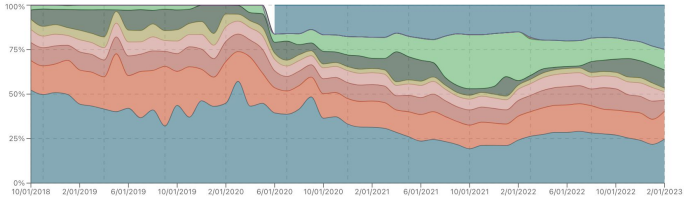


By the numbers

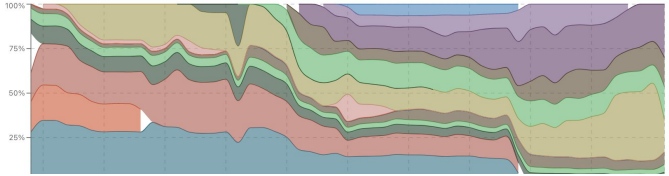
Cumulative CO2e Metric Tonnes: 41.9

Service Percentage

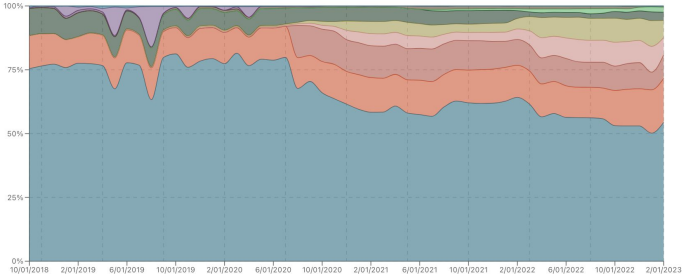
Azavea Account Percentage All time



Client Account Percentage All time



Service Percentage All time



Cloud Carbon Footprint

- Repo: https://github.com/azavea/cloud-carbon-footprint
- Investment backlog: https://github.com/azavea/azavea-investment-backlog/issues/19

42 metric tonnes of CO2e

1. Carbon sequestered by **50 acres of forest** in one year
2. **80 flights** from Ottawa to Vancouver
3. **100k** miles driven by a car
4. **5000** gallons of gas
5. **100** Barrels of oil
6. **6M** smartphones charged

https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

ESG Analytics

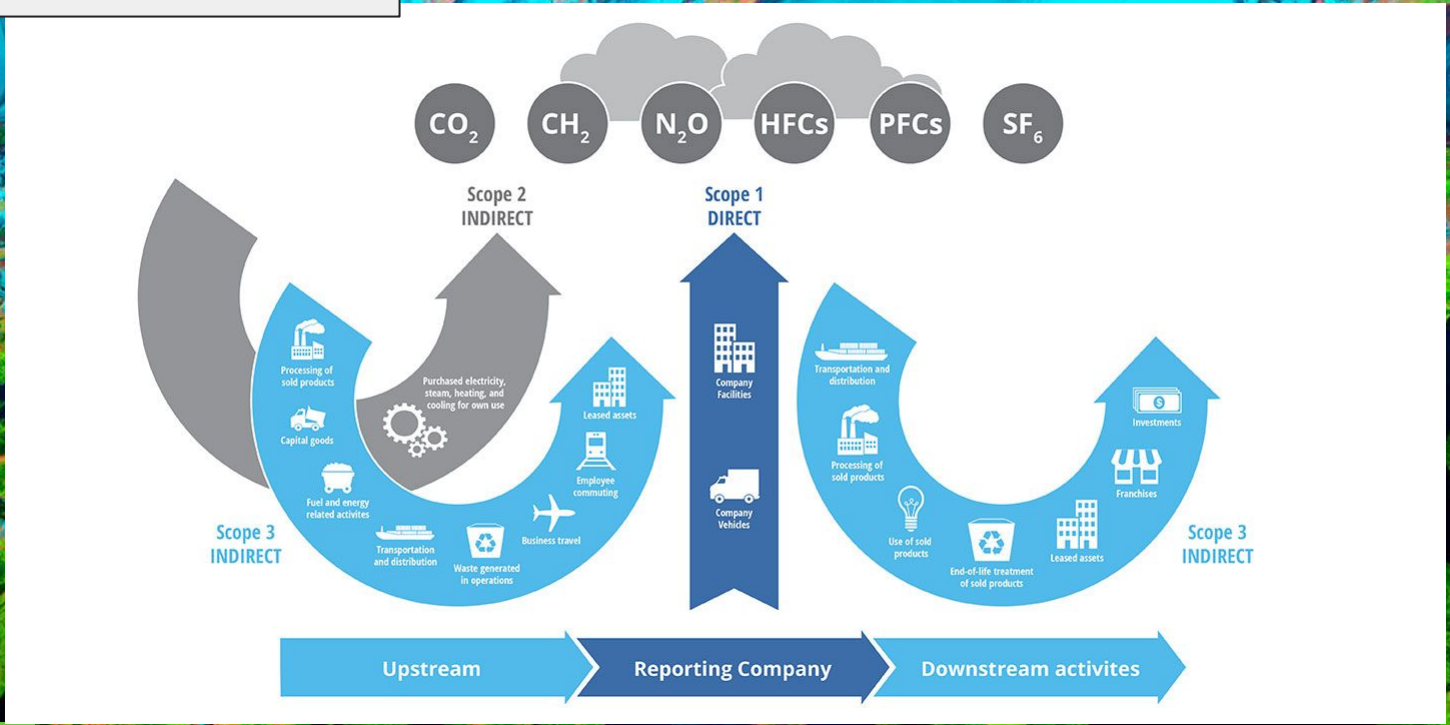
- Corporations measure and track regulatory and voluntary environmental commitments

Carbon Offsets

- Cost $15/tonne or more depending on quality
- Regulatory, voluntary

Measurement, Reporting, Verification (MRV)

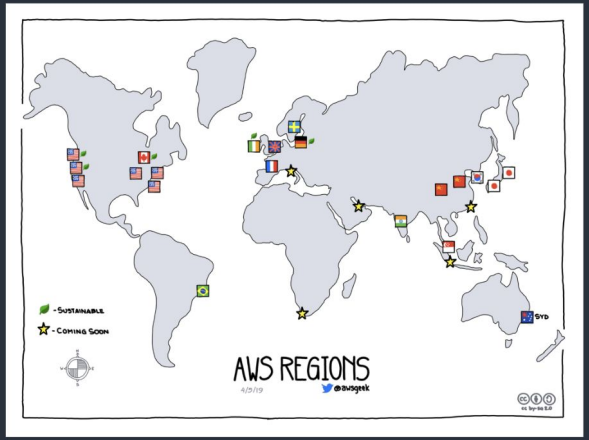
- Of carbon reduction activities



GHGs at Azavea

1. Tracking electricity, travel, commute over time
2. [TSM by Robert]

Greenhouse Gas Emissions, Energy, COVID, and Azavea



Software, Infrastructure & Network

https://www.websitecarbon.com/website/azavea-com/

Carbon results for

azavea.com

This page was last tested on 13 Sep, 2022. Test again

Hurrah! This web page is cleaner than 68% of web pages tested

https://www.websitecarbon.com/website/azavea-com/

Only 0.29g of CO2 is produced every time someone visits this web page.

This web page appears to be running on sustainable energy

https://www.websitecarbon.com/website/azavea-com/

Over a year, with ±25,000 monthly page views, azavea.com produces

86.3kg of CO2 equivalent.

The same weight as 0.58 sumo wrestlers and as much CO2 as boiling water for 11,694 cups of tea

https://www.websitecarbon.com/website/wildfirerisk-org-explore-exposure-type-39-39075-3900053634/

Uh oh! This web page is dirtier than 71% of web pages tested

Oh my, 0.85g of CO_2 is produced every time someone visits this web page.

This web page appears to be running on sustainable energy

https://www.websitecarbon.com/website/opensupplyhub-org/

Hurrah! This web page is cleaner than 58% of web pages tested

Only 0.39g of CO_2 is produced every time someone visits this web page.

Oh no, it looks like this web page uses bog standard energy

If this site used green hosting, then it would emit 9% less CO_2

https://www.websitecarbon.com/website/public-tableau-com-app-profile-andr-oliveira8781-viz-banksy-home/

Uh oh! This web page is dirtier than 80% of web pages tested

Oh my, 1.23g of CO2 is produced every time someone visits this web page.

Oh no, it looks like this web page uses bog standard energy

If this site used green hosting, then it would emit 9% less CO2

For reference

The median is approximately 0.5 grams per page view and the mean is approximately 0.9 grams per page view

https://www.websitecarbon.com

25k visits x 1.2g x 12mo = 0.4 tonnes CO2e

1. Carbon sequestered by **0.5 acres of forest** in one year
2. **1 flights** from Ottawa to Vancouver
3. **1000** miles driven by a car
4. **50** gallons of gas
5. **1** Barrels of oil
6. **50k** smartphones charged

https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

https://sustainablewebdesign.org/calculating-digital-emissions/

Emissions Calculation Formulas

Using the above data, we came up with these formulas:

Energy per visit in kWh (E):

E = [Data Transfer per Visit (new visitors) in GB x 0.81 kWh/GB x 0.75] + [Data Transfer per Visit (returning visitors) in GB x 0.81 kWh/GB x 0.25 x 0.02]

Emissions per visit in grams CO2e (C):

C = E x 442 g/kWh (or alternative/region-specific carbon

Energy Efficient Websites

better

- SEO
- UX
- Copywriting

→ Less time searching → Less energy

→ *Also great accessibility*

reduce

- Fonts
- Images
- Video

→ Less network → Less energy

For example: Azavea.com: 2MB images, 150K of fonts

PageSpeed

https://pagespeed.web.dev

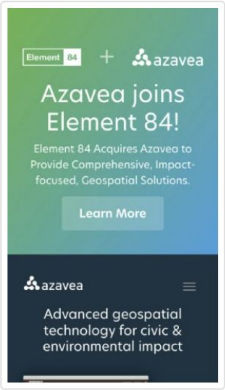
Performance	Accessibility	Best Practices	SEO
63	81	92	86

63

Performance

Values are estimated and may vary. The performance score is calculated directly from these metrics. See calculator.

▲ 0–49 ■ 50–89 ● 90–100



METRICS

Expand view

■ First Contentful Paint
2.5 s

■ Time to Interactive
5.4 s

Element 84

PageSpeed

https://pagespeed.web.dev

OPPORTUNITIES

Opportunity	Estimated Savings
Properly size images	2.25 s
Eliminate render-blocking resources	1.29 s
Reduce unused JavaScript	0.7 s
Reduce unused CSS	0.15 s

These suggestions can help your page load faster. They don't directly affect the Performance score.

DIAGNOSTICS

- Ensure text remains visible during webfont load
- Reduce the impact of third-party code — Third-party code blocked the main thread for 590 ms
- Does not use passive listeners to improve scrolling performance
- Image elements do not have explicit `width` and `height`
- First Contentful Paint (3G) — 4890 ms
- Minimize main-thread work — 2.8 s

Coding best practices

1. Clean code, DRY, Doc, Fmt - Maintainable, fast onboarding, ++++
2. Automation, testing regression, security - Better Integrity, Availability
3. Refactoring, Optimizing I/O, Caching - Run faster
4. Measure, log - observability, Know how well its running
5. Analytics - targets, anomalies show problems

Architecture

1. Optimize and rightsize - Use recommendations to take action
   a. One instance with CPU at 60% uses less power than two at 30%
   b. Use autoscaling - scheduled, load threshold
   c. Batch processing is better than ad-hoc
2. Location - many locations with dirty mix of energy in the area offset with clean energy projects
3. Storage - solid state is energy intensive, scale down to infrequent access and lower as needed
4. Sustainability Pillar - AWS Well-Architected Framework
   a. https://docs.aws.amazon.com/wellarchitected/latest/sustainability-pillar/best-practices-for-sustainability-in-the-cloud.html

AWS Well-Architected Framework - Sustainability Pillar

Region selection	SUS01-BP01 Choose Regions near Amazon renewable energy projects and Regions where the grid has a published carbon intensity that is lower than other locations (or Regions)	Choose Regions near Amazon renewable energy projects and Regions where the grid has a published carbon intensity that is lower than other locations (or Regions).
User behavior patterns	SUS02-BP01 Scale infrastructure with user load	Identify periods of low or no utilization and scale down resources to eliminate excess capacity and improve efficiency.
User behavior patterns	SUS02-BP02 Align SLAs with sustainability goals	Define and update Service Level Agreements (SLAs) such as availability or data retention periods to minimize the number of resources required to support your workload while continuing to meet business requirements
User behavior patterns	SUS02-BP03 Stop the creation and maintenance of unused assets	Analyze application assets and asset access patterns to identify redundancy, underutilization, and potential decommission targets. Consolidate generated assets with redundant content to remove the resources consumed when duplicating outputs. Decommission unused assets to free consumed resources and reduce the number of resources used to support the workload.
User behavior patterns	SUS02-BP04 Optimize geographic placement of workloads for user locations	Analyze network access patterns to identify where your customers are connecting from geographically. Select Regions and services that reduce the distance network traffic must travel to decrease the total network resources required to support your workload
User behavior patterns	SUS02-BP05 Optimize team member resources for activities performed	Optimize resources provided to team members to minimize the sustainability impact while supporting their needs. For example, perform complex operations, such as rendering and compilation, on highly utilized shared cloud desktops instead of on underutilized high-powered single-user systems.
Software and architecture patterns	SUS03-BP01 Optimize software and architecture for asynchronous and scheduled jobs	Use efficient software designs and architectures to minimize the average resources required per unit of work. Implement mechanisms that result in even utilization of components to reduce resources that are idle between tasks and minimize the impact of load spikes.
Software and architecture patterns	SUS03-BP02 Remove or refactor workload components with low or no use	Monitor workload activity to identify changes in utilization of individual components over time. Remove components that are unused and no longer required, and refactor components with little utilization to limit wasted resources.
Software and architecture patterns	SUS03-BP03 Optimize areas of code that consume the most time or resources	Monitor workload activity to identify application components that consume the most resources. Optimize the code that runs within these components to minimize resource usage while maximizing performance.
Software and architecture patterns	SUS03-BP04 Optimize impact on customer devices and equipment	Understand the devices and equipment your customers use to consume your services, their expected lifecycle, and the financial and sustainability impact of replacing those components. Implement software patterns and architectures to minimize the need for customers to replace devices and upgrade equipment.
Software and architecture patterns	SUS03-BP05 Use software patterns and architectures that best support data access and storage patterns	Understand how data is used within your workload, consumed by your users, transferred, and stored. Select technologies to minimize data processing and storage requirements.

AWS Well-Architected Framework - Sustainability Pillar

Data patterns	SUS04-BP01 Implement a data classification policy	Classify data to understand its significance to business outcomes. Use this information to determine when you can move data to more energy-efficient storage or safely delete it.
Data patterns	SUS04-BP02 Use technologies that support data access and storage patterns	Use storage that best supports how your data is accessed and stored to minimize the resources provisioned while supporting your workload.
Data patterns	SUS04-BP03 Use lifecycle policies to delete unnecessary data	Manage the lifecycle of all your data and automatically enforce deletion timelines to minimize the total storage requirements of your workload.
Data patterns	SUS04-BP04 Minimize over-provisioning in block storage	To minimize total provisioned storage, create block storage with size allocations that are appropriate for the workload. Use elastic volumes to expand storage as data grows without having to resize storage attached to compute resources.
Data patterns	SUS04-BP05 Remove unneeded or redundant data	Duplicate data only when necessary to minimize total storage consumed. Use backup technologies that deduplicate data at the file and block level.
Data patterns	SUS04-BP06 Use shared file systems or object storage to access common data	Adopt shared storage and single sources of truth to avoid data duplication and reduce the total storage requirements of your workload. Fetch data from shared storage only as needed. Detach unused volumes to make more resources available.
Data patterns	SUS04-BP07 Minimize data movement across networks	Use shared storage and access data from regional data stores to minimize the total networking resources required to support data movement for your workload.
Data patterns	SUS04-BP08 Back up data only when difficult to recreate	To minimize storage consumption, only back up data that has business value or is needed to satisfy compliance requirements.
Hardware patterns	SUS05-BP01 Use the minimum amount of hardware to meet your needs	Using the capabilities of the cloud, you can make frequent changes to your workload implementations. Update deployed components as your needs change.
Hardware patterns	SUS05-BP02 Use instance types with the least impact	Continually monitor the release of new instance types and take advantage of energy efficiency improvements, including those instance types designed to support specific workloads such as machine learning training, inference, and video transcoding.
Hardware patterns	SUS05-BP03 Use managed services	Managed services shift responsibility for maintaining high-average utilization, and sustainability optimization of the deployed hardware to AWS. Use managed services to distribute the sustainability impact of the service across all tenants of the service, reducing your individual contribution.
Hardware patterns	SUS05-BP04 Optimize your use of GPUs	Graphics Processing Units (GPUs) can be a source of high-power consumption, and many GPU workloads are highly variable, such as rendering, transcoding, and machine learning training and modeling.

AWS Well-Architected Framework - Sustainability Pillar

Development and deployment process	SUS06-BP01 Adopt methods that can rapidly introduce sustainability improvements	Test and validate potential improvements before deploying them to production. Account for the cost of testing when calculating potential future benefit of an improvement. Develop low-cost testing methods to enable delivery of small improvements.
Development and deployment process	SUS06-BP02 Keep your workload up-to-date	Up-to-date operating systems, libraries, and applications can improve workload efficiency and enable easier adoption of more efficient technologies.
Development and deployment process	SUS06-BP03 Increase utilization of build environments	Use automation and infrastructure-as-code to bring pre-production environments up when needed and take them down when not used.
Development and deployment process	SUS06-BP04 Use managed device farms for testing	Managed device farms spread the sustainability impact of hardware manufacturing and resource usage across multiple tenants.

Network

- Location - choose for clean energy **and proximity to the end user**
- Use CDN to be closer to more users
- Optimize to lower network transfer

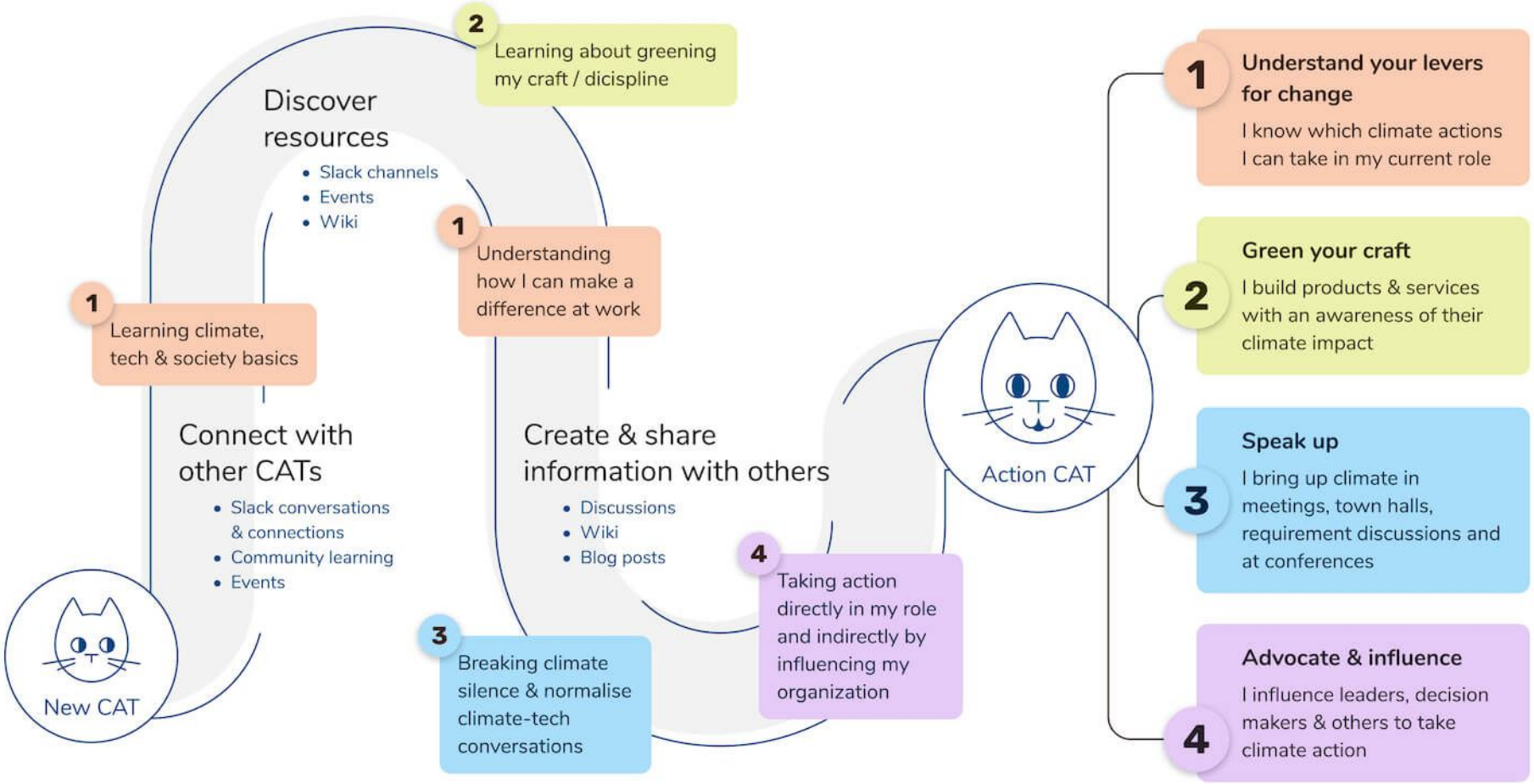
DNS and Software Abuse

- Networking is the stage for DNS abuse and so much of the internet's traffic is due to abuse like Spam, Phishing, Botnets, Malware leading to all forms of DDOS
- 40% of all traffic comes from bots

Getting Involved

ClimateAction.tech

A community of practice of tech workers that provides support and guidance for systemic change in our organisations and industries, to face the climate crisis.


New CAT
1
Learning climate, tech & society basics
Connect with other CATs
• Slack conversations & connections
• Community learning
• Events
Discover resources
• Slack channels
• Events
• Wiki
2
Learning about greening my craft / dicispline
1
Understanding how I can make a difference at work
Create & share information with others
• Discussions
• Wiki
• Blog posts
3
Breaking climate silence & normalise climate-tech conversations
4
Taking action directly in my role and indirectly by influencing my organization
Action CAT
1
Understand your levers for change
I know which climate actions I can take in my current role
2
Green your craft
I build products & services with an awareness of their climate impact
3
Speak up
I bring up climate in meetings, town halls, requirement discussions and at conferences
4
Advocate & influence
I influence leaders, decision makers & others to take climate action

W3C Sustainability

- Create guidelines, tools, and resources for web and digital professionals to incorporate environmental sustainability and related principles into their workflows and work practices
- Committees
  - UX Design
  - Web Development
  - Hosting, Infrastructure, Systems
  - Analytics, Measurement, Reporting
  - Business Strategy, Product Management
- I have been contributing to the Infra committee
- https://www.w3.org/community/sustyweb/

W3C Sustainability - Infrastructure

- Guideline 1.1 : Choose a sustainable hosting provider
- Guideline 1.2 : Limit usage of additional environments
- Guideline 1.3 : Automate to fit the needs
- Guideline 1.4 : Test for non-regression
- Guideline 1.5 : Frequency for refresh is relevant to user needs
- Guideline 1.6 : Duplication of data is relevant to user needs
- Guideline 1.7 : Measure and display
- Guideline 1.8 : Enable asynchronous processing and communication
- Guideline 1.9 : Use server-side caching
- Guideline 1.10: Use edge computing
- Guideline 1.11: Use lowest infrastructure tier meeting business
- Guideline 1.12 : Store data according to user needs

W3C Sustainability - WebDev

- Guideline 1.1: Minify your HTML, CSS and JavaScript
- Guideline 1.2: Optimize browser caching
- Guideline 1.3: Compress your files
- Guideline 1.4: Use code-splitting within projects
- Guideline 1.5: Apply tree shaking to code
- Guideline 1.6: Ensure content and code are accessible
- Guideline 1.7: Avoid code duplication
- Guideline 1.8: Set a project performance budget
- Guideline 1.9: Avoid using plug-ins or inefficient third party tooling
- Guideline 1.10: Use error pages and redirects carefully

W3C Sustainability - WebDev

- Guideline 2.1: Use HTML elements correctly
- Guideline 2.2: Lazy Load render blocking content
- Guideline 2.3: Provide suitable way-finding mechanisms
- Guideline 2.4: Validate form errors and external input
- Guideline 2.5: Description
- Guideline 3.1: Use CSS preference & media queries
- Guideline 3.2: Develop a mobile-first layout
- Guideline 4.1: Avoid unethical coding techniques
- Guideline 4.2: Use beneficial JavaScript & its API's
- Guideline 4.3: Ensure your scripts are secure
- Guideline 4.4: Manage dependencies

For us at Element 84

- Awareness - this presentation, your own research
- Measure - “What gets measured gets done”
- Help our customers know their cloud and web carbon footprint and help them with compliance and reporting
- Speak about web sustainability within our industry
- If nothing else let’s just make the fastest software around

References

- Green Web Foundation
- W3C Web Sustainability
- GCP PUE
- Etsy Estimating kWH in cloud
- Cloud carbon footprint
- Green Energy Efficient Progressive Web Apps
- 20 ways to make your website more energy efficient
- How Web Content Can Affect Power Usage
- Reduce the carbon emissions of your website

Fin