Your cloud emits CO2

Olivier Bierlaire

🐦 🐙 @obierlaire

elastic

CARBONIFER

"I have all my infra in the cloud, so I do not emit CO2."

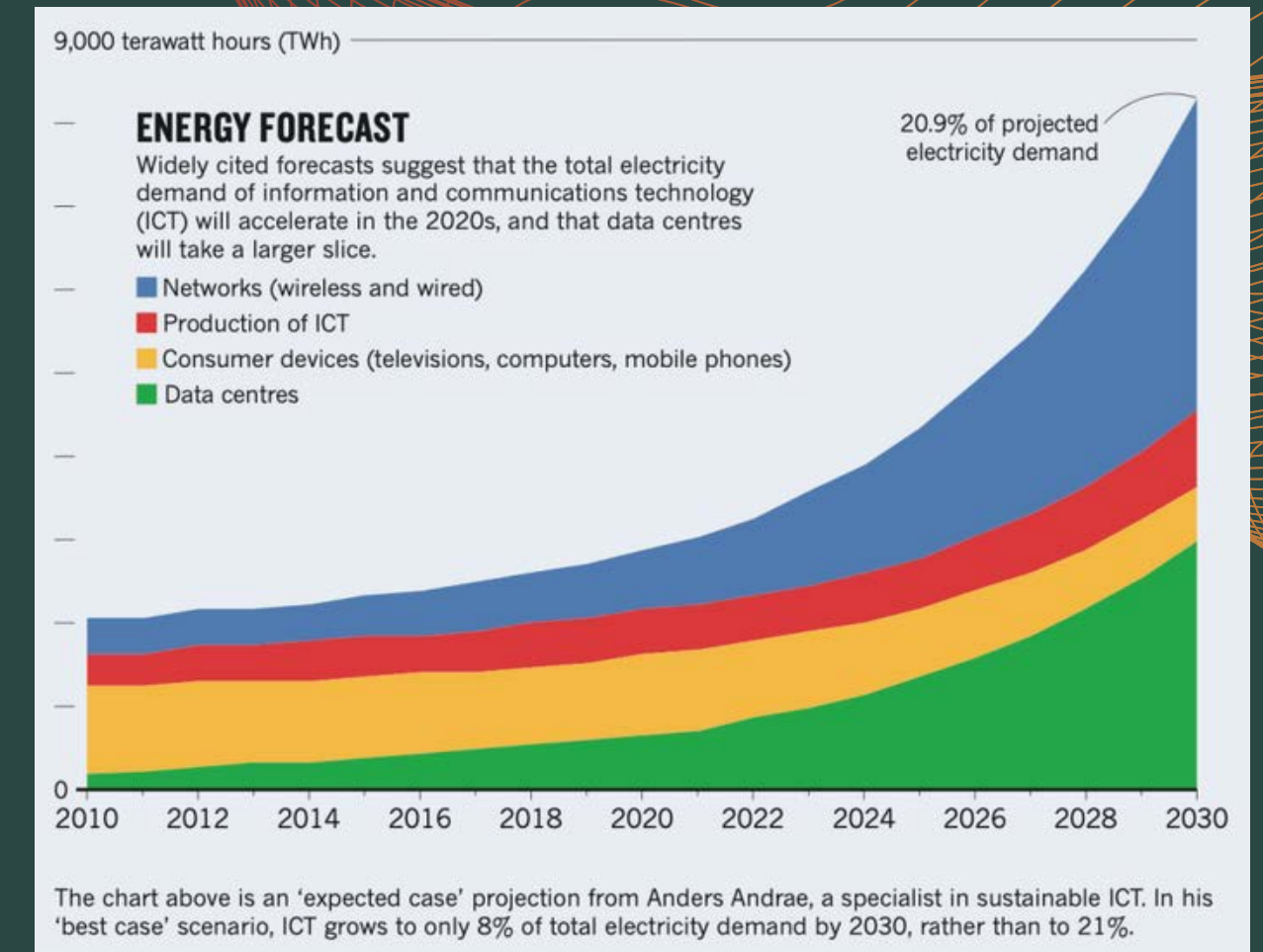# Voracious Datacenters

Distribution of energy consumption per source for the production and use of digital devices in 2017.

[Source: *The Shift Project* 2018, as of Andrae & Edler 2015]
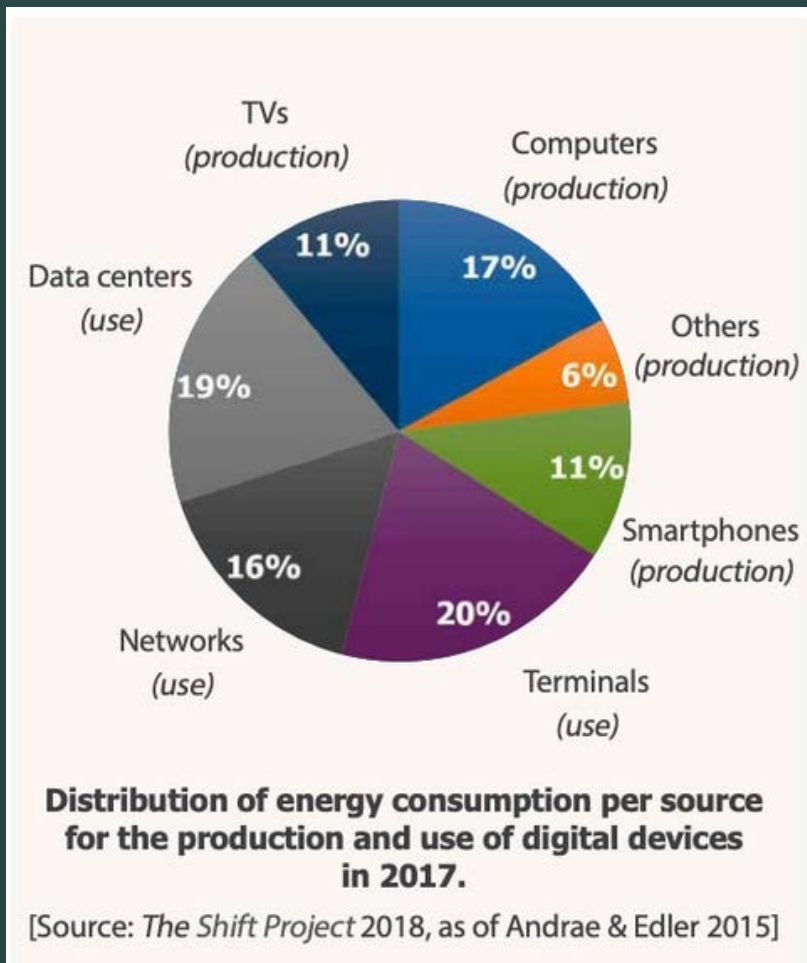
20-25 %

electricity used by the digital sector

1.3 % total electricity worldwide, excluding crypto mining – IEA

9,000 terawatt hours (TWh)

ENERGY FORECAST
Widely cited forecasts suggest that the total electricity demand of information and communications technology (ICT) will accelerate in the 2020s, and that data centres will take a larger slice.

- Networks (wireless and wired)
- Production of ICT
- Consumer devices (televisions, computers, mobile phones)
- Data centres

20.9% of projected electricity demand

The chart above is an 'expected case' projection from Anders Andrae, a specialist in sustainable ICT. In his 'best case' scenario, ICT grows to only 8% of total electricity demand by 2030, rather than to 21%.

Voracious Datacenters

Digital technologies now responsible 4% of greenhouse gas emissions (GHG), and its energy consumption is **increasing by 9% a year** – The Shift Project

Source: IEA

330 Mt CO2

Global cloud computing emissions exceed those from commercial aviation

Share of global CO_2 emission generated by sector/category

Data Centres	3.7% (2.5%)
Aviation	
Shipping	
Rice Cultivation	
Tobacco & Food Processing	

Source: Climatiq Analysis, The Shift Project, OurWorldinData

climatiq
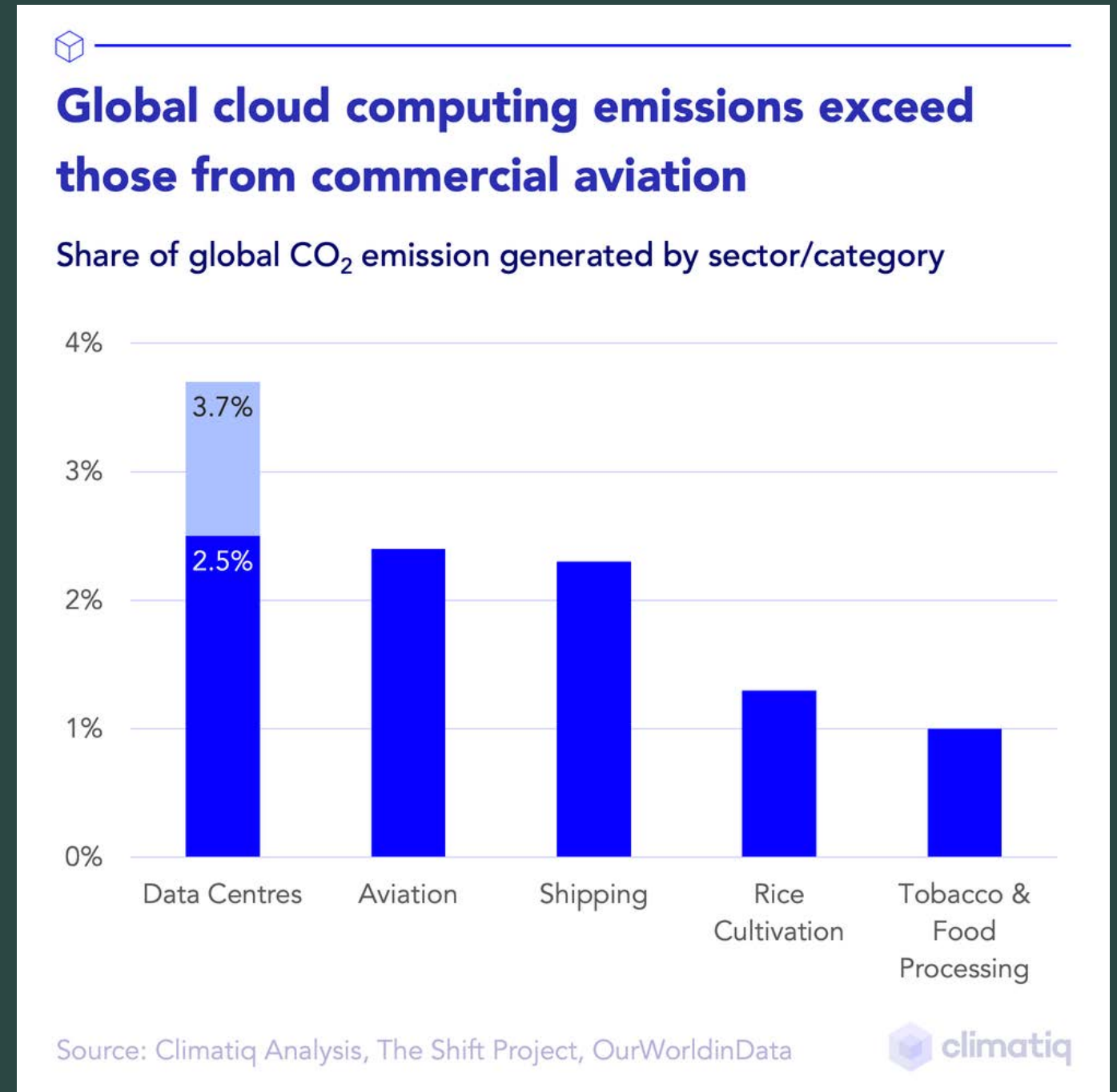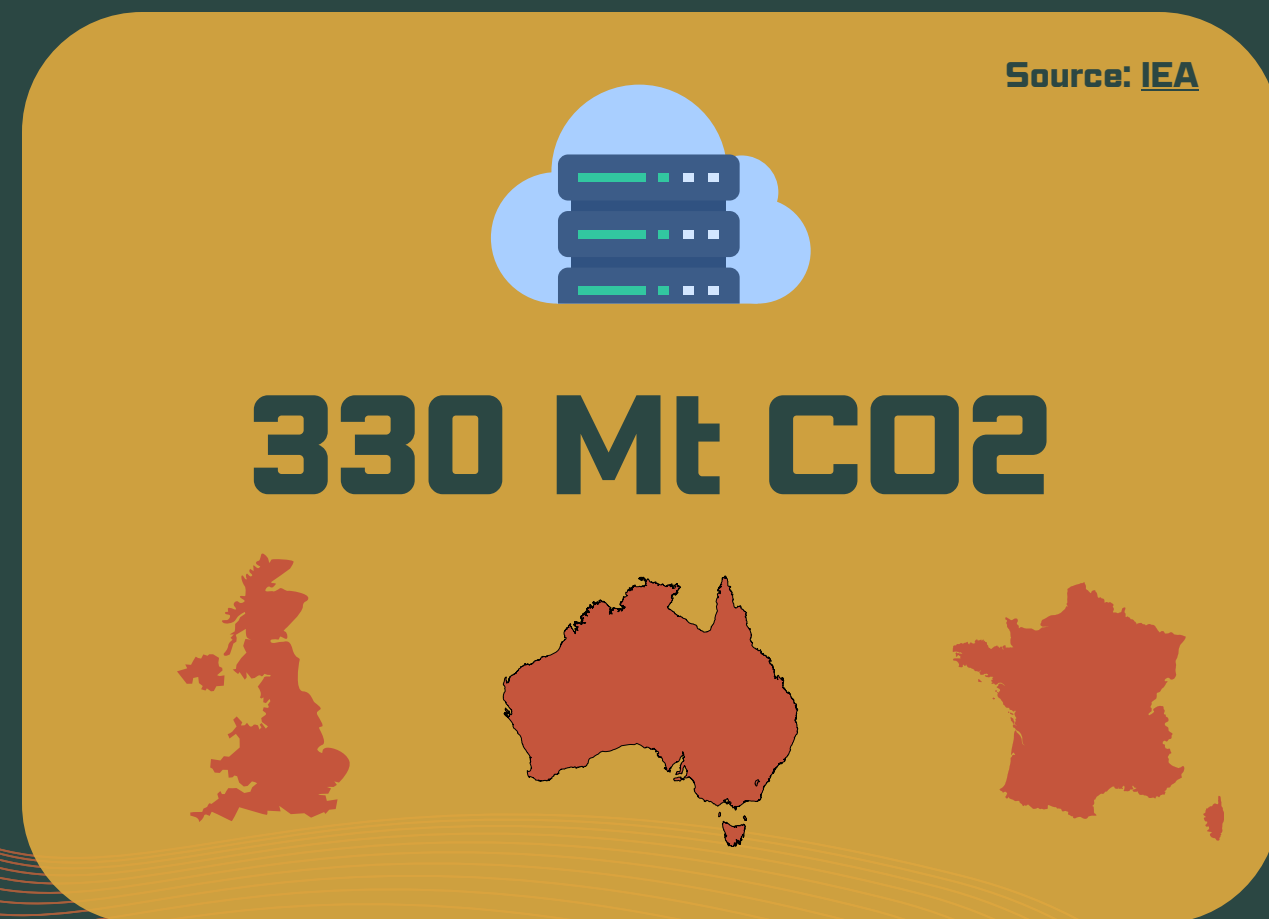
8 % by 2030 ?

Why bothering?

- Regulations and Compliance

- ESG funds

- Recruitment and Staff Retention

- Customer retention

- Cost reduction

The GHG protocol

- **Scope 1** : Direct emissions
- **Scope 2** : Indirect emissions related purchased energy
- **Scope 3** : Other indirect emissions (value chain emissions)
  - business travel
  - raw material purchased
  - services purchased
  - ...

GHG Scope	2	3
Private Cloud	Energy	Embodied
Public Cloud	-	Energy + Embodied
Hybrid Cloud	Some Energy	Some Energy + Embodied
Front End	-	Energy + Embodied

Green Software Foundation
greensoftware.org

creative commons
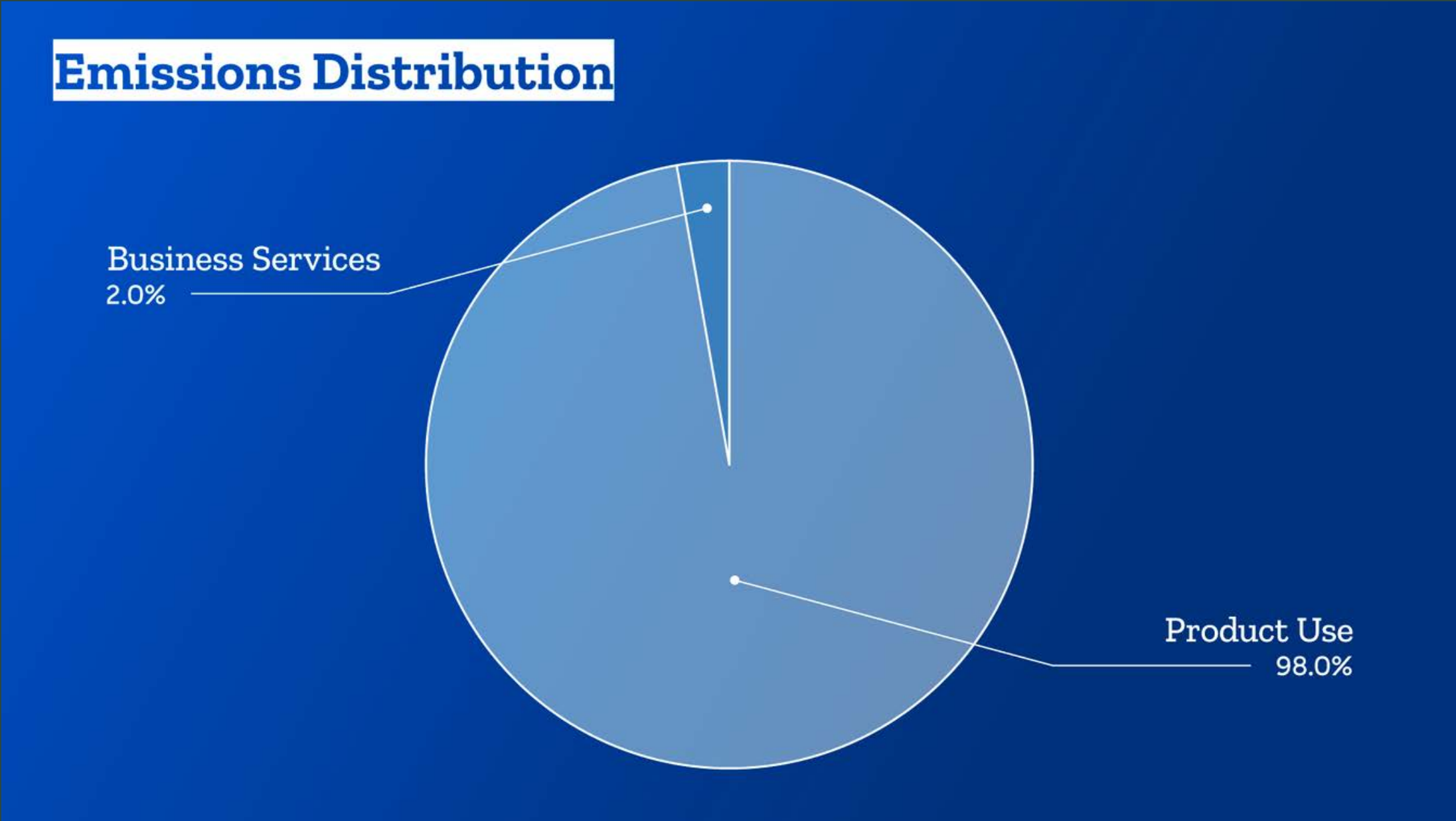
Scope ?

Mozilla - 2019

Regulations

- **CSRD**
  - Corporate Sustainability Reporting Directive
  - 2024 for large companies, 2026 for listed SMEs
  - scope 1,2 and **scope 3**

- **SFDR**
  - Sustainable Finance Disclosure Regulation
  - **financed scope 3**

- **SEC Climate Disclosure Rule**
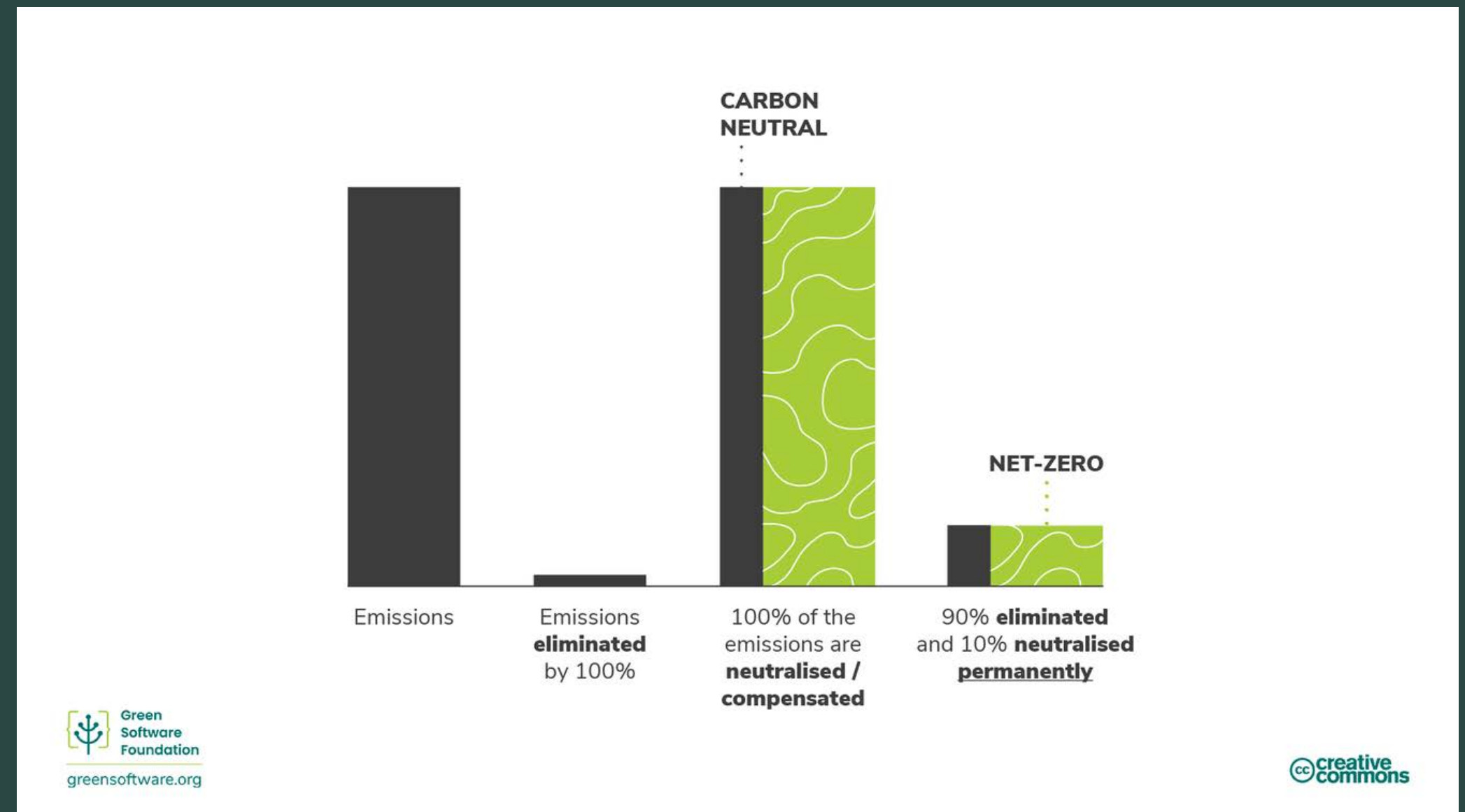 - scope 1,2 (scope 3 optional)
  - 2023

Commitments

- CO2 Offset
  - Compensation
  - Removal

- Elimination:
  - not emitting CO2
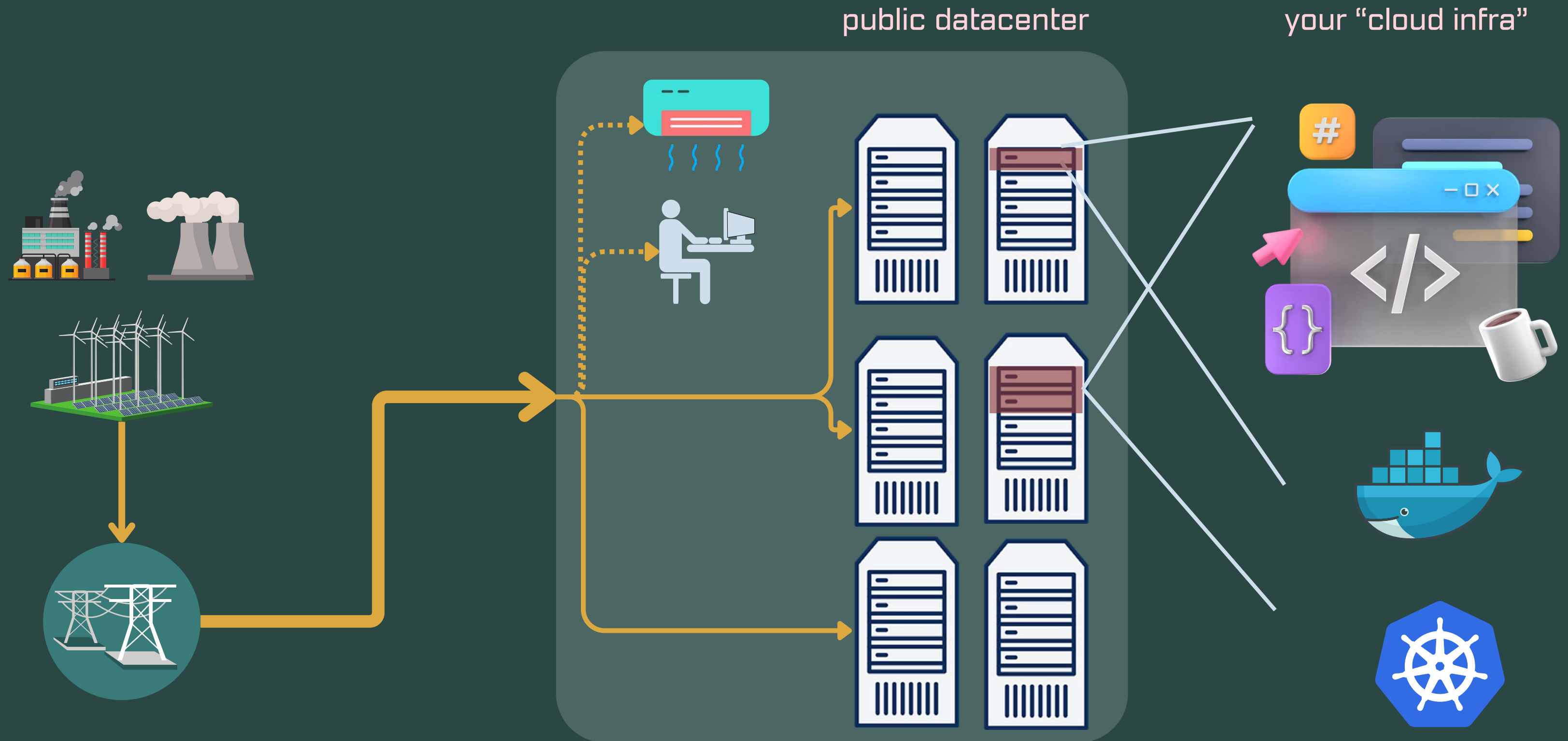 - eliminating source of CO2

Commitments

- **Carbon Neutral**
  - focus on offset

- **Net Zero:**
  - focus on elimination
  - offset the rest

- **100% Renewable**
  - powered by
  - matched by

Measure cloud infrastructure

Powering your cloud

public datacenter

your "cloud infra"

Software Carbon Intensity

Embodied Emissions

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

CO₂

necessary to create

4 YEARS

the lifespan of the server

4000 KG

1000 KG   1000 KG   1000 KG   1000 KG

0   1   2   3   4 YEARS

Green Software Foundation
greensoftware.org

creative commons
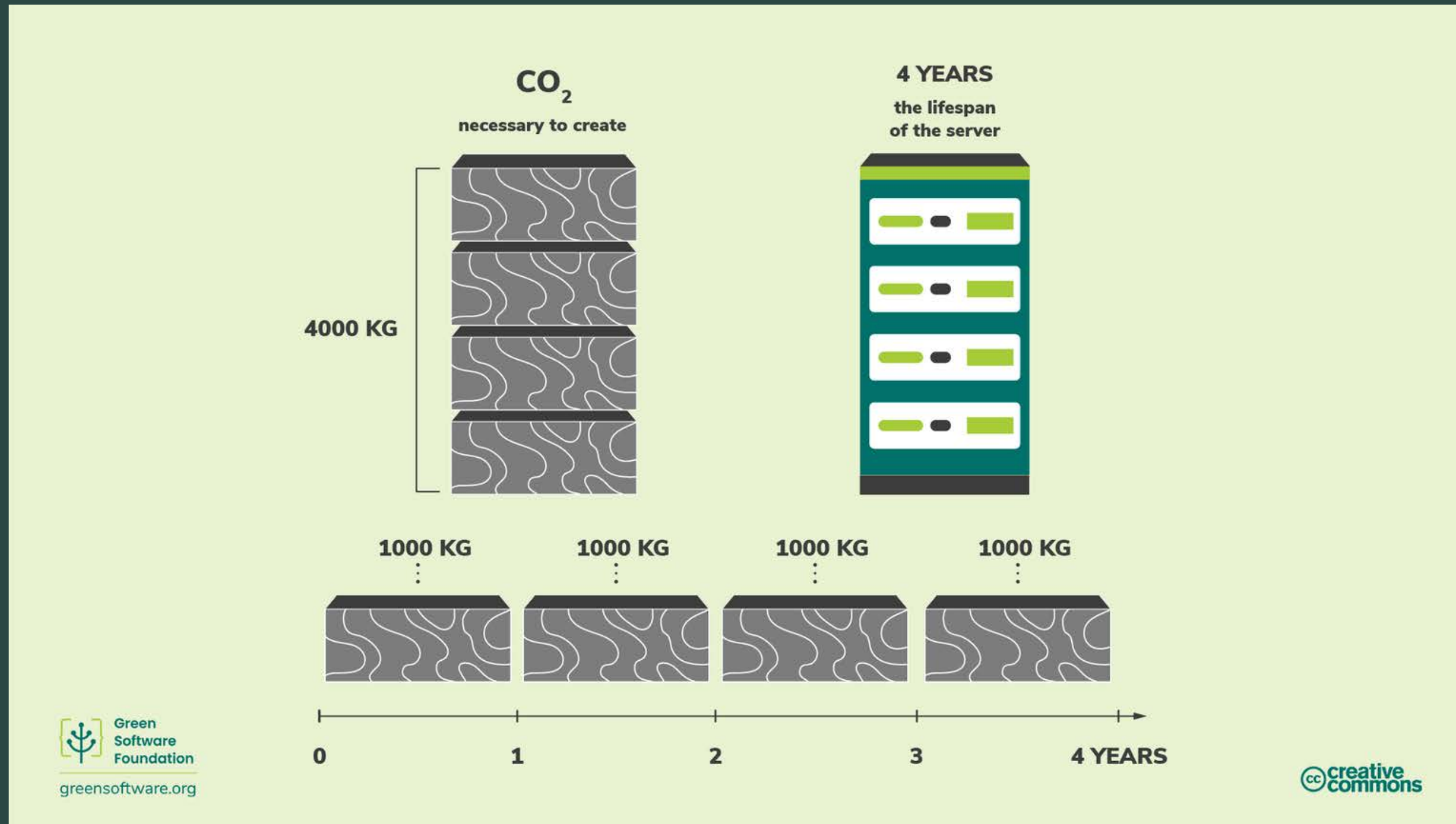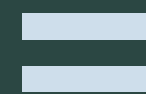
Use Emissions

Energy of software/VM (kWh)

×

Power usage effectiveness (PUE)

×

Carbon intensity of the grid
(gCO2eq / kWh)

=

Greenhouse Gas Emissions
(gCO2eq/h)

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

AWS m4.large : 2 CPU / 8 Gb RAM
50% use
- **10 Wh** = 0.01 kWh

AWS Ireland
- PUE = **1.2**

316 gCO2/kWh

0.01 x 1.2 x 316 =
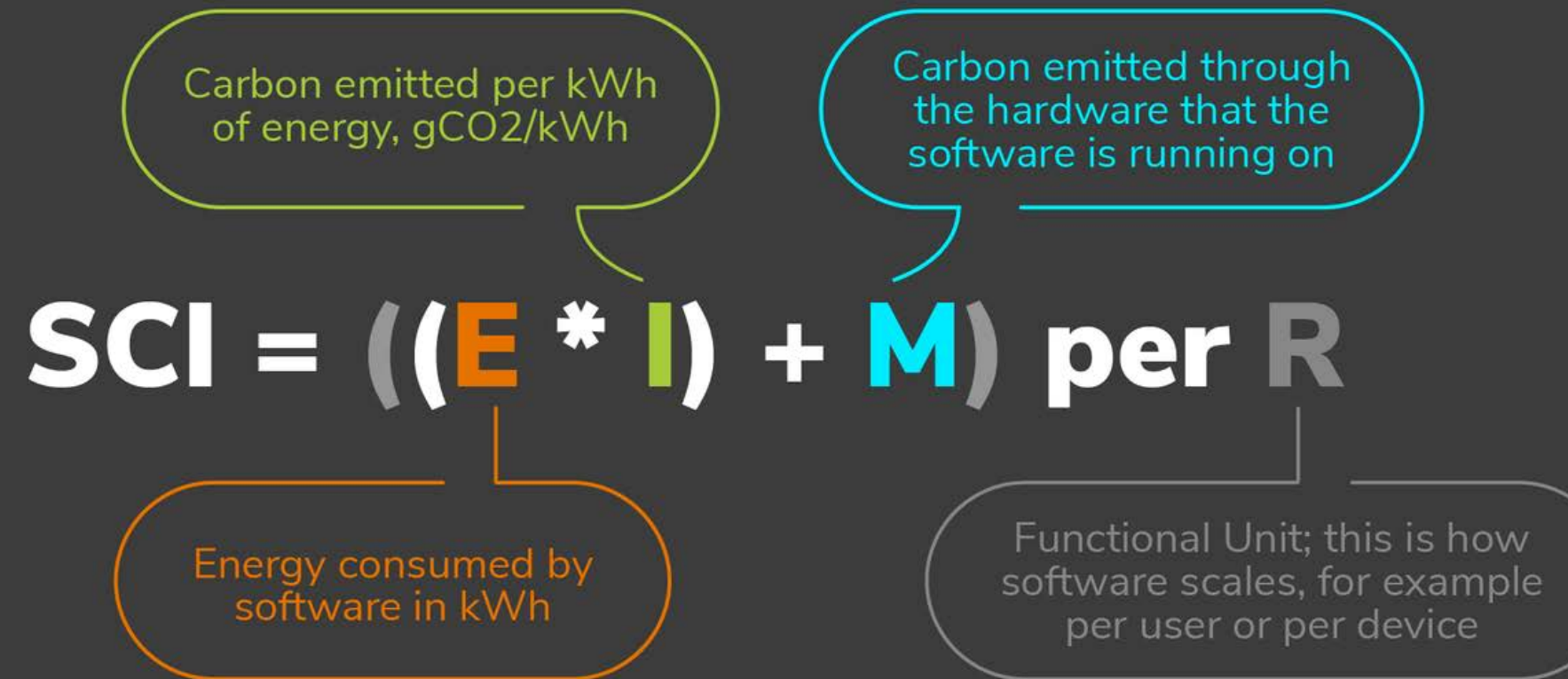**3.8** gCO2eq/h

Software Carbon Intensity

AWS m4.large in Ireland :

$$(E * I) = 3.8 \text{ gCO2} / h$$

$$M = 1.2 \text{ gCO2} / h$$

$$\overline{}$$

$$SCI = 5 \text{ gCO2} / h$$

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

Green Software Foundation
greensoftware.org

creative commons

Available Data

- Average carbon intensity of regional grids (gCO2/kWh)

- Live carbon intensity: app.electricitymaps.com

- Power usage effectiveness (PUE)
  - Amazon Web Services : 1.135
  - Google Cloud : 1.1, ...

"less" available data

- Energy consumed by hardware
  - CPU / GPU
    - Model/type
    - % usage
  - Memory
  - Storage
  - Network
  - => Estimations, Coefficients ...

- Embodied emissions of hardware
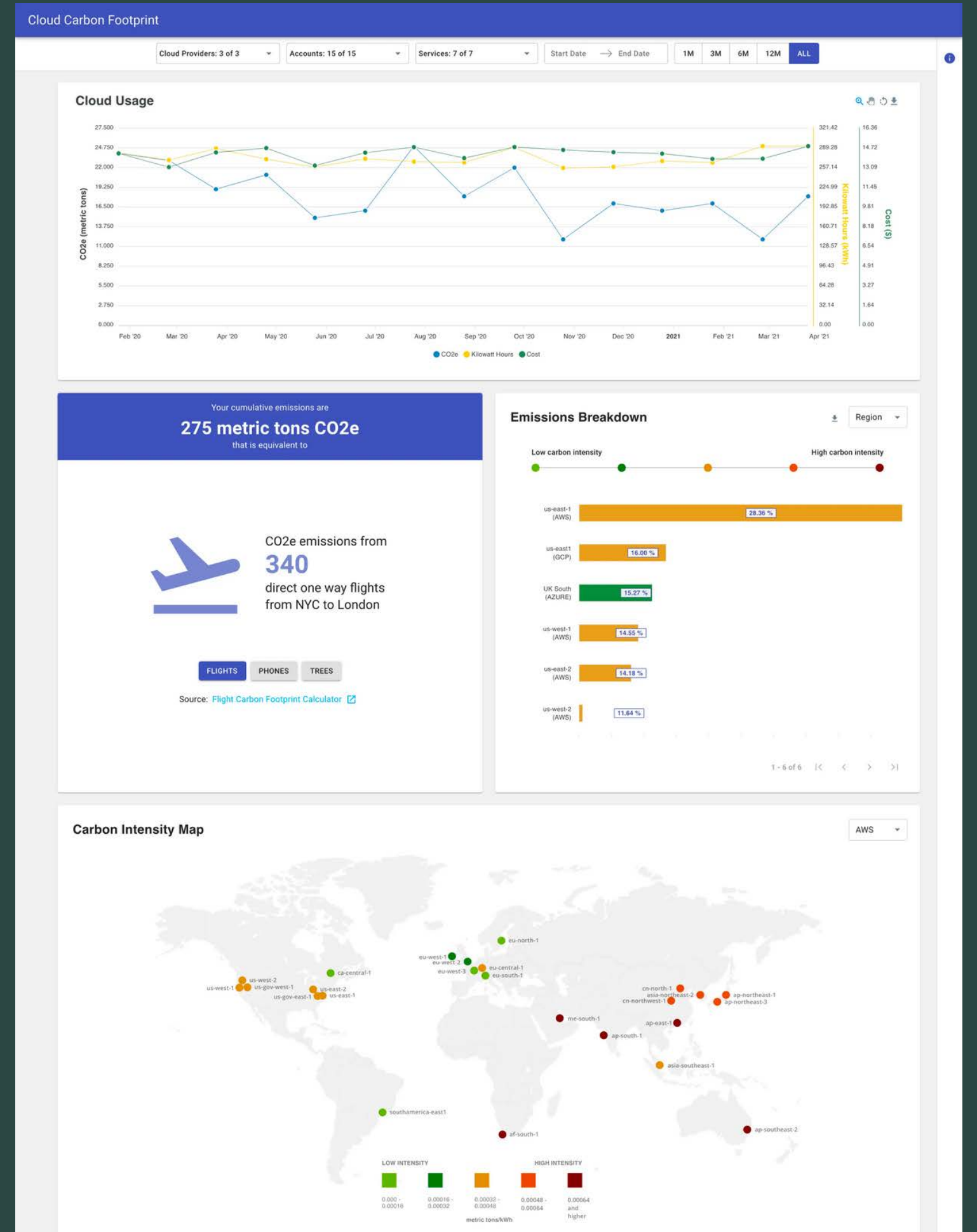
- Energy-mix "weather" predictions

Measure

- Cloud Providers
  - AWS Carbon Footprint Tool
  - Google Cloud Carbon Footprint
  - Microsoft Azure Sustainability Calculator

- Cloud Carbon Footprint
  - read bills: AWS, GCP…

Measure

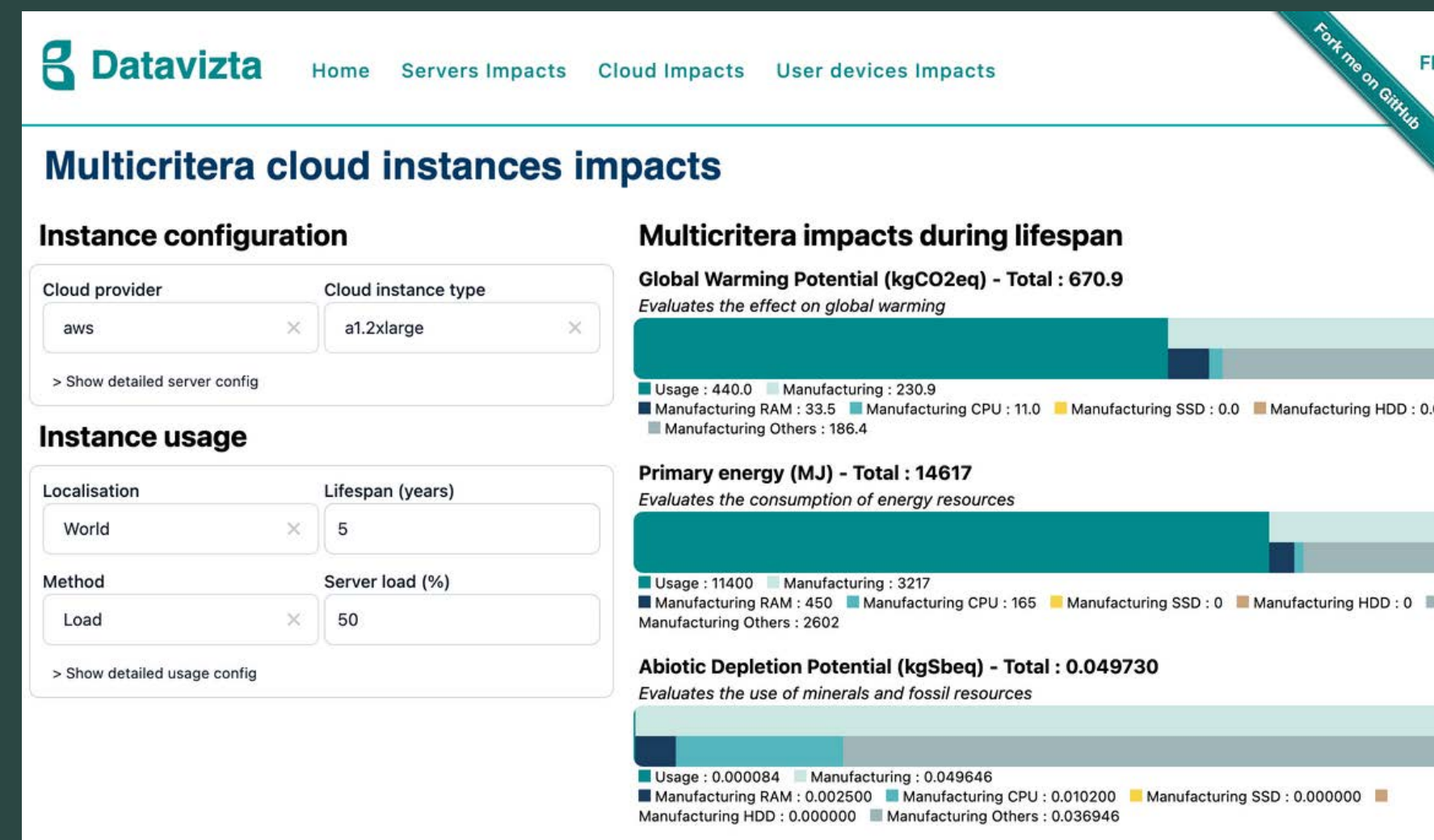- Scaphandre: monitoring CPU power

- Climatiq: API

- Boavista: API

Multicritera cloud instances impacts

Instance configuration

Cloud provider
aws

Cloud instance type
a1.2xlarge

> Show detailed server config

Instance usage

Localisation
World

Lifespan (years)
5

Method
Load

Server load (%)
50

> Show detailed usage config

Multicritera impacts during lifespan

Global Warming Potential (kgCO2eq) - Total : 670.9
Evaluates the effect on global warming

Usage : 440.0   Manufacturing : 230.9
Manufacturing RAM : 33.5   Manufacturing CPU : 11.0   Manufacturing SSD : 0.0   Manufacturing HDD : 0.0
Manufacturing Others : 186.4

Primary energy (MJ) - Total : 14617
Evaluates the consumption of energy resources

Usage : 11400   Manufacturing : 3217
Manufacturing RAM : 450   Manufacturing CPU : 165   Manufacturing SSD : 0   Manufacturing HDD : 0
Manufacturing Others : 2602

Abiotic Depletion Potential (kgSbeq) - Total : 0.049730
Evaluates the use of minerals and fossil resources

Usage : 0.000084   Manufacturing : 0.049646
Manufacturing RAM : 0.002500   Manufacturing CPU : 0.010200   Manufacturing SSD : 0.000000
Manufacturing HDD : 0.000000   Manufacturing Others : 0.036946

Carbonifer

- https://github.com/carboniferio/carbonifer
- https://carbonifer.io
- opensource
- **estimates Terraform project**

CARBONIFER

```
resource "google_compute_instance" "example" {
    name = "example"
    machine_type = "e2-standard-2"
    zone = "europe-west9-a"

    boot_disk {
      initialize_params {
        image = "debian-cloud/debian-11"
        size = 567
        type = "pd-balanced"
      }
    }
}
```

resource type	name	count	emissions per instance
google_compute_instance	example	1	0.5692 gCO2eq/h
	Total	1	0.5692 gCO2eq/h

Green Software Foundation

- https://github.com/Green-Software-Foundation/awesome-green-software

Reduction

Reduction

- Green-coding / Software Ecodesign

- Choice of instance type
  - Right size
  - Last generation (graviton...)

- Migrate to
  - Hyperscaler
  - "net-zero" datacenter?

- Keep it to a minimum
  - auto-scaling groups
  - containers
  - ...
- Change region / zone
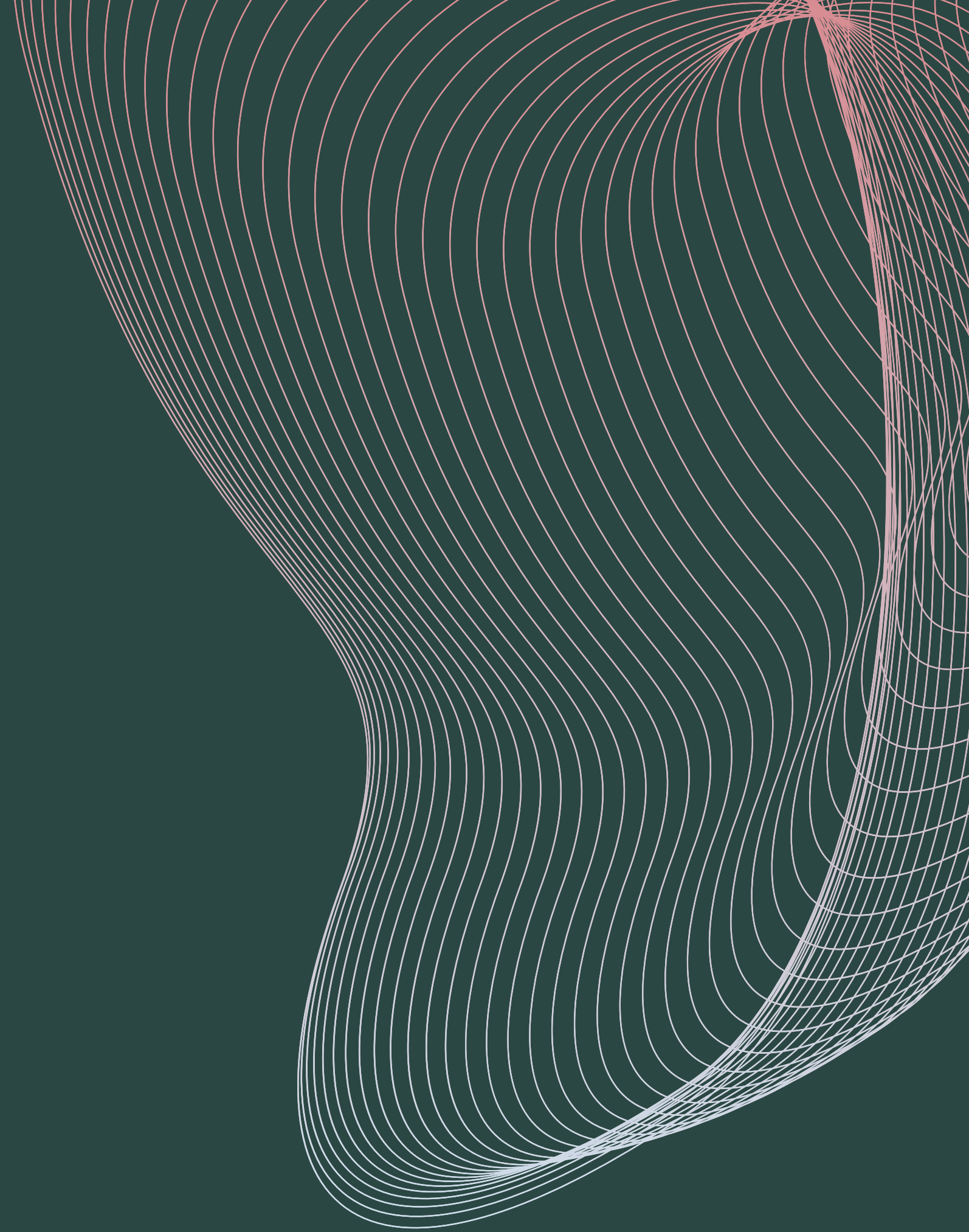
Hyperscalers

aws

Net–Zero by 2040
100% renewable energy by 2025

...

Google Cloud

Net–Zero by 2030
50% emissions by 2030
(scope 1,2,3)

Microsoft

Carbon Negative by 2030
50% emissions by 2030
(scope 1,2,3)

DENV-R

EXOSCALE

...

on premise
numerous underused servers

cloud
fewer highly used server

Improvement:
- PUE (AC, ..)
- Hardware Lifespane
- Renewable energy

⚠️ Rebound effect

FinOps => GreenOps

Autoscaling Groups
Scheduled Scaling
Serverless

⚠️ Reserved Instances

night

day

NOT SURE IF I AM SAVING MONEY
OR SAVING PLANET EARTH
imgflip.com

Choose your region

Google Cloud Region	Location	Google CFE	Grid carbon intensity (gCO2eq / kWh)
europe-central2	Warsaw	0.24	738
europe-north1	Finland	0.97	112
europe-southwest1	Madrid	0.67	160
europe-west1	Belgium	0.80	123
europe-west2	London	0.85	166
europe-west3	Frankfurt	0.96	413
europe-west4	Netherlands	0.57	317
europe-west6	Zurich	0.85	118
europe-west8	Milan	0.42	323
europe-west9	Paris	0.87	71
europe-west12	Turin	0.42	323

Carbon Awareness

CARBON INTENSITY

400

CO₂

1h long

100

0

00:00 01:00 02:00 03:00 04:00 05:00 06:00 07:00 08:00 TIME

CO₂

1h long

Run software when the carbon intensity is low

01:00 02:00 03:00
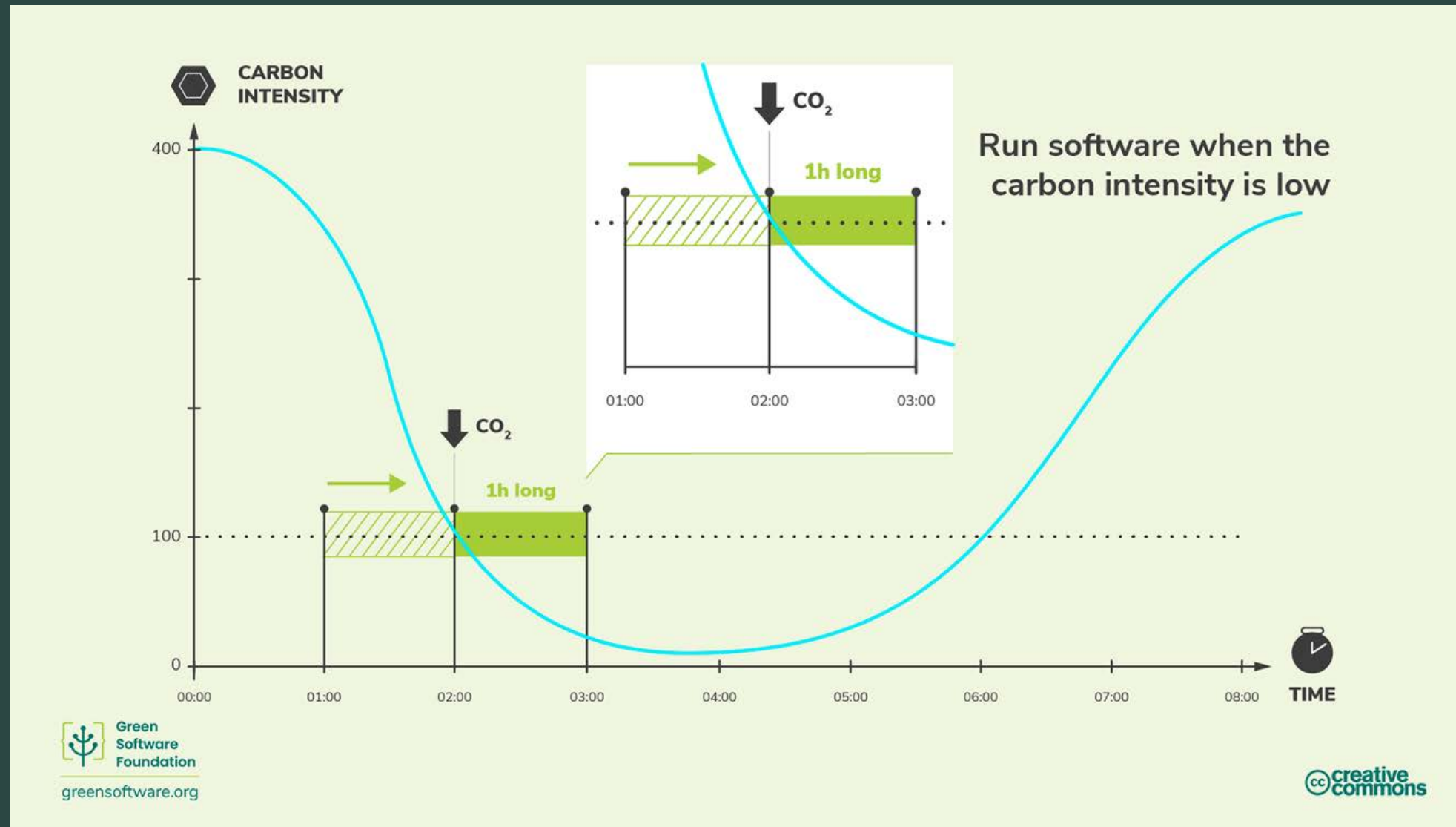
Green Software Foundation
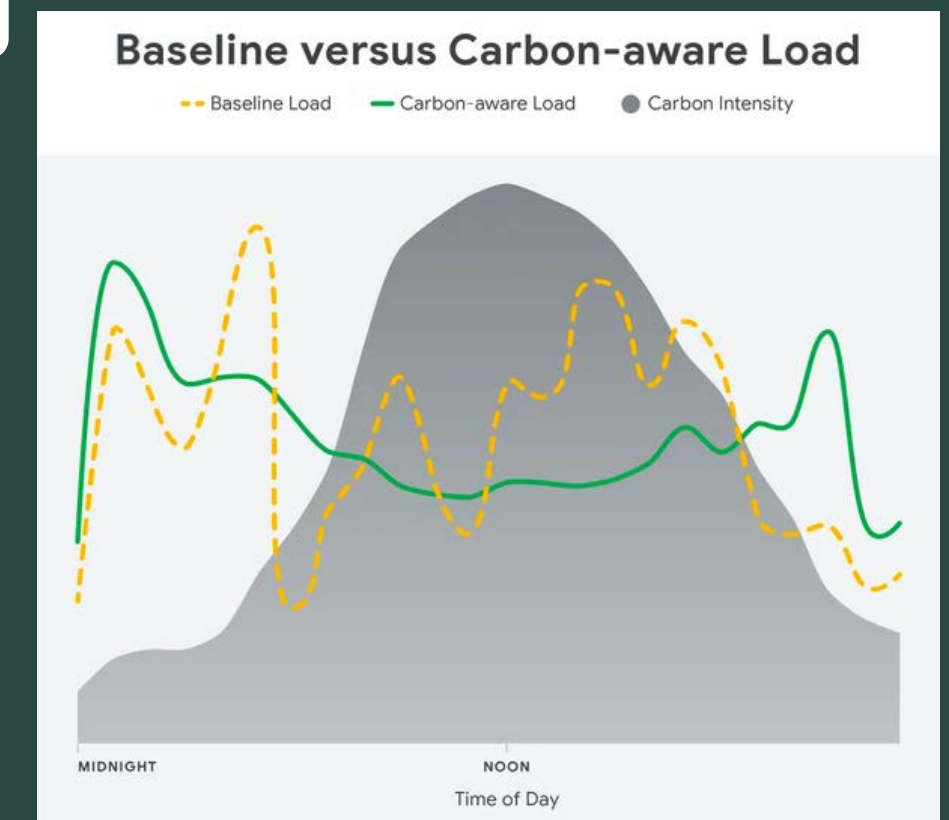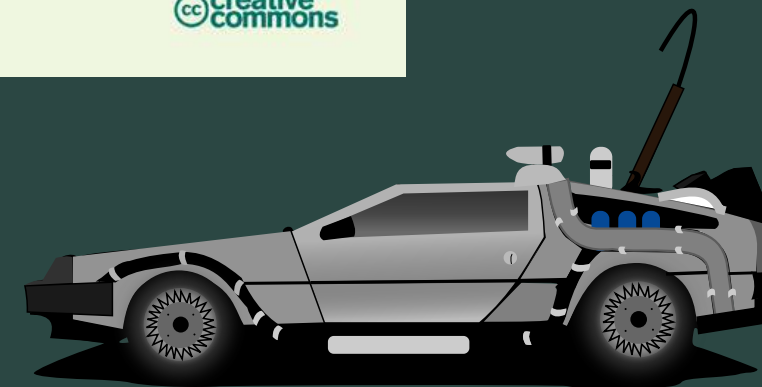greensoftware.org

creative commons
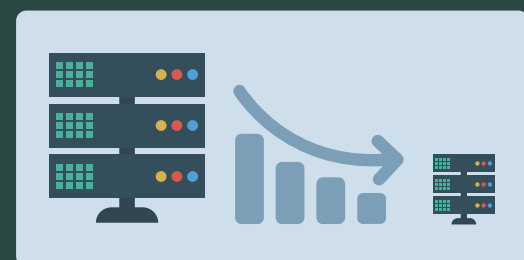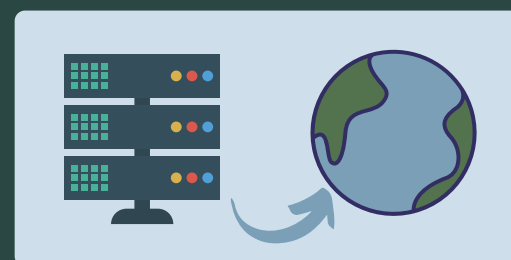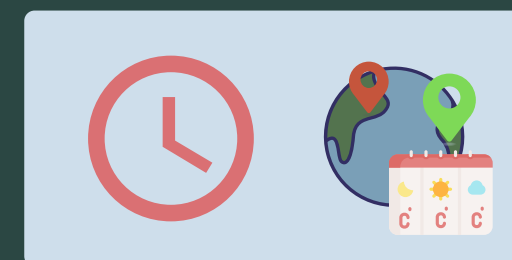
Temporal Shifting

Examples :
- Image/Video processing
- AI model traning
- Machine Learning
- DB indexing
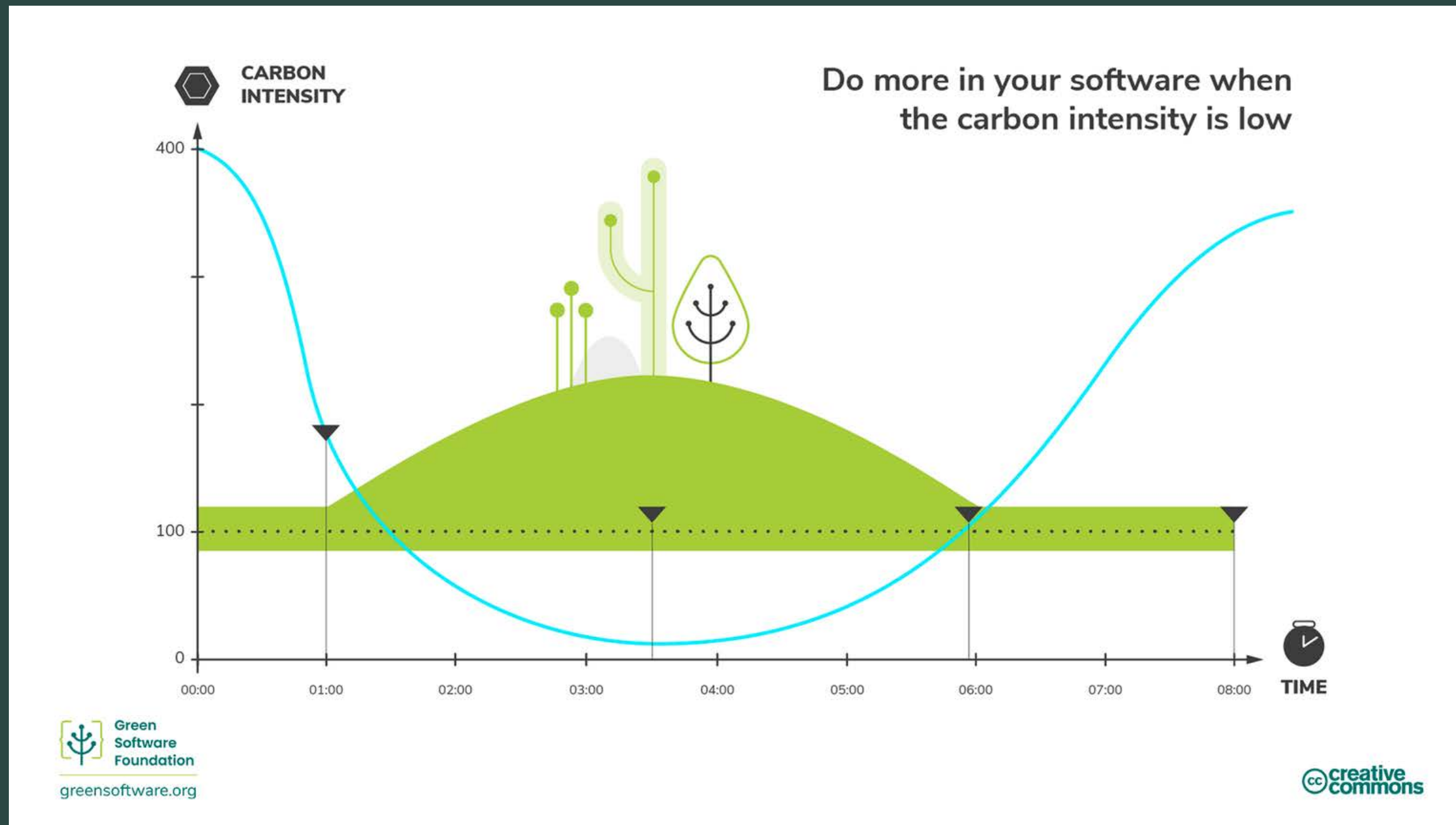
Studies show these actions can result in 45% to 99%

At Google:

Baseline versus Carbon-aware Load

-- Baseline Load — Carbon-aware Load • Carbon Intensity

MIDNIGHT   NOON

Time of Day

Carbon Awareness

Do more in your software when the carbon intensity is low

CARBON INTENSITY

Green Software Foundation
greensoftware.org

creative commons

Examples :
- video quality
- CI server

Low resolution meme

Pixel art

Demand Shaping
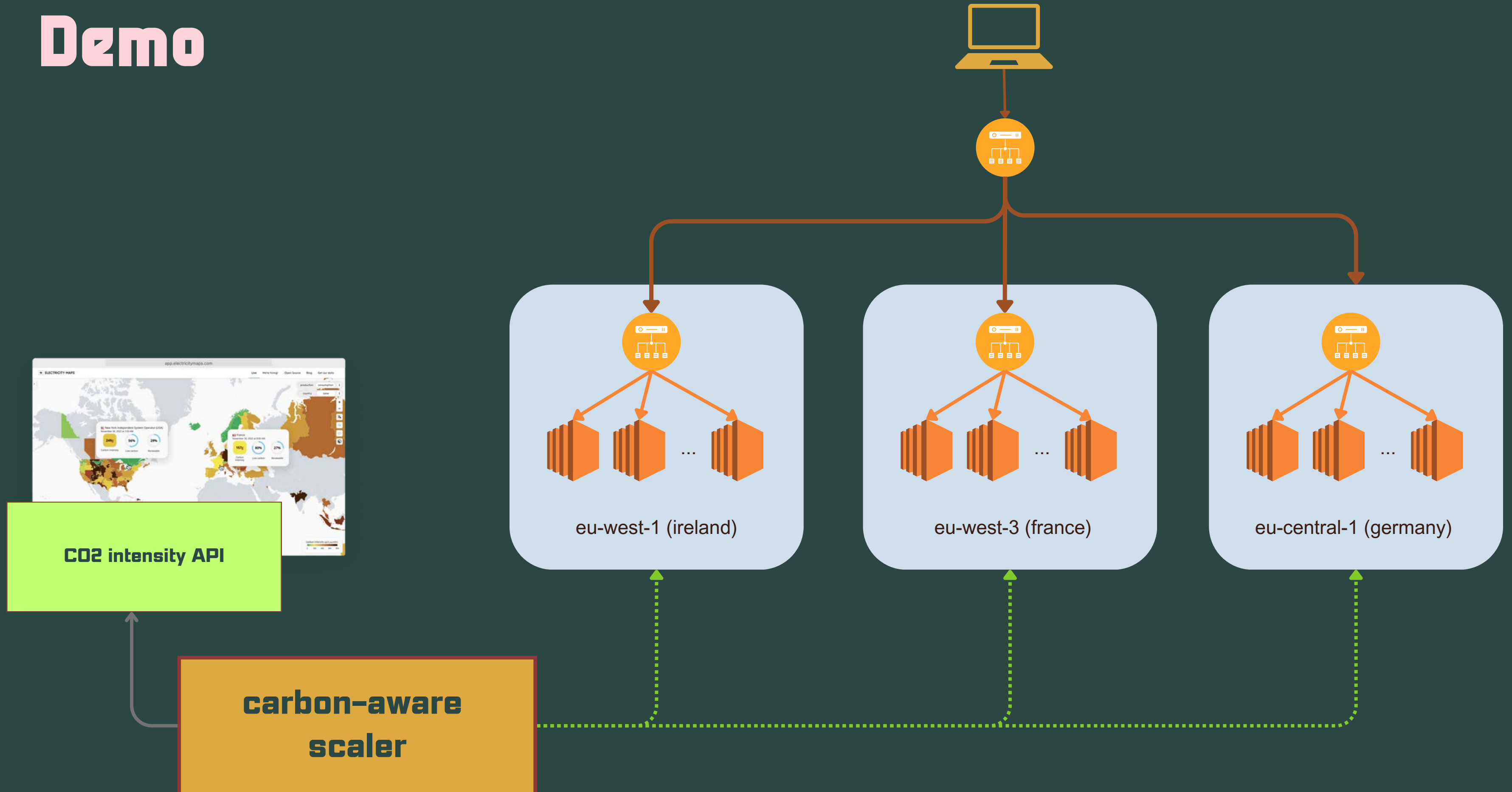
Carbon Awareness

500
gCO2/kWh

20
gCO2/kWh

Spatial Shifting

HotCarbon'23: Bringing Carbon Awareness to Multi-cloud Application Delivery:
21 % reduction (51% with acceptable latency)

Demo
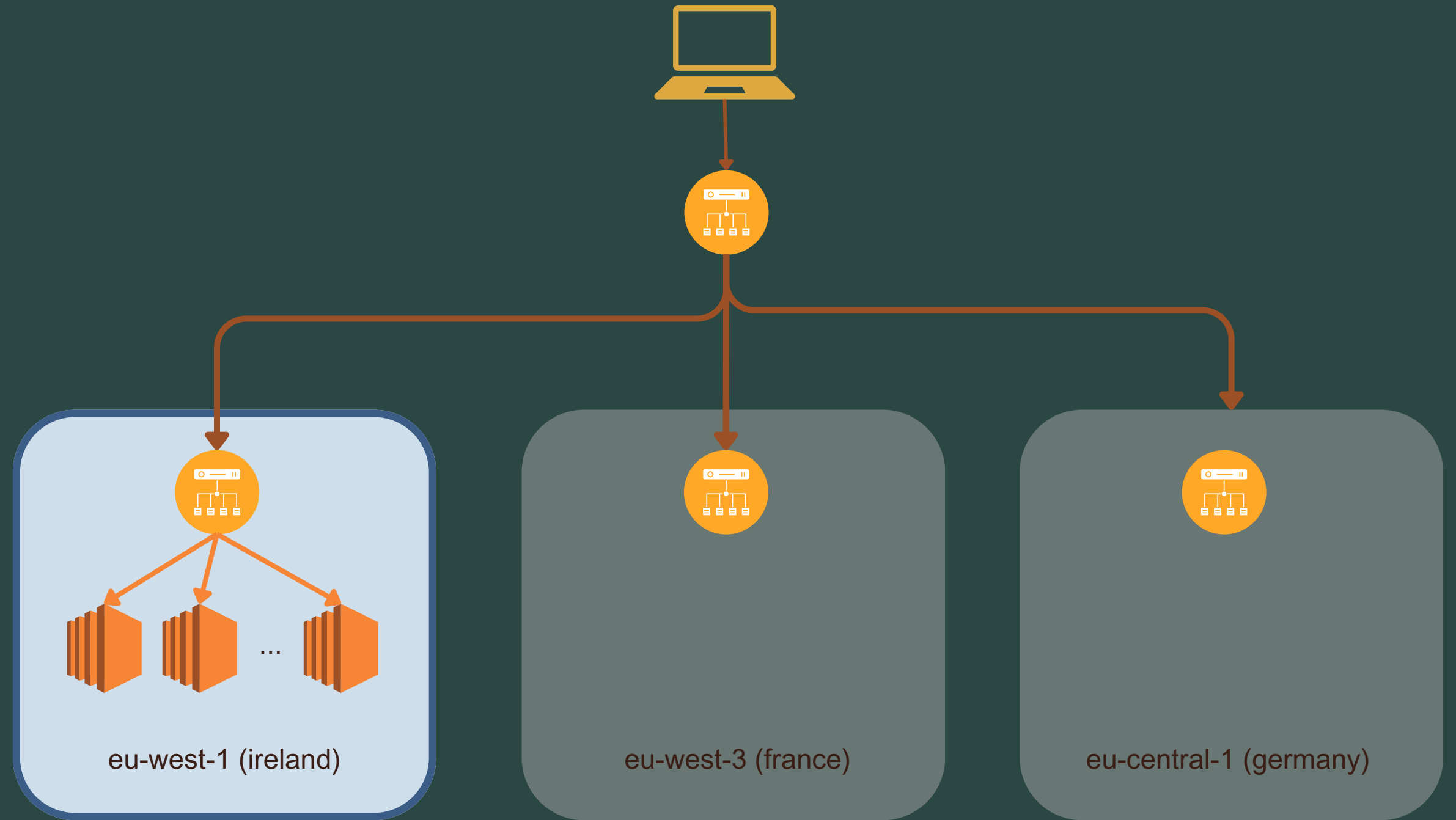
CO2 intensity API

carbon-aware scaler

eu-west-1 (ireland)

eu-west-3 (france)

eu-central-1 (germany)

Demo

Ireland	**61 gCO2/kWh**
France	**112 gCO2/kWh**
Germany	**405 gCO2/kWh**

carbon-aware scaler

eu-west-1 (ireland)

eu-west-3 (france)

eu-central-1 (germany)

Demo

Ireland	**65 gCO2/kWh**
France	**31 gCO2/kWh**
Germany	**357 gCO2/kWh**

eu-west-1 (ireland)

eu-west-3 (france)

eu-central-1 (germany)

carbon-aware scaler

Demo

Ireland	**156 gCO2/kWh**
France	**31 gCO2/kWh**
Germany	**357 gCO2/kWh**

carbon-aware scaler

eu-west-1 (ireland)

eu-west-3 (france)

eu-central-1 (germany)
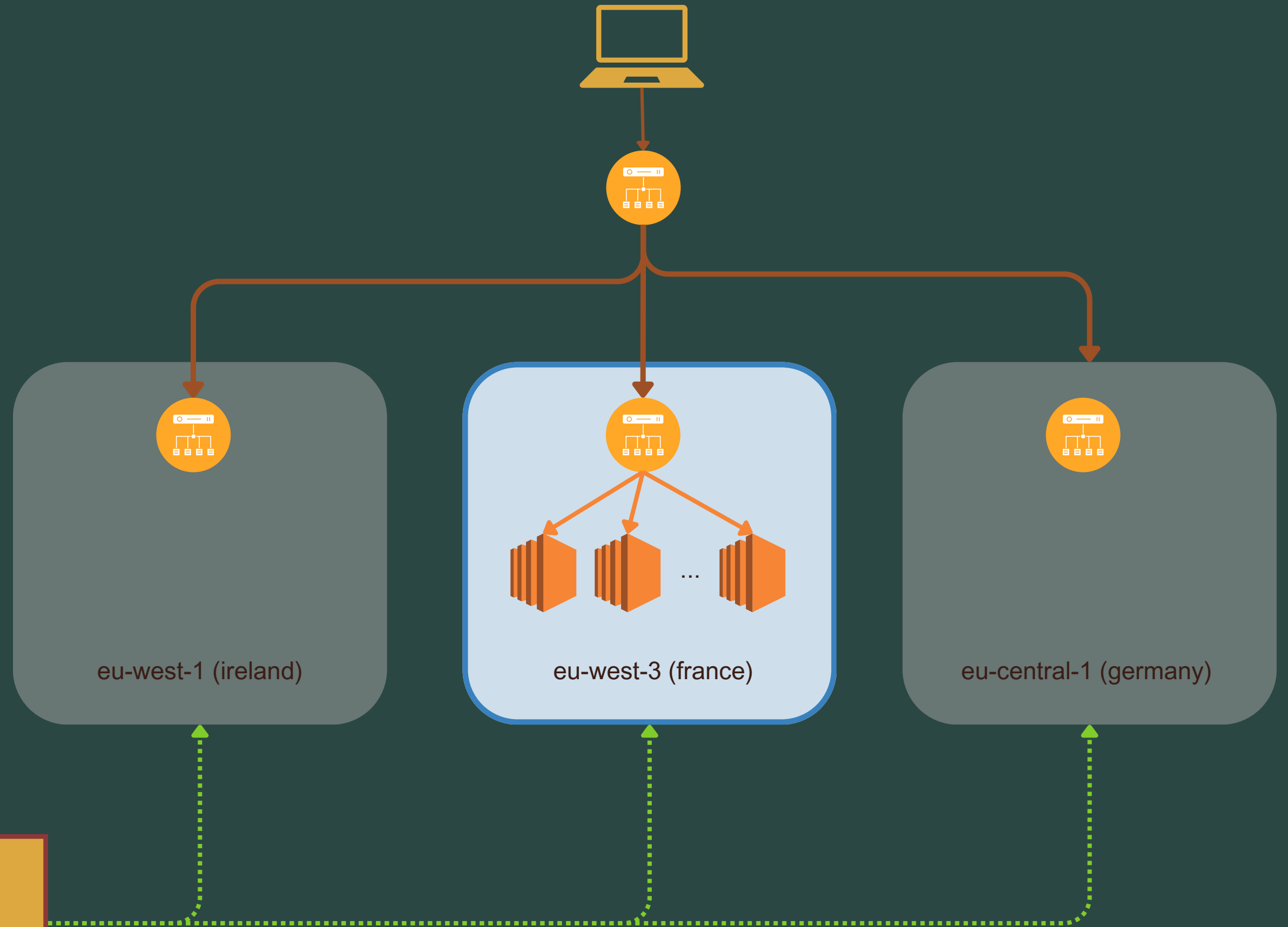
Collect usage metrics

Estimate kWh

Estimate Carbon Emissions (gCO2/h)

Plan / Analyse / Correlate

Actions: reduce, schedule according to grid CO2

Carbon-Awareness

Take-Away

Thank you

✉ olivier@carbonifer.io

🐦 🐙 @obierlaire

in linkedin.com/in/olivierbierlaire

Green Software Foundation

Environment Variables

boavizta.org