Toward a Carbon-Aware Cloud

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elastic

CARBONIFER

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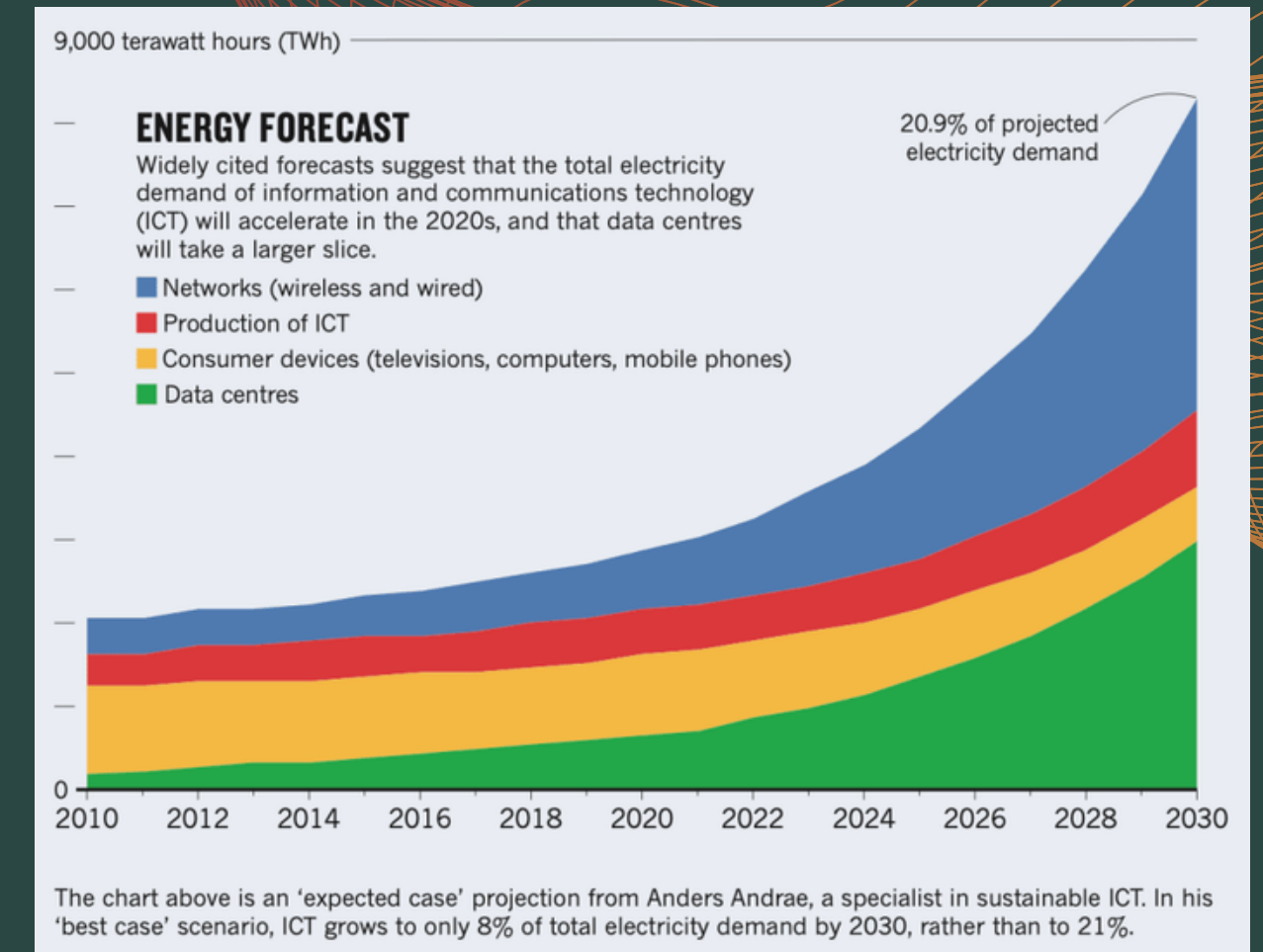
Voracious Datacenters

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]
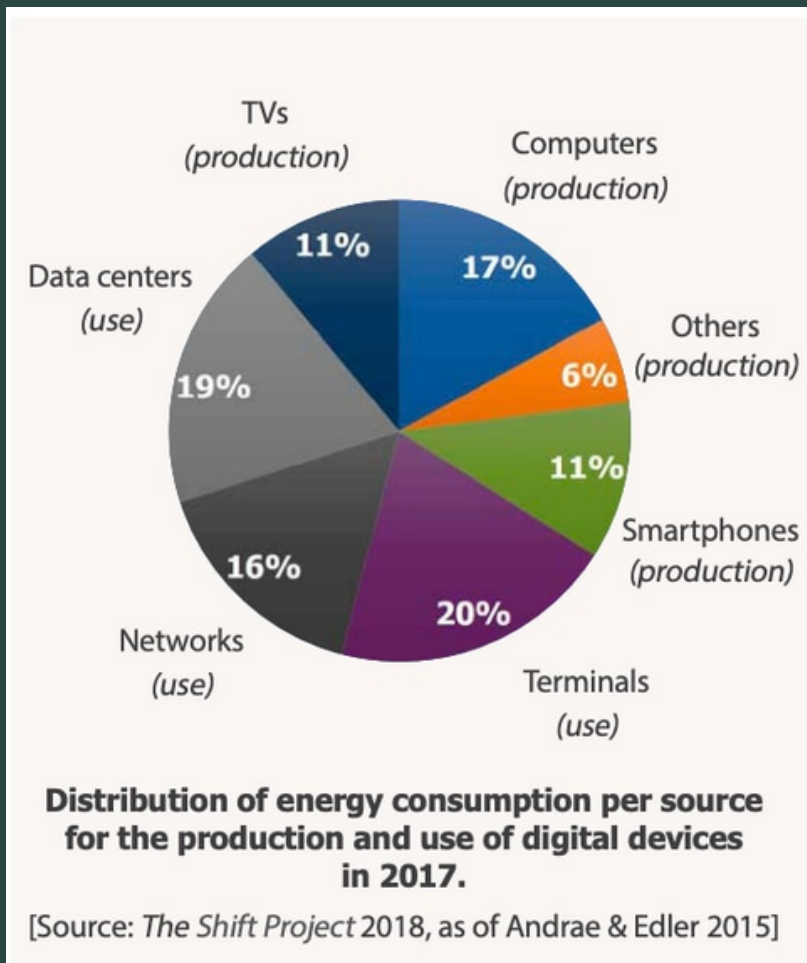
20-25 %

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 emit 4% of greenhouse gas emissions (GHG), and its energy consumption is **increasing by 9% a year** – <u>The Shift Project</u>

Source: <u>IEA</u>

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
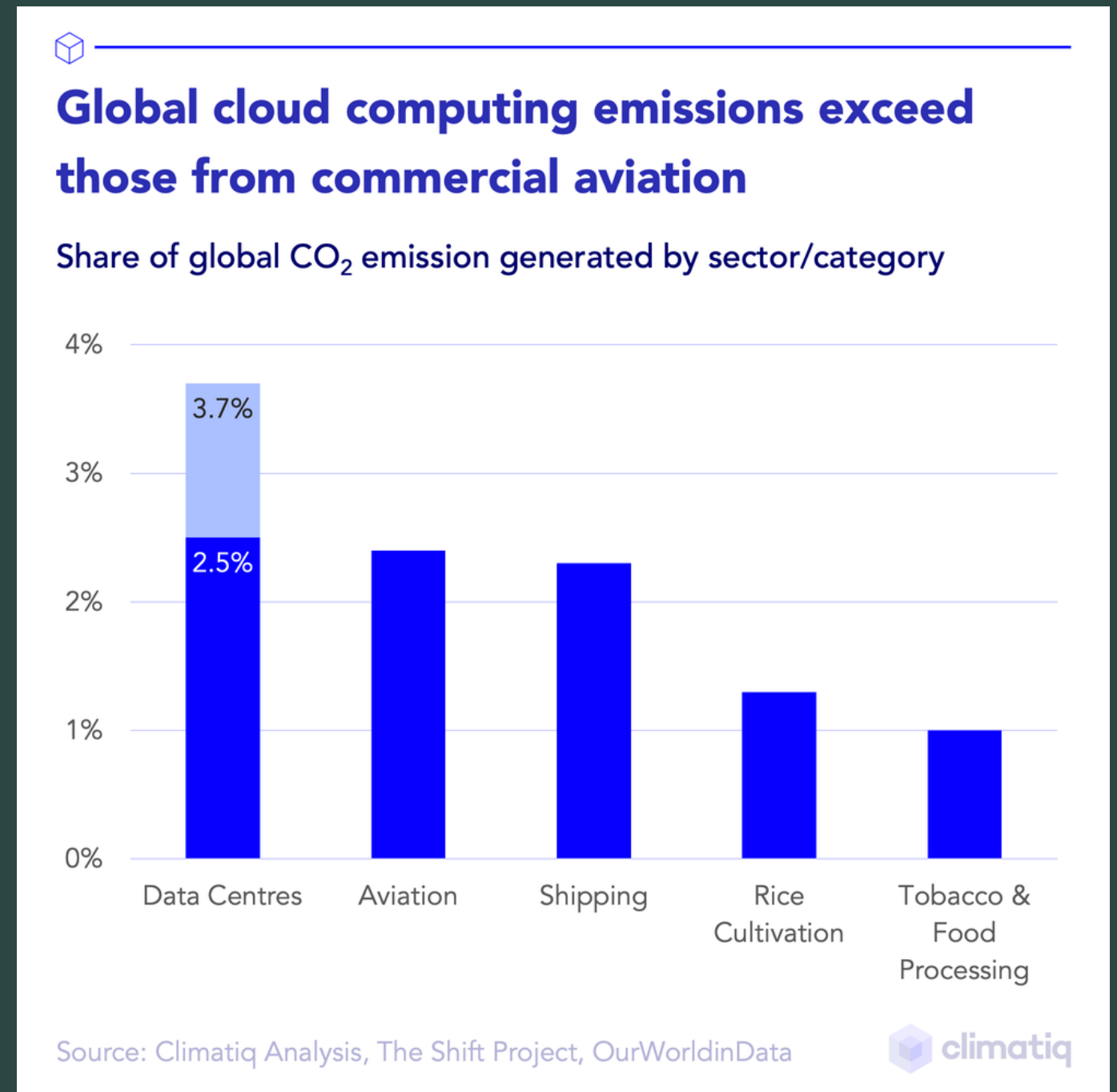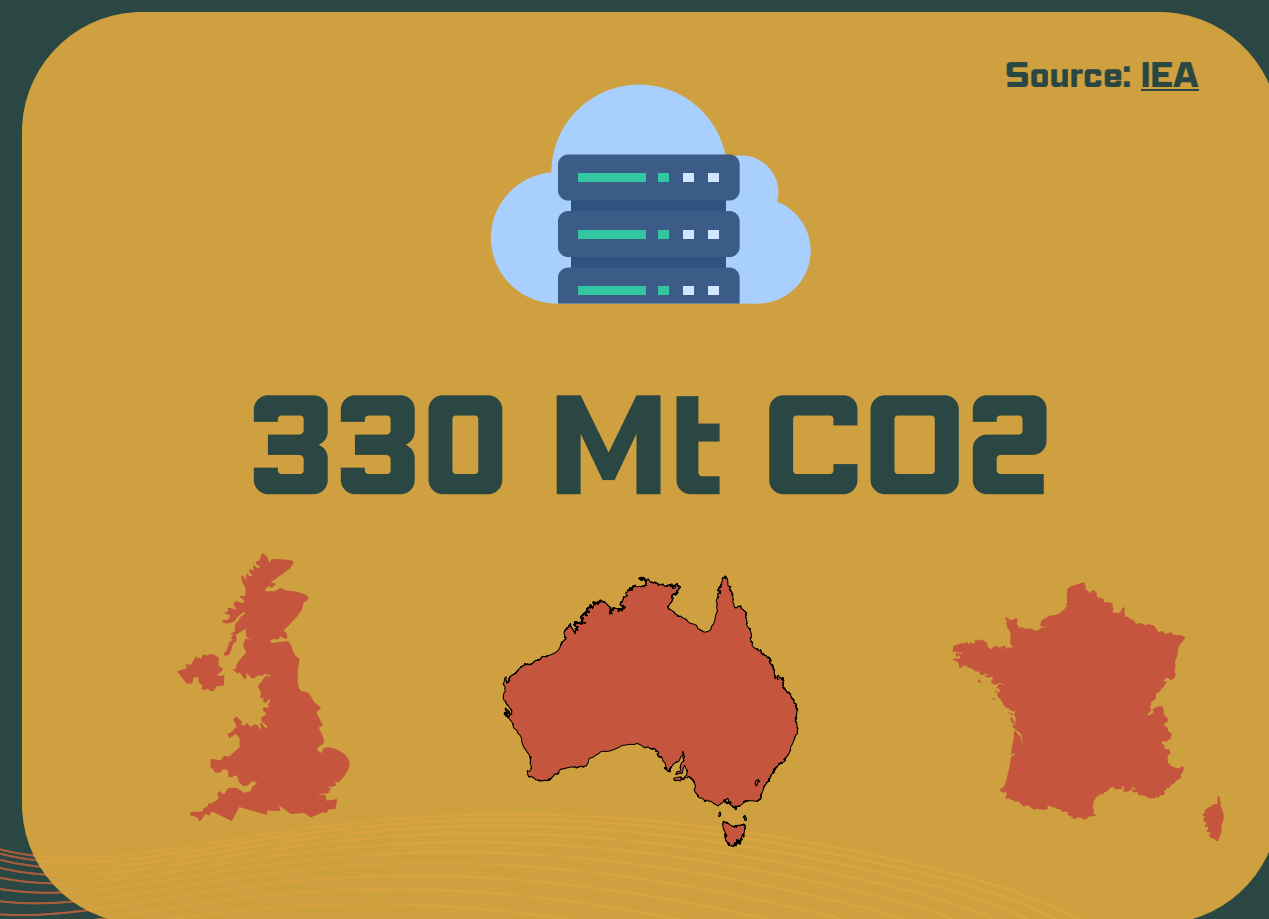
8 % by 2030 ?

Why bothering?

- Regulations and Law 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

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
  - financial sector
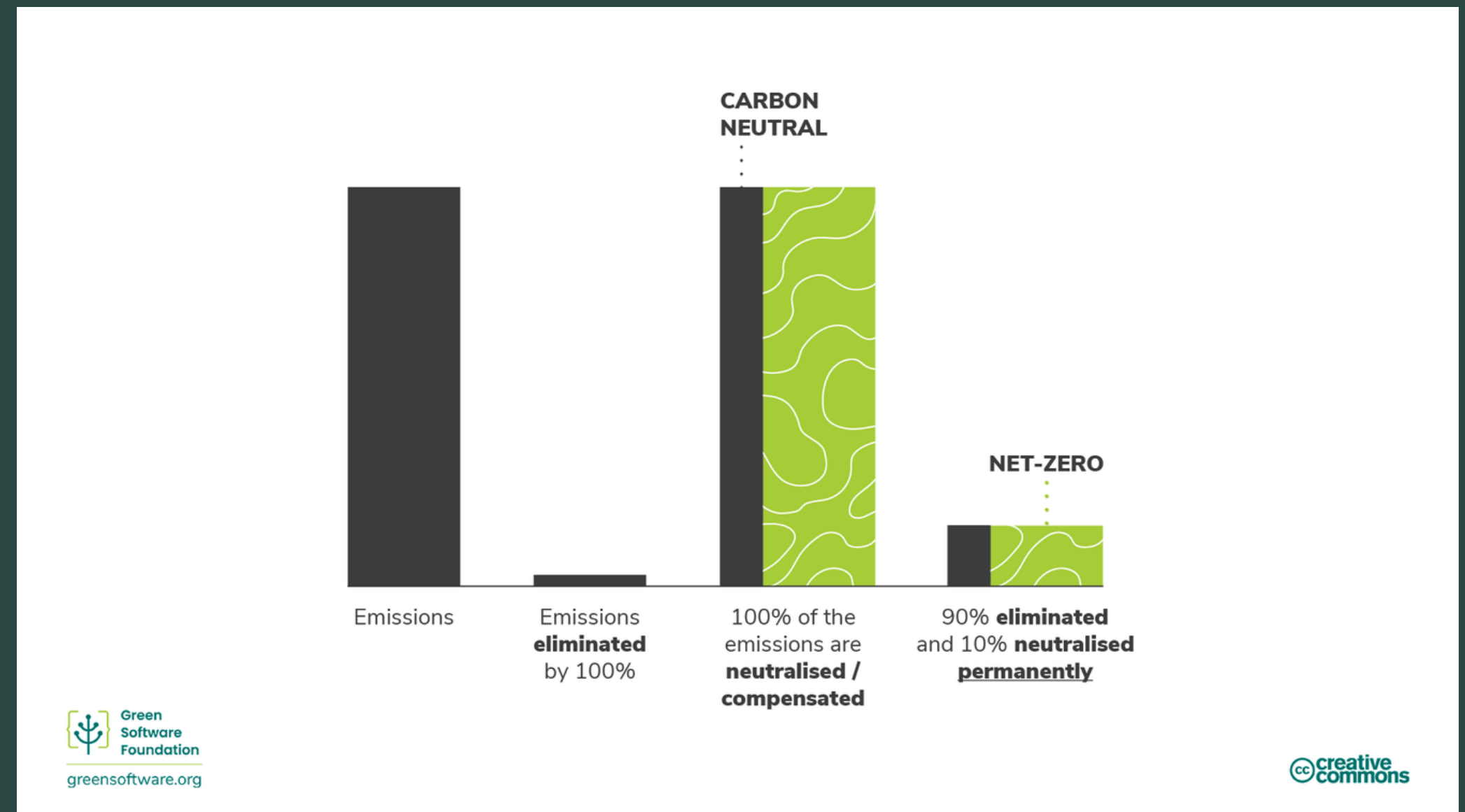 - financed scope 3

Commitments

- CO2 Offset
  - Compensation
  - Removal

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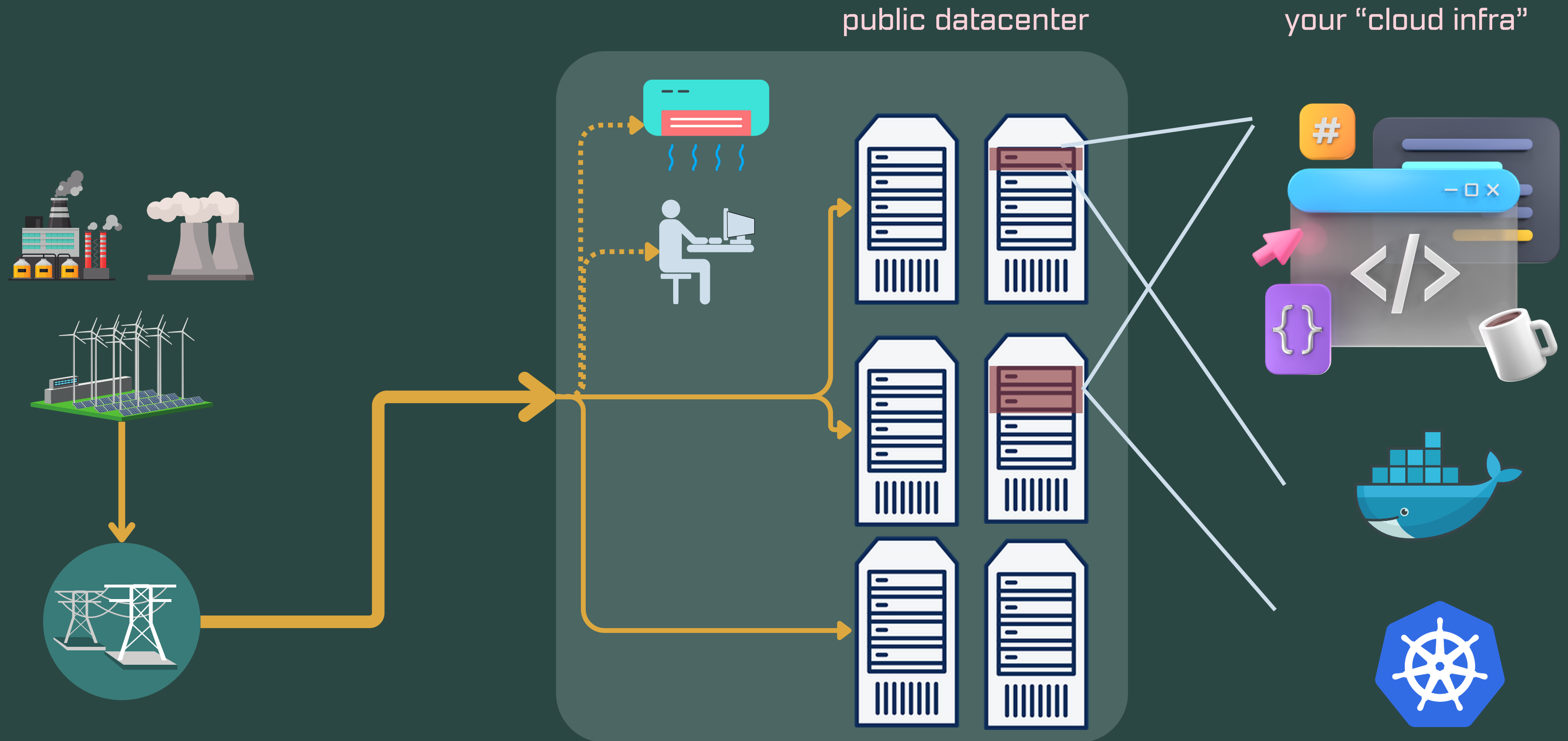 - eliminating source of CO2

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
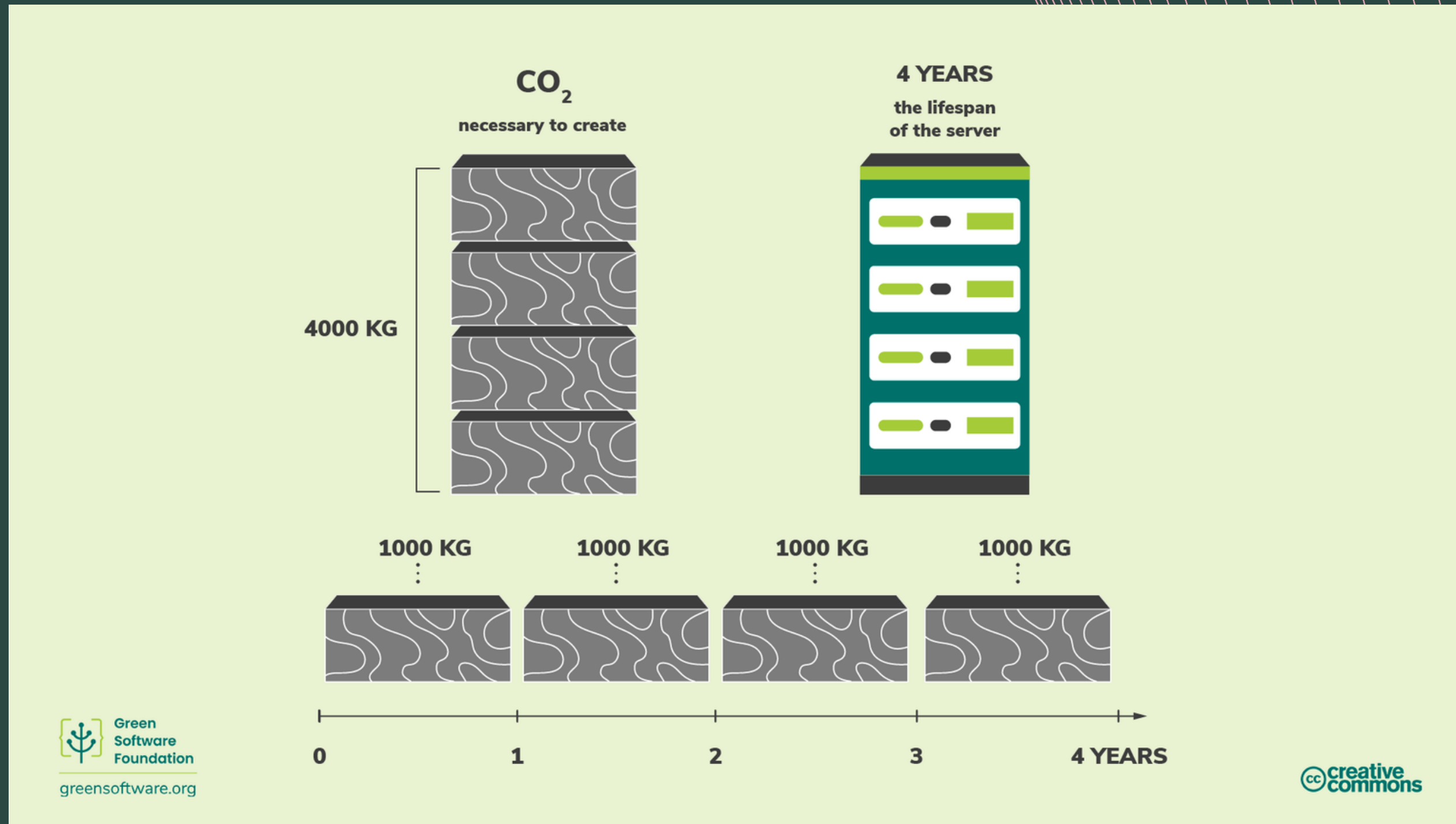
Carbon emitted per kWh of energy, gCO2/kWh

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

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greensoftware.org

creative commons

gCO2eq / hour

Embodied Emissions

Use Emissions

Energy of software/VM (kWh)

✕

Power usage effectiveness (PUE)
exemple: 1.5

✕

Carbon intensity of the grid
(gCO2eq / kWh)

=

Greenhouse Gas Emissions
(gCO2eq/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

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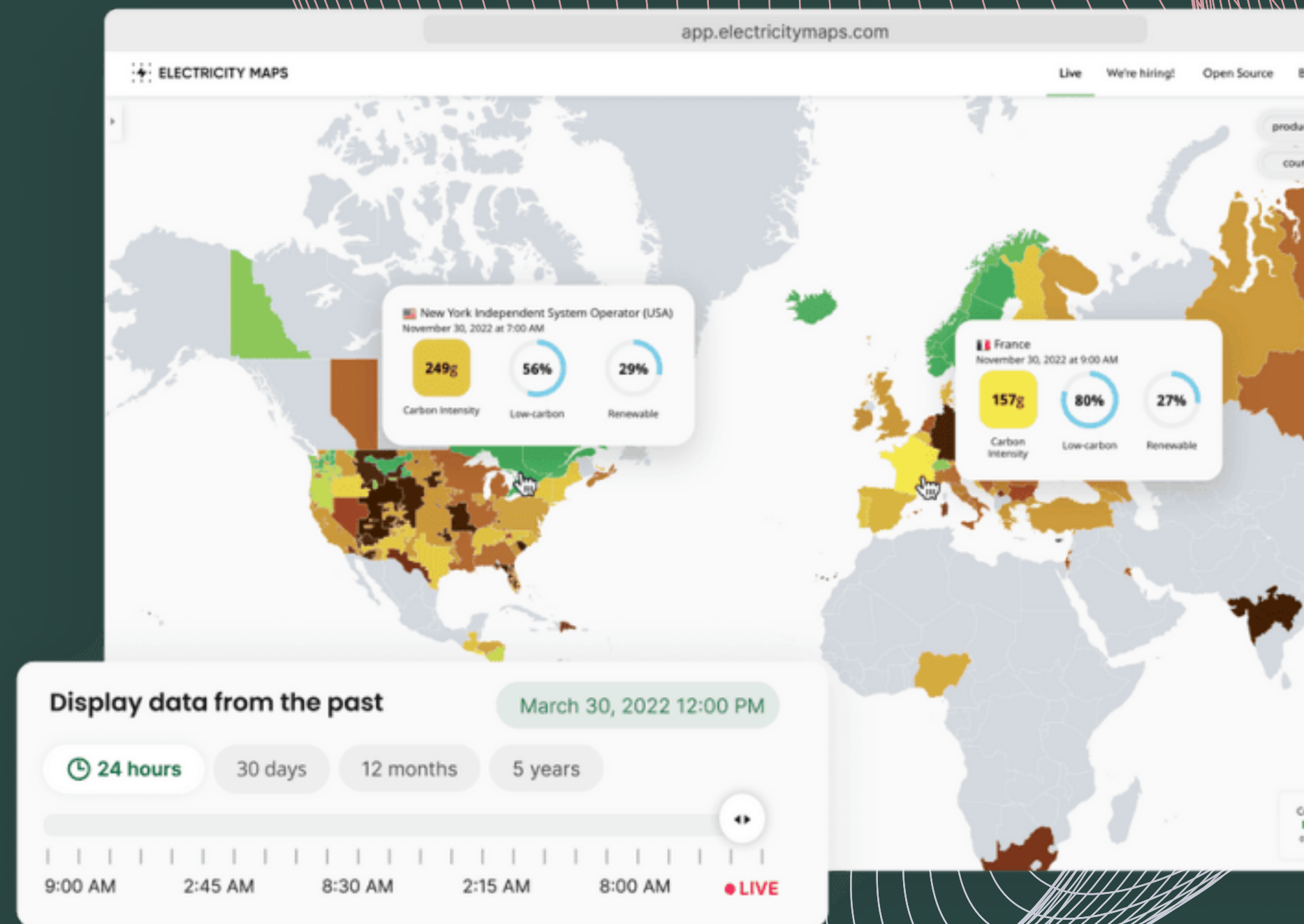Green Software Foundation
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AWS t2.nano : 1 CPU / 0.5 Gb RAM
- **125g** of CO2 per month in **France**
- **600g** of CO2 per month in **Germany**

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
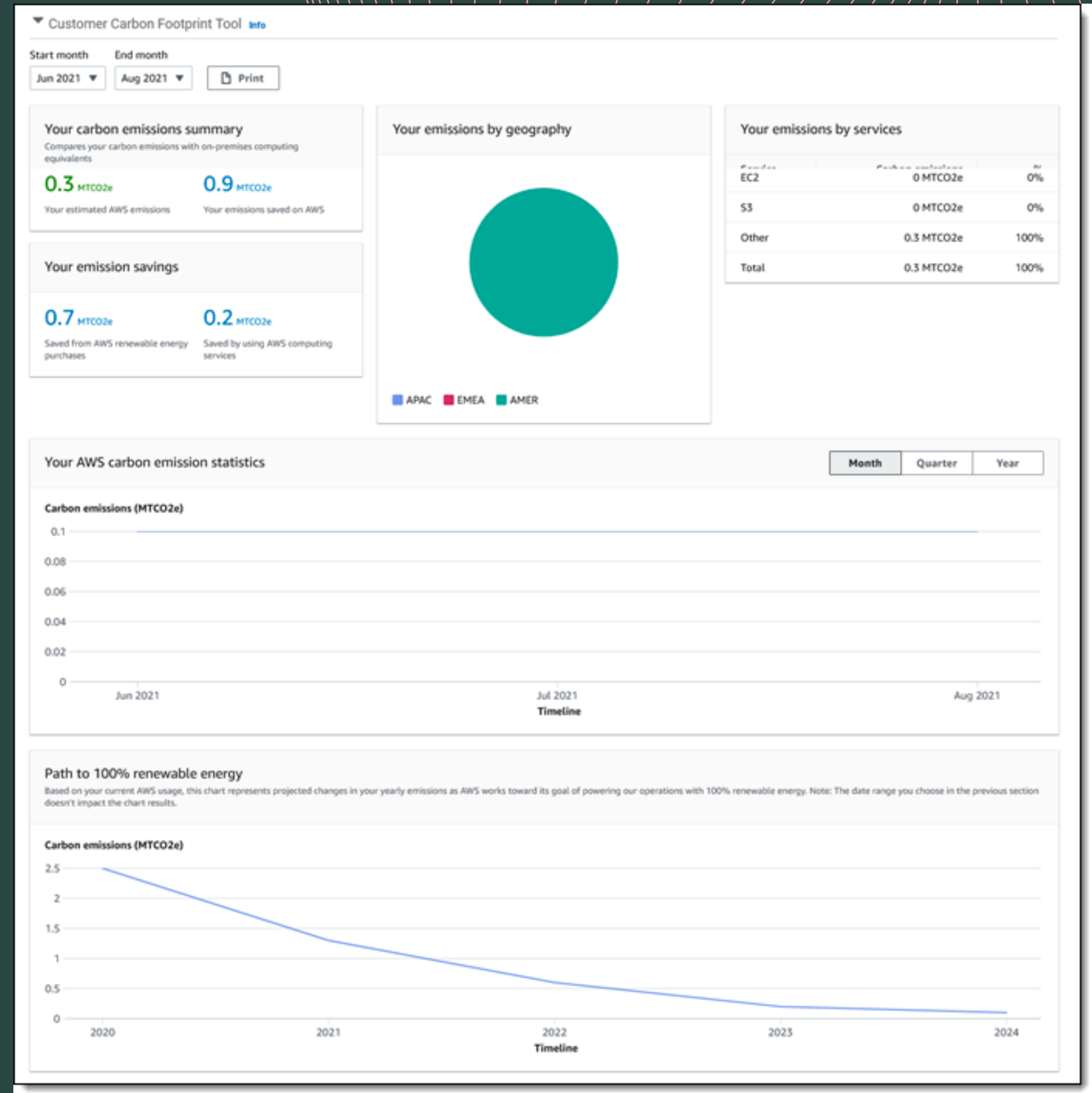 - Google Cloud : 1.1, ...

"less" available data

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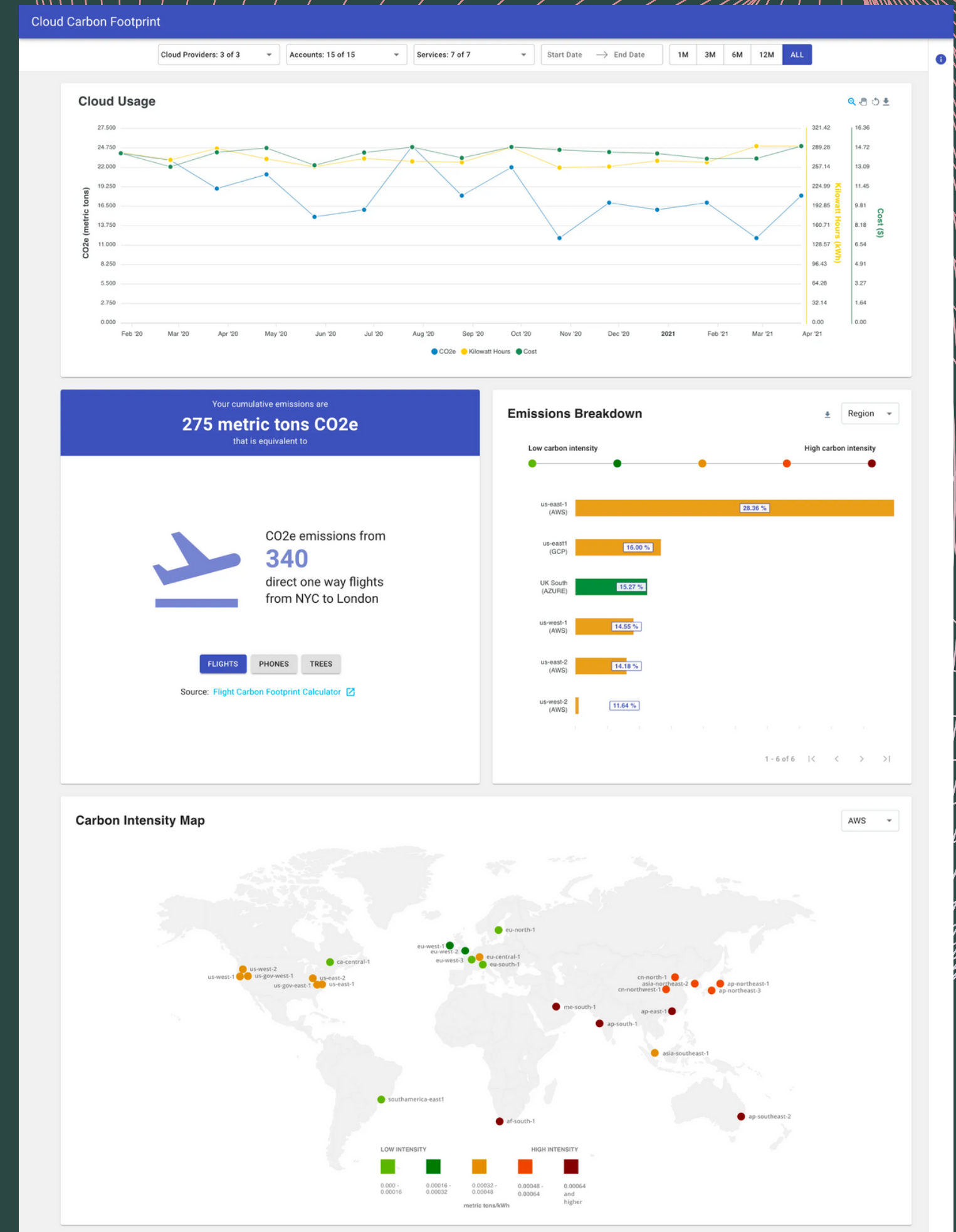
- Energy-mix "weather" predictions

Cloud Provider

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

Cloud carbon footprint

- [Cloud Carbon Footprint](#)
- opensource
- sponsored by Toughworks
- read bills of AWS, GCP...
  - Time usage of instance types...
  - Estimate using ratios (50% usage CPU...)

https://demo.cloudcarbonfootprint.org/

Climatiq

- https://www.climatiq.io/
- commercial api
- gives CO2 for an estimation factor
  - cloud computing instance
  - any domain (transportation, freight)
- Lot of data sources

```
curl --request POST \
--url https://beta4.api.climatiq.io/compute/azure/instance \
--header 'Authorization: Bearer API_KEY' \
--data '{
    "region": "uk_west",
    "instance": "h8",
    "duration": 24,
    "duration_unit": "h"
}'
```

```
{
    "total_co2e": 0.7436632058974948,
    "total_co2e_unit": "kg",
    "memory_estimate": {
        "co2e": 0.13822429911349482,
        "co2e_unit": "kg",
        "co2e_calculation_method": "ar5",
        "co2e_calculation_origin": "source",
        "emission_factor": {
            "name": "Electricity supplied from grid"
```

climatiq

Boavizta

- https://www.boavizta.org/
- opensource
  - free api
  - free dataset (hardware consumption....)
- gives CO2 for an instance type use:
  - manufacture (embodied)
  - use

```
{
  "provider": "aws",
  "instance_type": "t2.micro",
  "usage": {
    "hours_use_time": 1000,
    "usage_location": "FRA",
    "time_workload": [
      {
        "time_percentage": 100,
        "load_percentage": 50
      }
    ]
  }
}
```
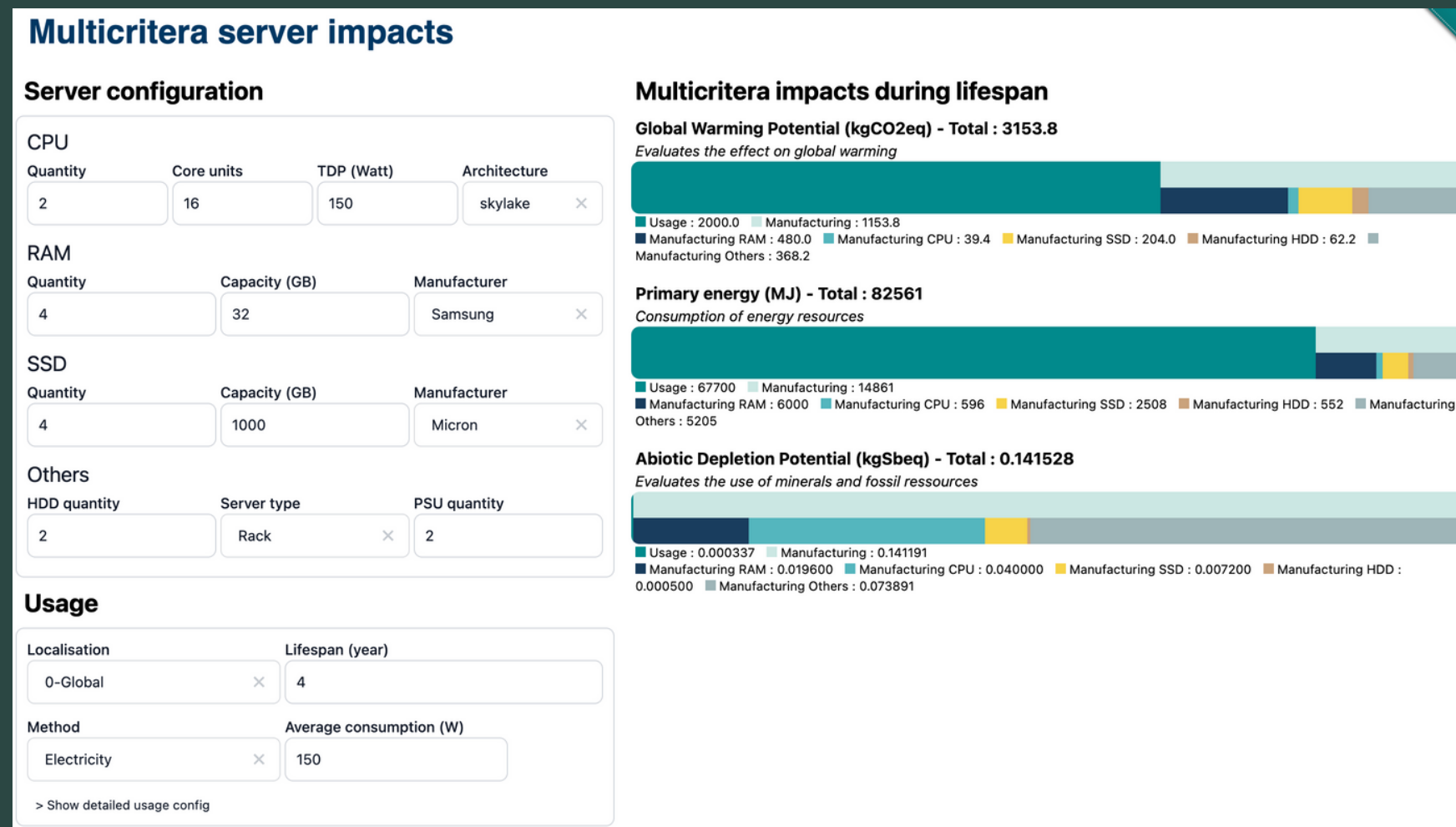
```
{
  "gwp": {
    "manufacture": 34.0,
    "use": 0.7,
    "unit": "kgCO2eq"
  },
  "pe": {
    "manufacture": 440.0,
    "use": 80.1,
    "unit": "MJ"
  },
  "adp": {
    "manufacture": 0.0043,
    "use": 3.45e-07,
    "unit": "kgSbeq"
  }
}
```

Multicritera server impacts

Server configuration

CPU

Quantity	Core units	TDP (Watt)	Architecture
2	16	150	skylake ✕

RAM

Quantity	Capacity (GB)	Manufacturer
4	32	Samsung ✕

SSD

Quantity	Capacity (GB)	Manufacturer
4	1000	Micron ✕

Others

HDD quantity	Server type	PSU quantity
2	Rack ✕	2

Usage

Localisation	Lifespan (year)
0-Global ✕	4

Method	Average consumption (W)
Electricity ✕	150

> Show detailed usage config

Multicritera impacts during lifespan

Global Warming Potential (kgCO2eq) - Total : 3153.8
Evaluates the effect on global warming

■ Usage : 2000.0 ■ Manufacturing : 1153.8
■ Manufacturing RAM : 480.0 ■ Manufacturing CPU : 39.4 ■ Manufacturing SSD : 204.0 ■ Manufacturing HDD : 62.2 ■ Manufacturing Others : 368.2

Primary energy (MJ) - Total : 82561
Consumption of energy resources

■ Usage : 67700 ■ Manufacturing : 14861
■ Manufacturing RAM : 6000 ■ Manufacturing CPU : 596 ■ Manufacturing SSD : 2508 ■ Manufacturing HDD : 552 ■ Manufacturing Others : 5205

Abiotic Depletion Potential (kgSbeq) - Total : 0.141528
Evaluates the use of minerals and fossil ressources

■ Usage : 0.000337 ■ Manufacturing : 0.141191
■ Manufacturing RAM : 0.019600 ■ Manufacturing CPU : 0.040000 ■ Manufacturing SSD : 0.007200 ■ Manufacturing HDD : 0.000500 ■ Manufacturing Others : 0.073891

Scaphandre

- https://hubblo.org/
- opensource
- read power consumption of CPU
- No CO2 estimation

Demo:

https://metrics.hubblo.org/

Carbonifer

- https://github.com/carboniferio/carbonifer
- https://carbonifer.io

- opensource
- command line
- **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

Reduction

Reduction

- Green-coding / Software Ecodesign

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

- Keep it to a minimum
  - auto-scaling groups
  - containers
  - ...

- Change region / zone
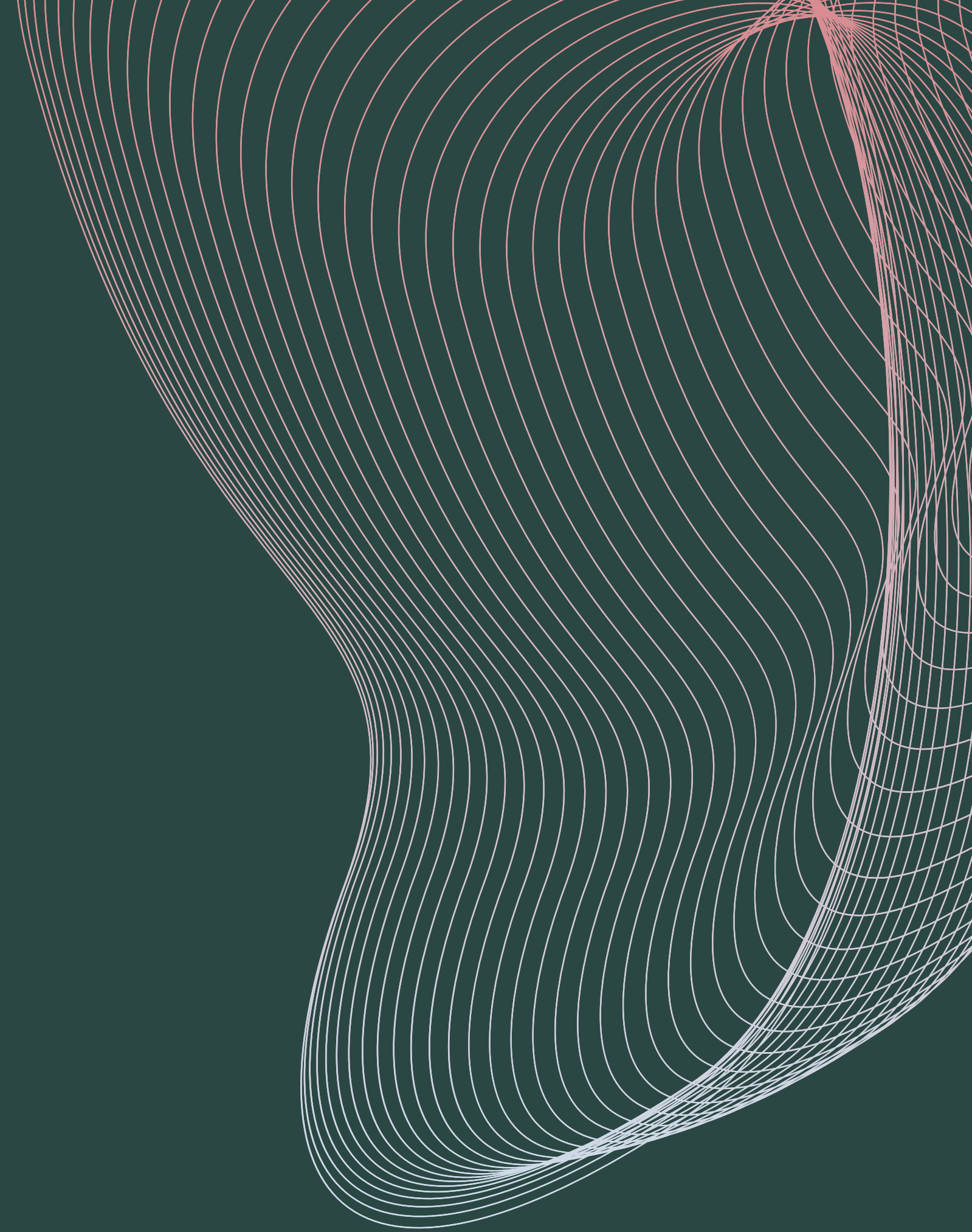
Hyperscalers

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)

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

on premise
numerous underused servers

cloud
fewer highly used server

FinOps => GreenOps

Autoscaling Groups
Scheduled Scaling
Serverless

night

day

Adapt infra to the demand

less $ = less gCO2

Choose your region wisely

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

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Follow the sun

- Renewable energy are weather sensitive (sun, wind...)
- day/night

- app.electricitymaps.com

- plan heavy asynchronous tasks according to energy mix of the grid

Carbon intensity in the last 24 hours

⤓ Get hourly historical, live, and forecast data with Electricity Maps API

120 gCO2/kWh   350 gCO2/kWh

COAL
GAS
WIND
SOLAR

DEMAND REMAINS THE SAME

WIND STOPS BLOWING

SUN STOPS SHINING

TIME

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Carbon Awareness

500 gCO2/kWh

20 gCO2/kWh
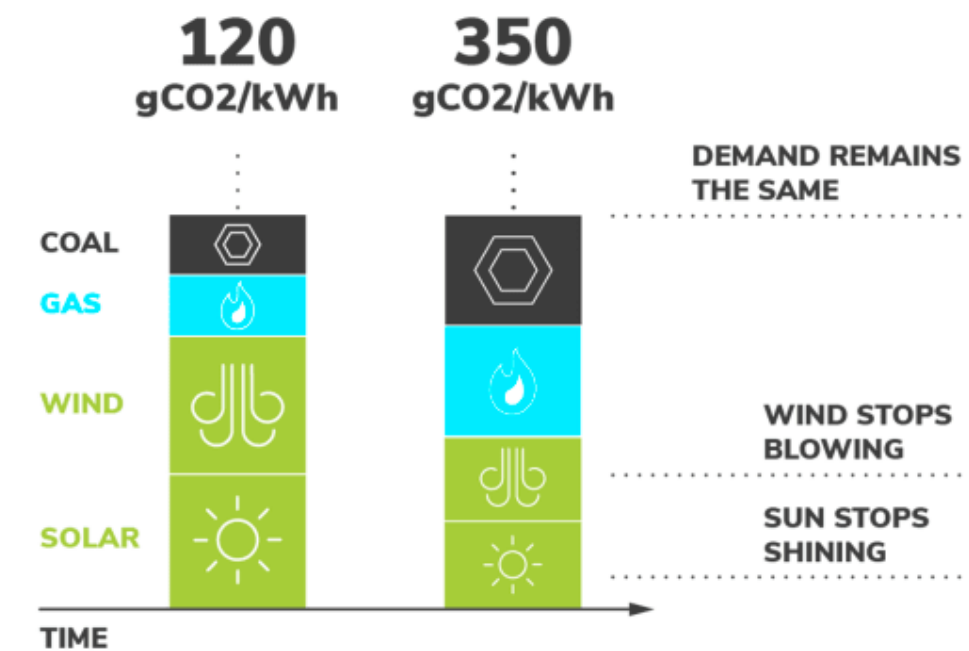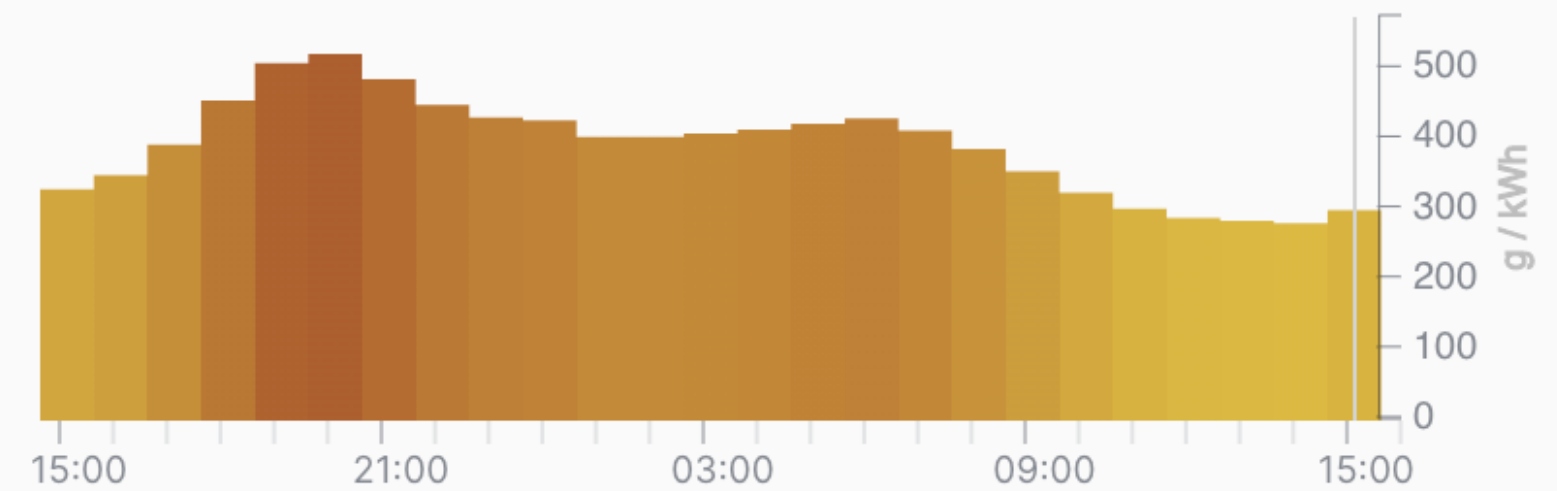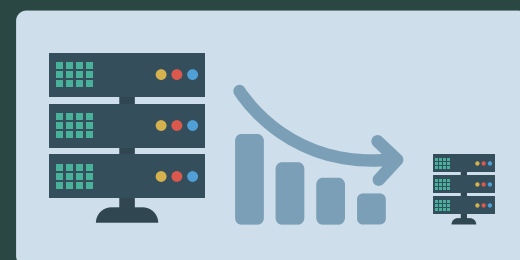
Resize
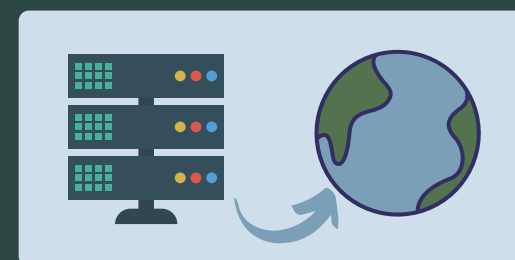
Move

Schedule

Carbon Awareness
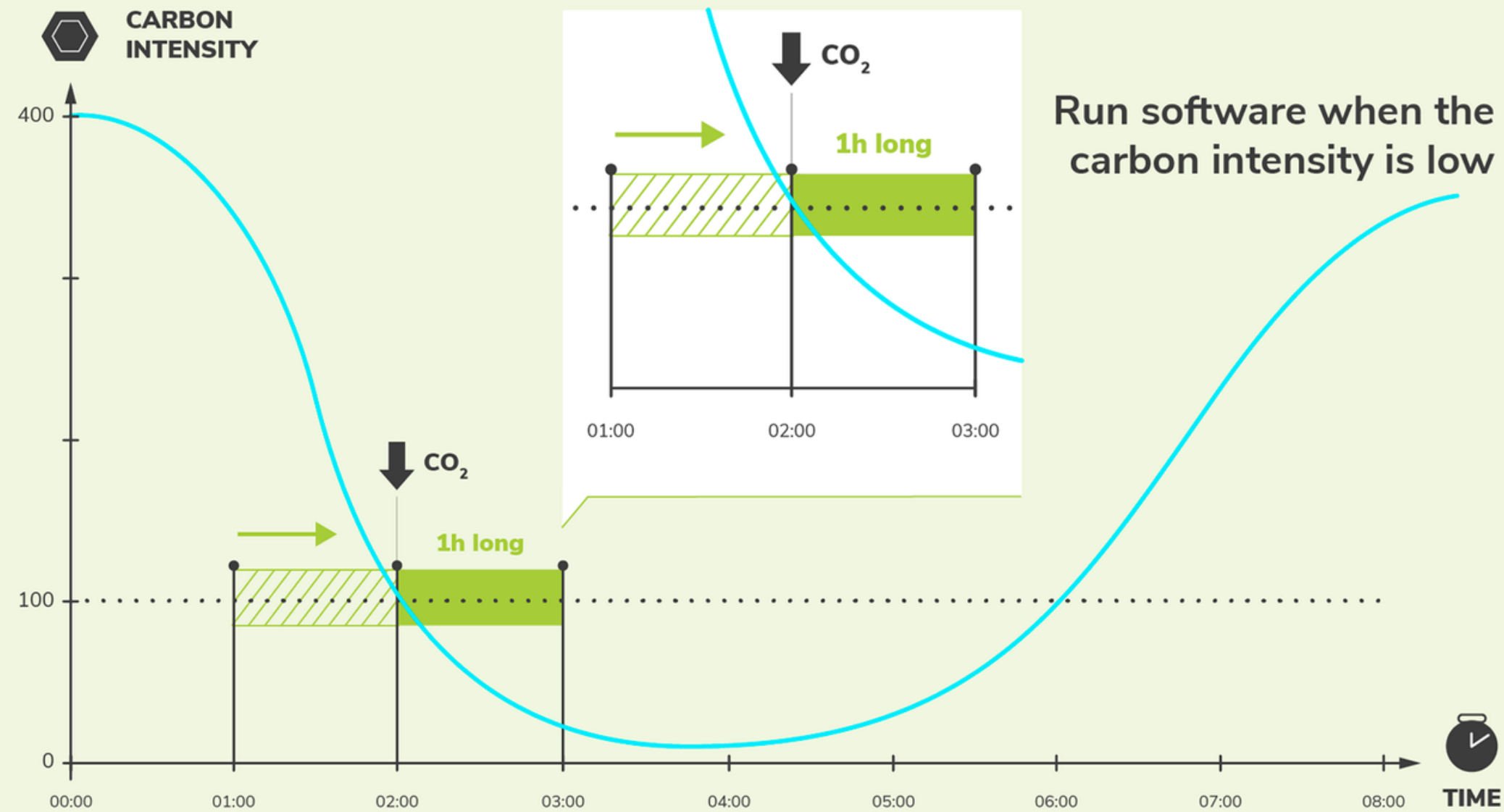
Examples :
- Image/Video processing
- AI model traning
- Machine Learning
- DB indexing

Temporal Shifting

Carbon Awareness
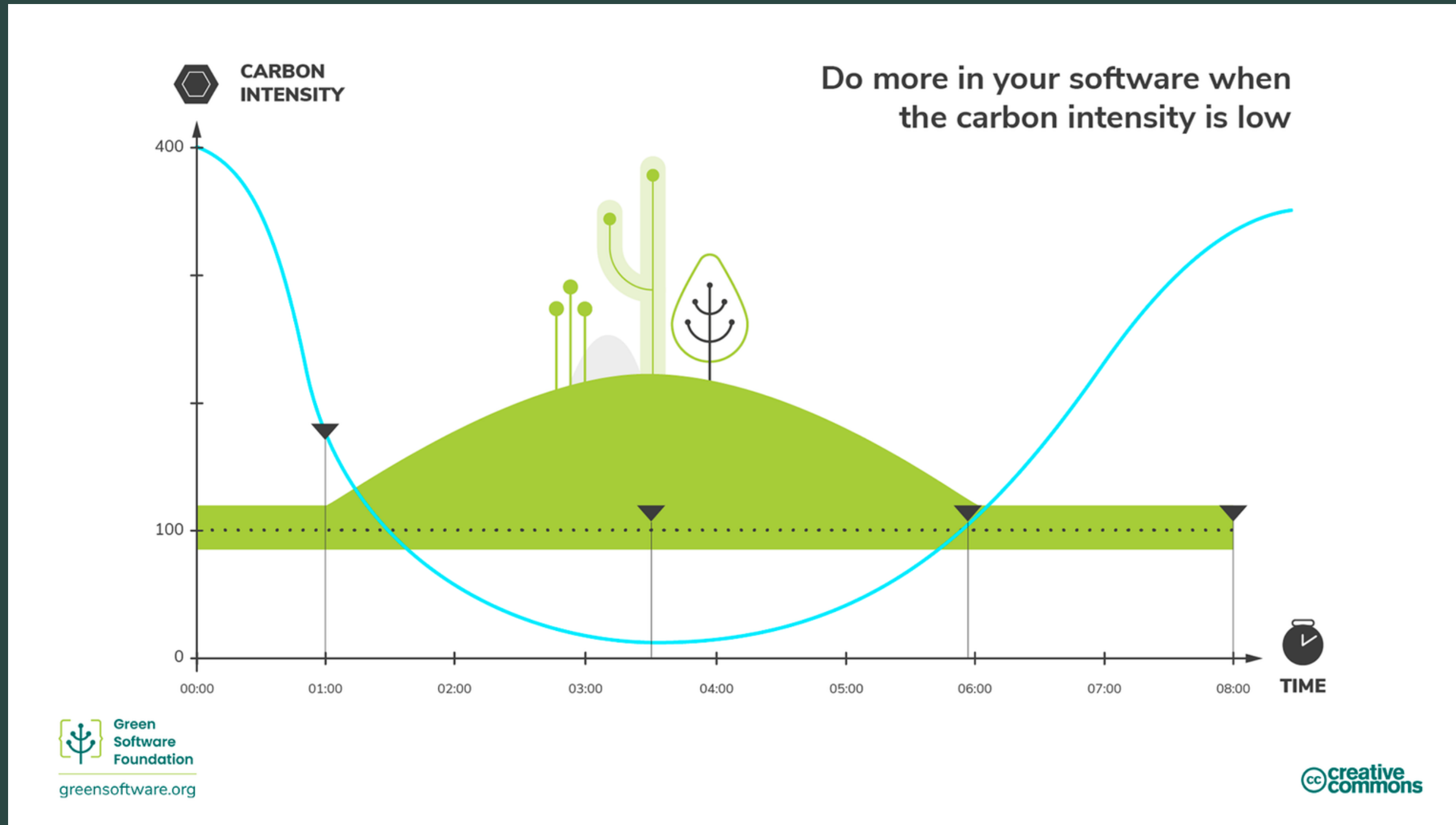
Examples :
- video quality
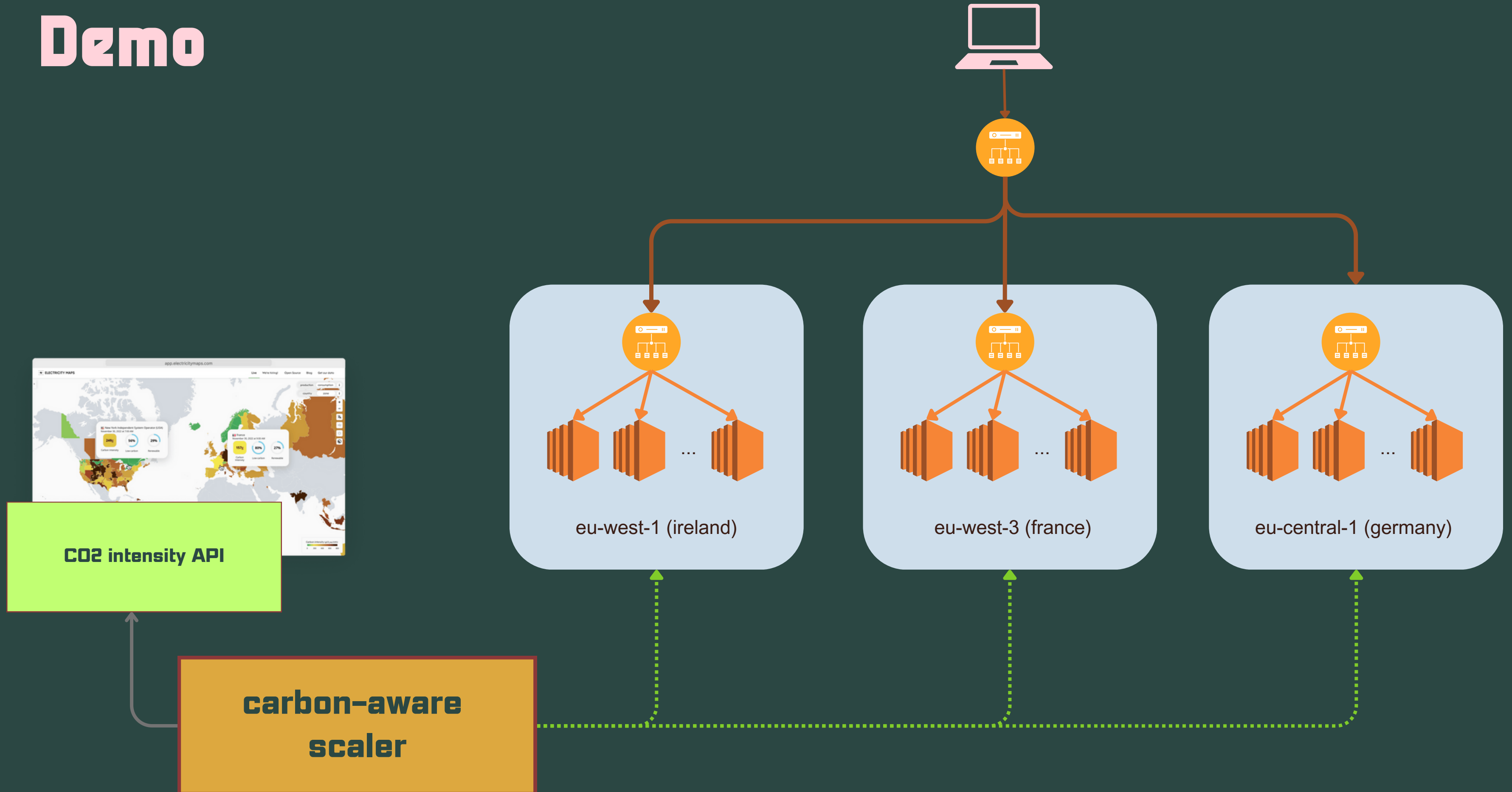- CI server

Demand Shaping

Carbon Awareness

500
gCO2/kWh

20
gCO2/kWh

Spatial Shifting

Demo

Demo

CO2 intensity API

carbon-aware scaler

eu-west-1 (ireland)

eu-west-3 (france)

eu-central-1 (germany)
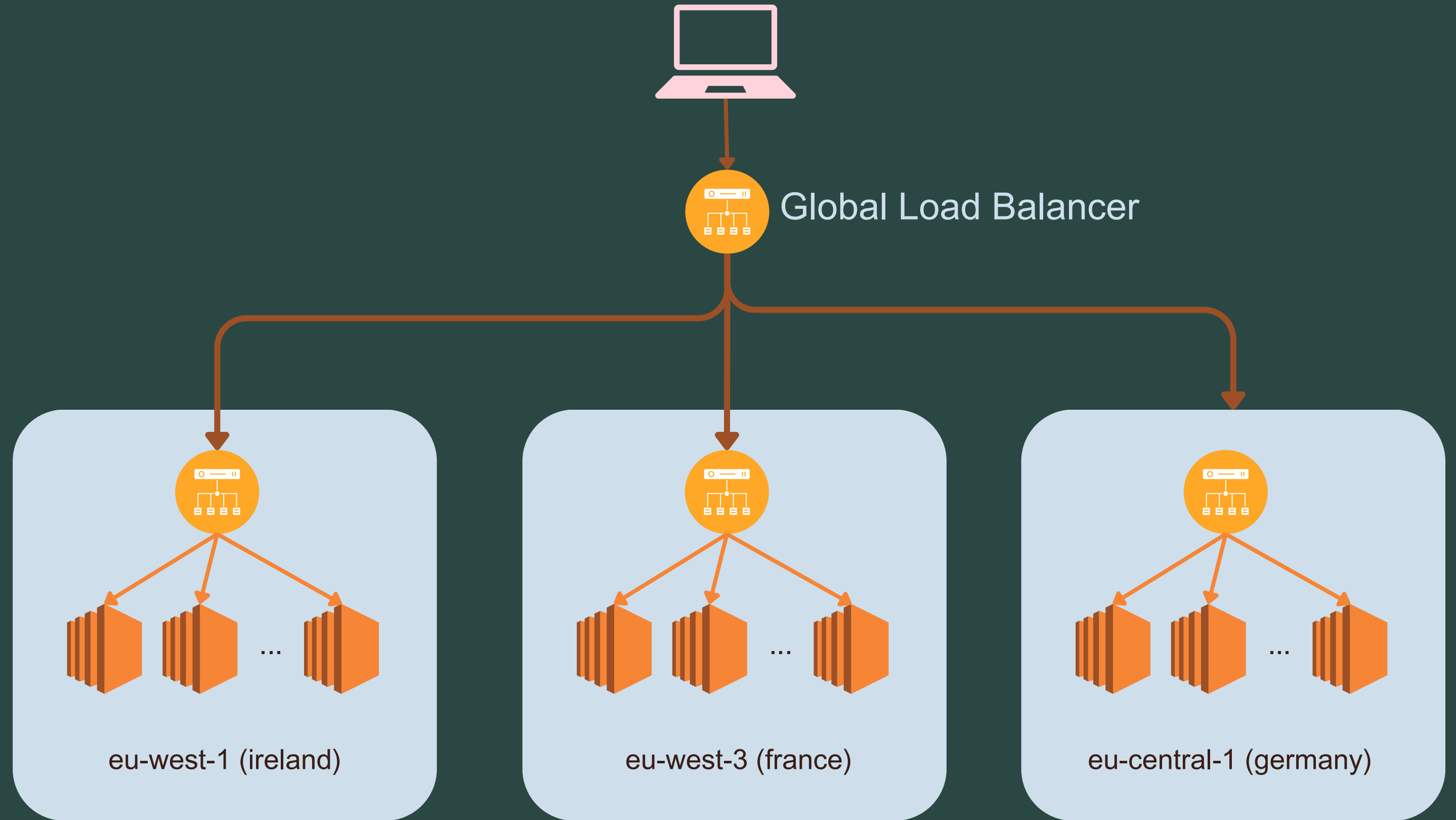
Demo

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

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)
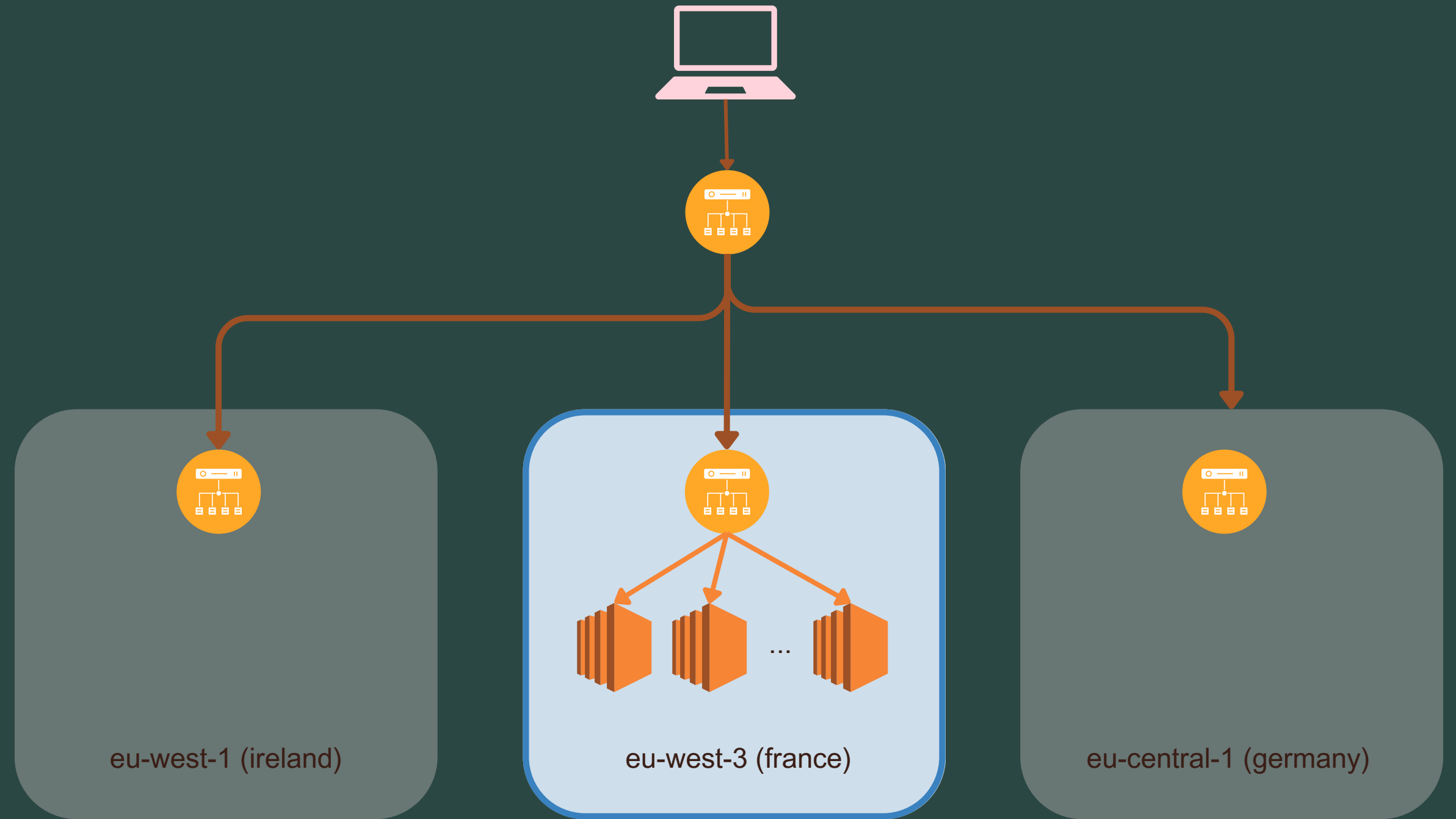
Demo

Take-Away

- Collect usage metrics
- Estimate kWh
- Estimate Carbon Emissions (gCO2/h)
- Plan / Analyse / Correlate
- Actions: reduce, schedule according to grid CO2
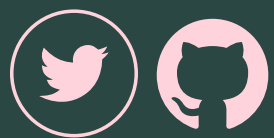- Carbon-Awareness

Thank you

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Carbon Aware Cloud

Environment Variables