

RUM' s USB' s TTX' s API' s SLI' s GUI' s SMS' s 2FA  
KPI' s UDP' s FTP' s CLI' s CPU' s IDE' s TCP' s TAR  
GPU' s LOL' s GPS' s OMG' s BRB' s LAN' s URL' s E2E  
SQL' s SLA' s SLO' s SRE' s GHG' s LED' s VPN' s AAD  
DOF' s TBH' s TTR' s OCE' s OKR' s TLA' s MAC' s TPS  
PSA' s PHP' s SWE' s TTL' s QAT' s OEM' s SSL' s BGP  
ASP' s NPM' s OOO' s NLP' s NFC' s PCB' s TMB' s AAR  
SEO' s SDE' s IOT' s DLL' s DRI' s QOS' s SDL' s ACK  
DNS' s FAQ' s ROI' s SCI' s VPC' s SDK' s ISP' s TMI

# Hello, I'm Bill!



Principal Engineering Manager



Chair, Patterns Working Group



# How much energy does your system consume?

Per User?

Per Request?

Per GB?

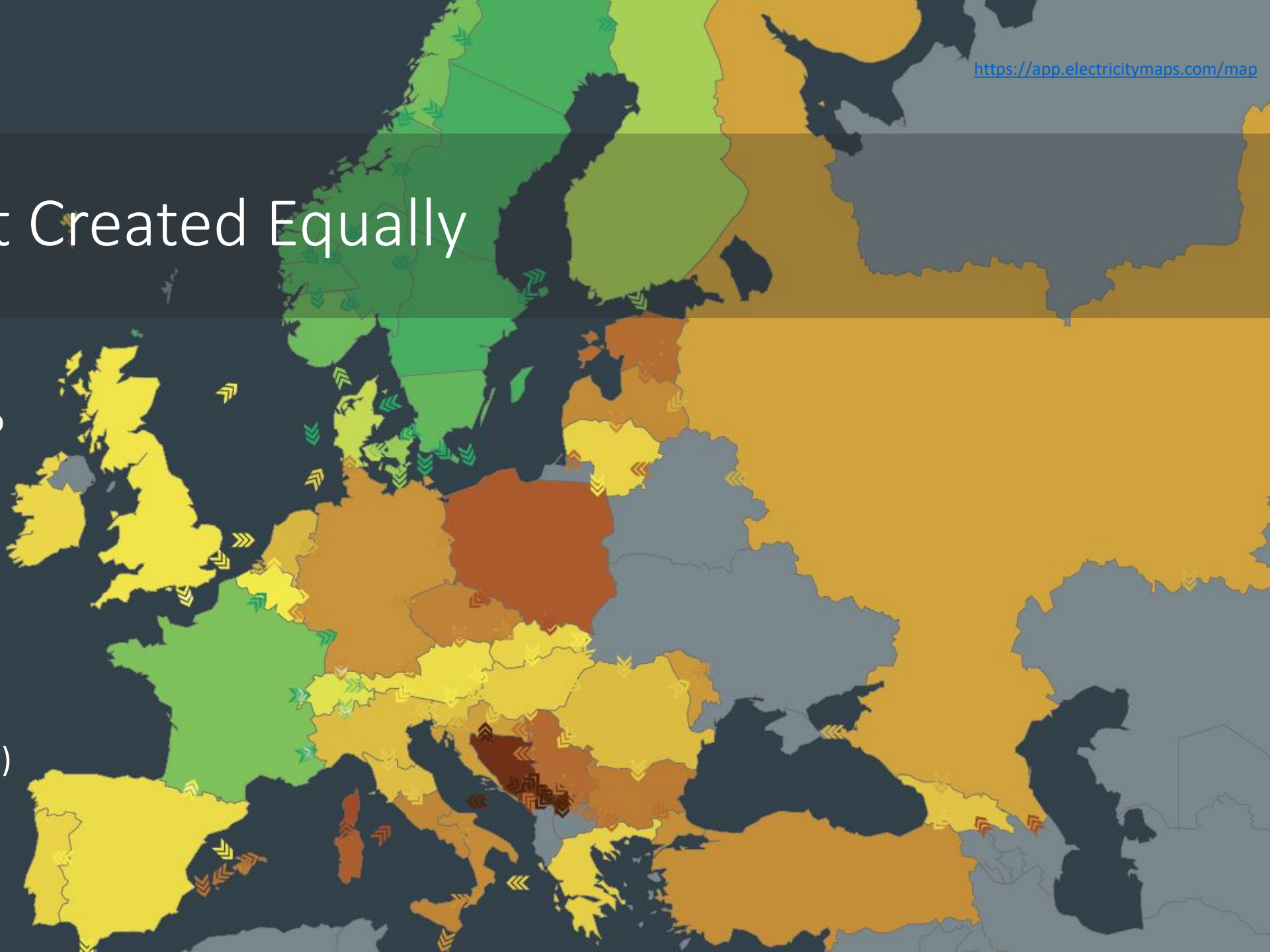
# Energy Is Not Created Equally

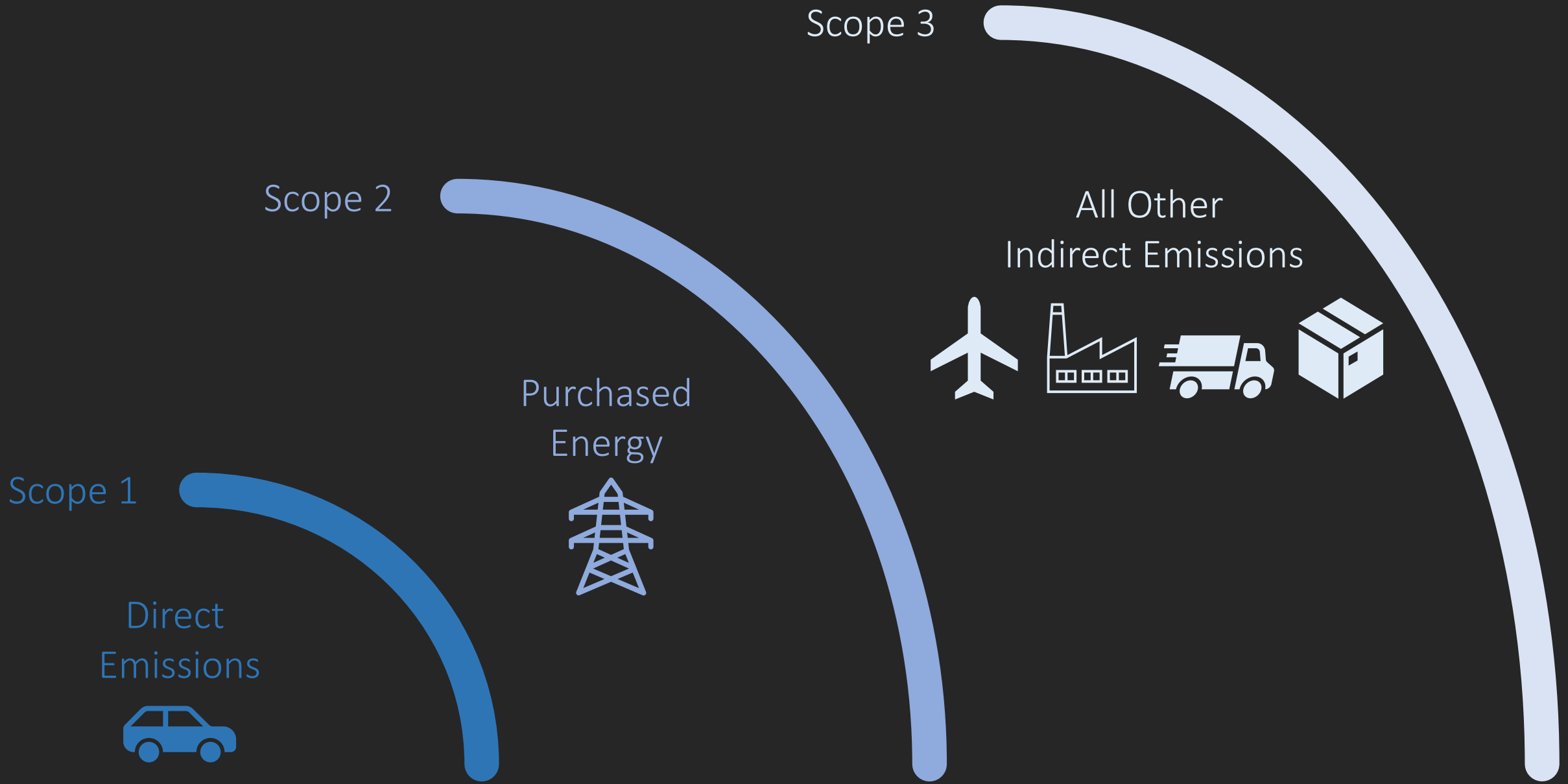
## Carbon Intensity

How much CO<sub>2</sub> it takes to create one kilowatt hour of electricity

## CO<sub>2</sub> Equivalent (CO<sub>2</sub>eq)

Normalization of Greenhouse Gases (GHGs) into equivalent CO<sub>2</sub> impact





Software  
Carbon  
Intensity

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

Carbon emitted per kWh  
of energy, gCO2/kWh

Embodied carbon of  
hardware running the  
software

Energy consumed by the  
software in kWh

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



Green  
Software  
Foundation

<https://grnsft.org/sci>

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

## Energy Calculation (kWh): 50% load for 24h

$$\text{kWh} = \text{Num CPUs} * \text{CPU Power Consumption} + \text{Memory Power Consumption} + \text{Num GPUs} * \text{GPU Power Consumption}$$

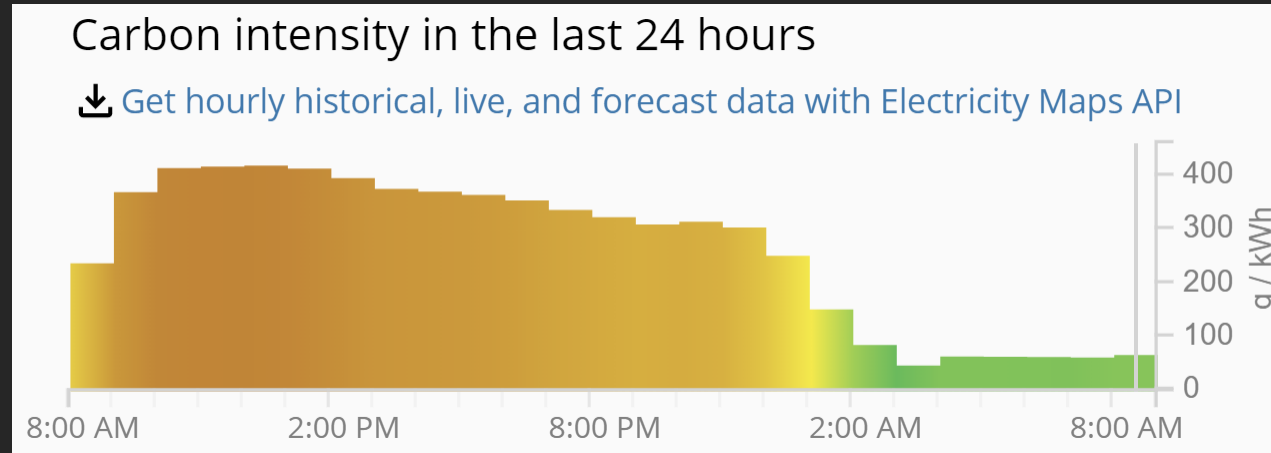
Azure [D8as v4](#) VM → [AMD EPYC 7452](#) processor → **155W TDP**

$$\text{kWh} = 8 * 1.86 \text{ kWh} + \sim 0 + 0 * 0$$

**14.88 kWh**

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

## Carbon Intensity: Azure West Europe (24h avg)



**265 gCO<sub>2</sub>/kWh**



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

## Embodied Carbon: D8as v4 VM over 24h

<https://github.com/cloud-carbon-footprint> → 1560.4 kg

1	AZURE					
2	Series	Virtual Machine	Instance vCPUs	Instance Memory	Total Platform Scope 3 Emissions (kgCO <sub>2</sub> eq)	Total Platform Scope 3 Emissions (mtCO <sub>2</sub> eq)
132	D2as – D96as v4	D64as v4	64	256	1560.4	1.5604
133	D2as – D96as v4	D8as v4	8	32	1560.4	1.5604
134	D2as – D96as v4	D96as v4	96	384	1560.4	1.5604
135	D2d – D64d v4	D16d v4	16	64	1482.9	1.4829
136	D2d – D64d v4	D2d v4	2	8	1482.9	1.4829

855 gCO<sub>2</sub>

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

## Functional Unit: Requests

Requests per second: 10

864,000

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

$$\text{SCI} = ((14.88 * 265) + 855) / 864,000$$

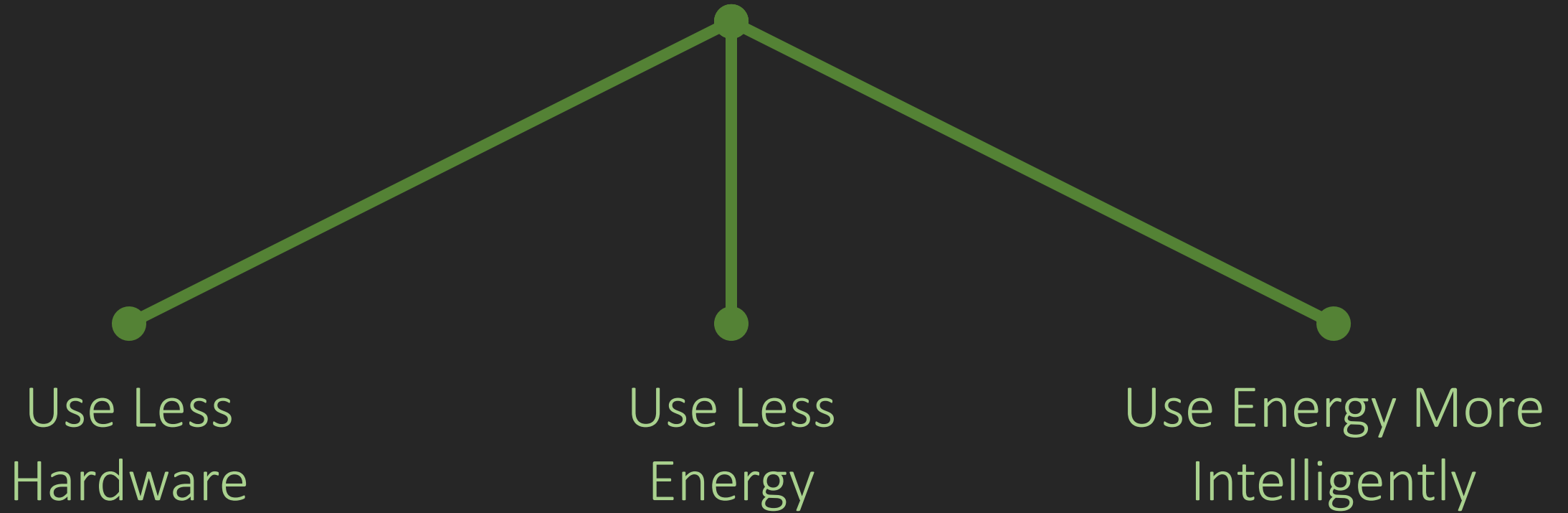
0.005553 carbon emission rate per request

**5.553**

carbon emissions rate per 1,000 requests



# How to reduce software carbon emissions



Sustainability = Reliability over time

A habitable planet is the ultimate reliability

Thank you!

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