



Architecting for a Greener Future

- SARA BERGMAN -

I want to talk
about solutions



About me

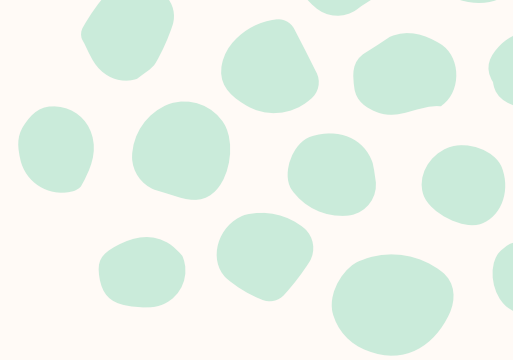
Sara Bergman

 Senior Software Engineer @
Microsoft

 Speaker and advocate for green
software practices at Microsoft and
externally

 Author of O'Reilly book "Building
Green Software"



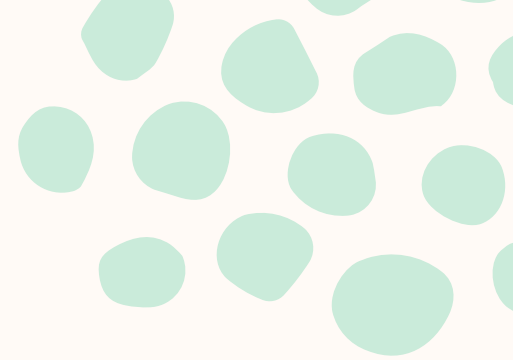


Where are you now?

Green Software Foundation



We are building a trusted ecosystem of people,
standards, tooling and best practices for green
software

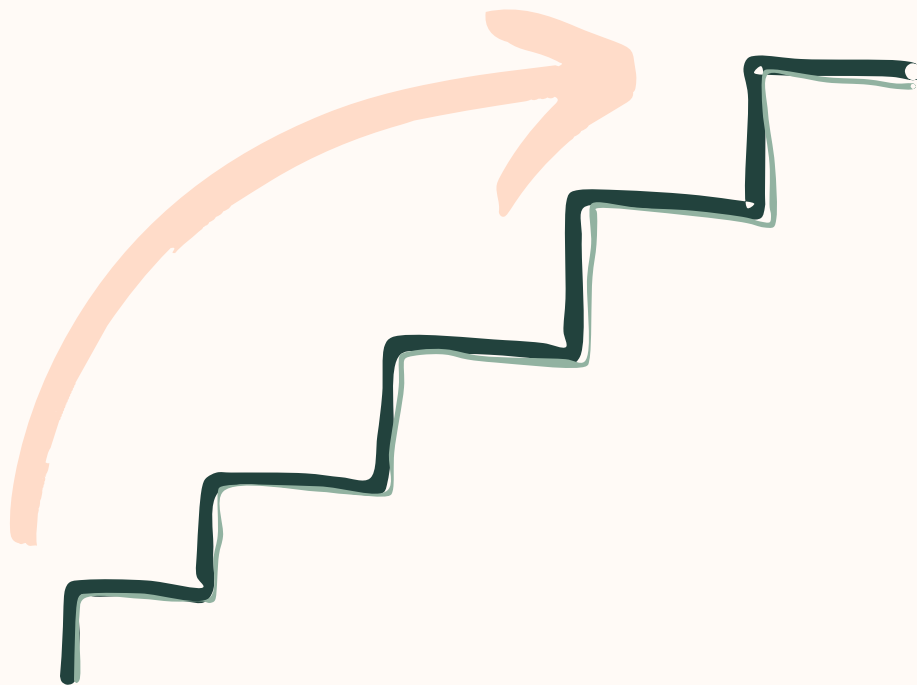


Green Software Maturity Matrix

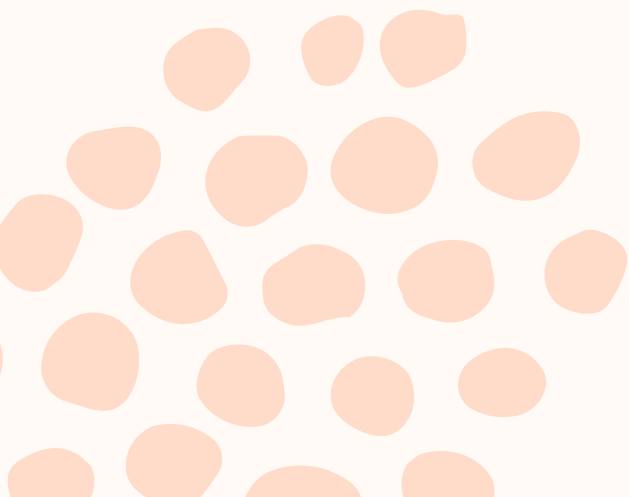
 {🌱}	ASPIRING	AWARE	ACTING	AWESOME	INSPIRING
 commitments					
 footprint					
 metrics					
 carbon ops					
 energy					
 devices					
 utilization					
 products					
 training					



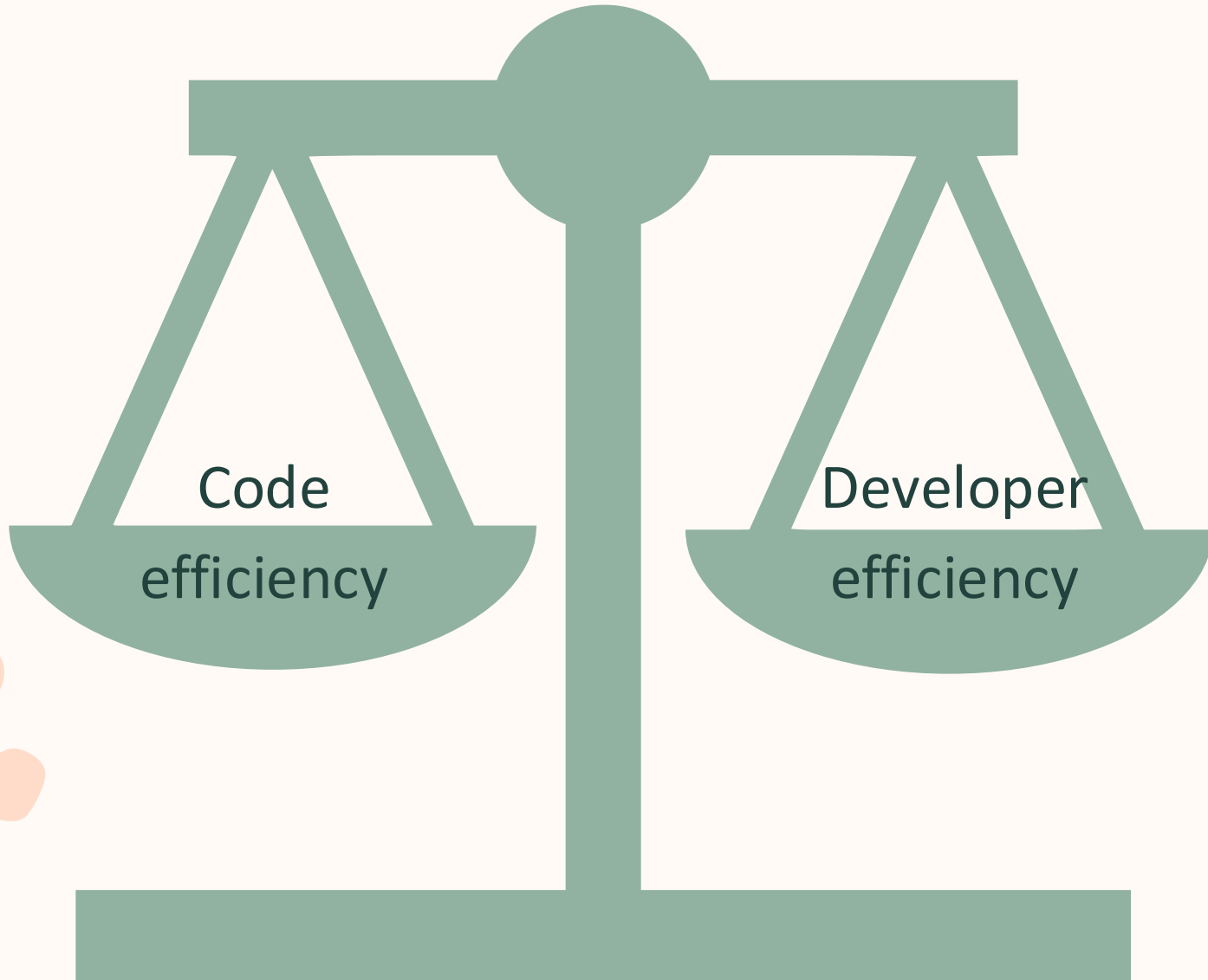
Going up the ladder!



Where do we
begin?

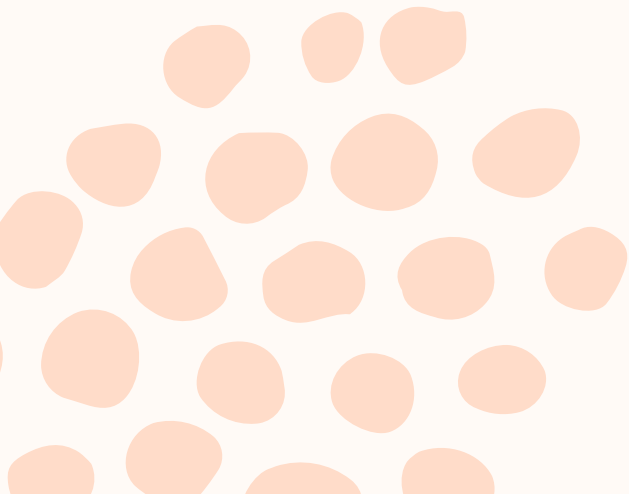


Code efficiency?

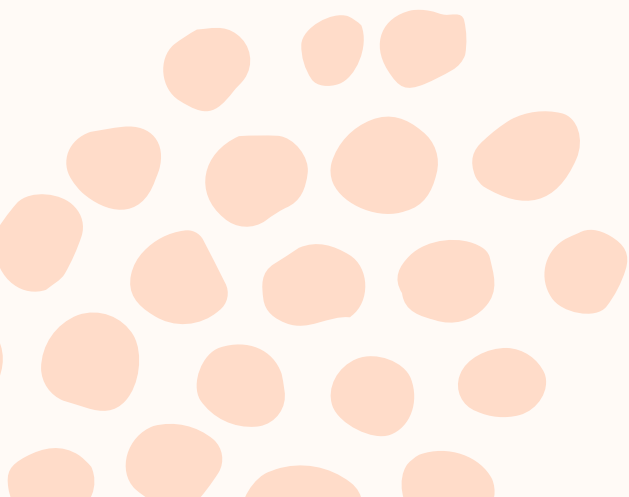


Data center efficiency?

Yes, but cloud users are still responsible for
sustainability IN the cloud



Architecting for green - Operational efficiency

A decorative graphic consisting of a thick orange outline of an oval, tilted at an angle. Inside the outline is a solid, semi-transparent orange oval of the same shape and orientation.

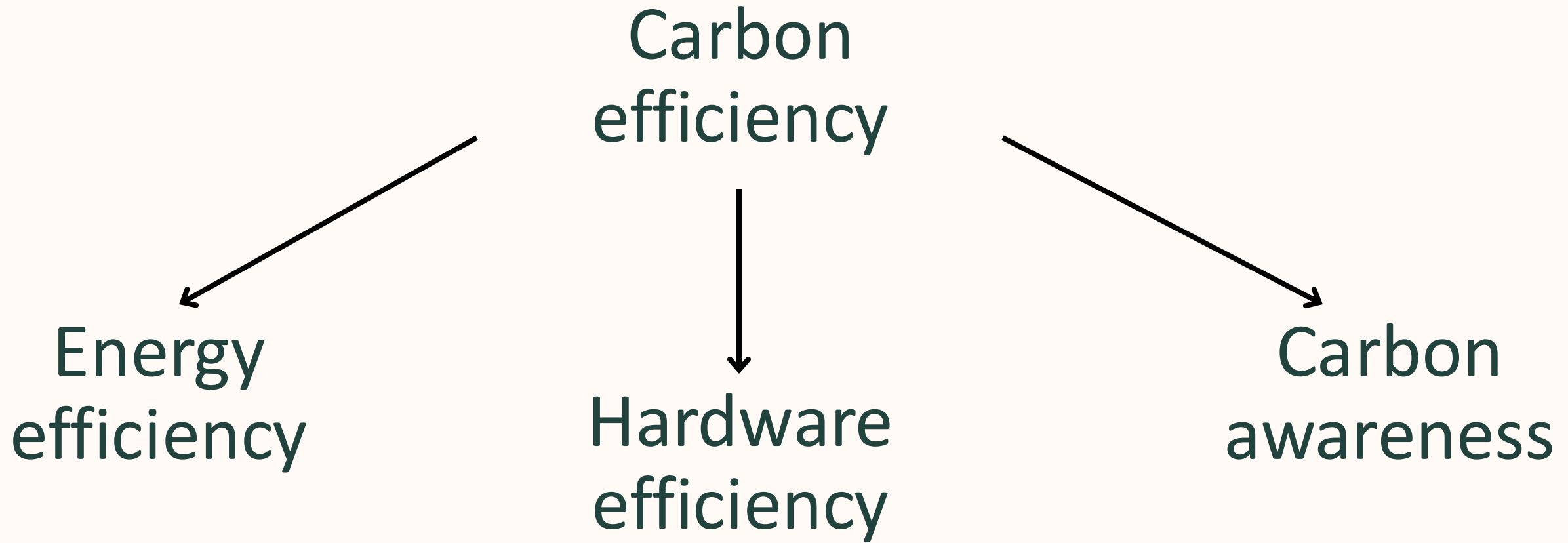
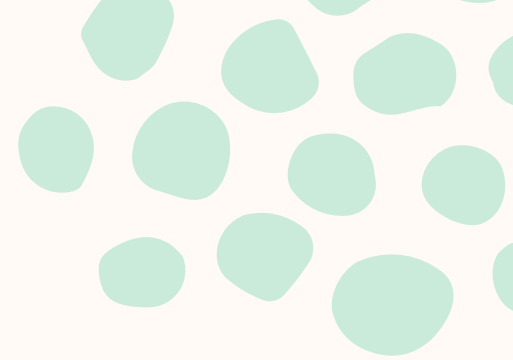
What makes software green?



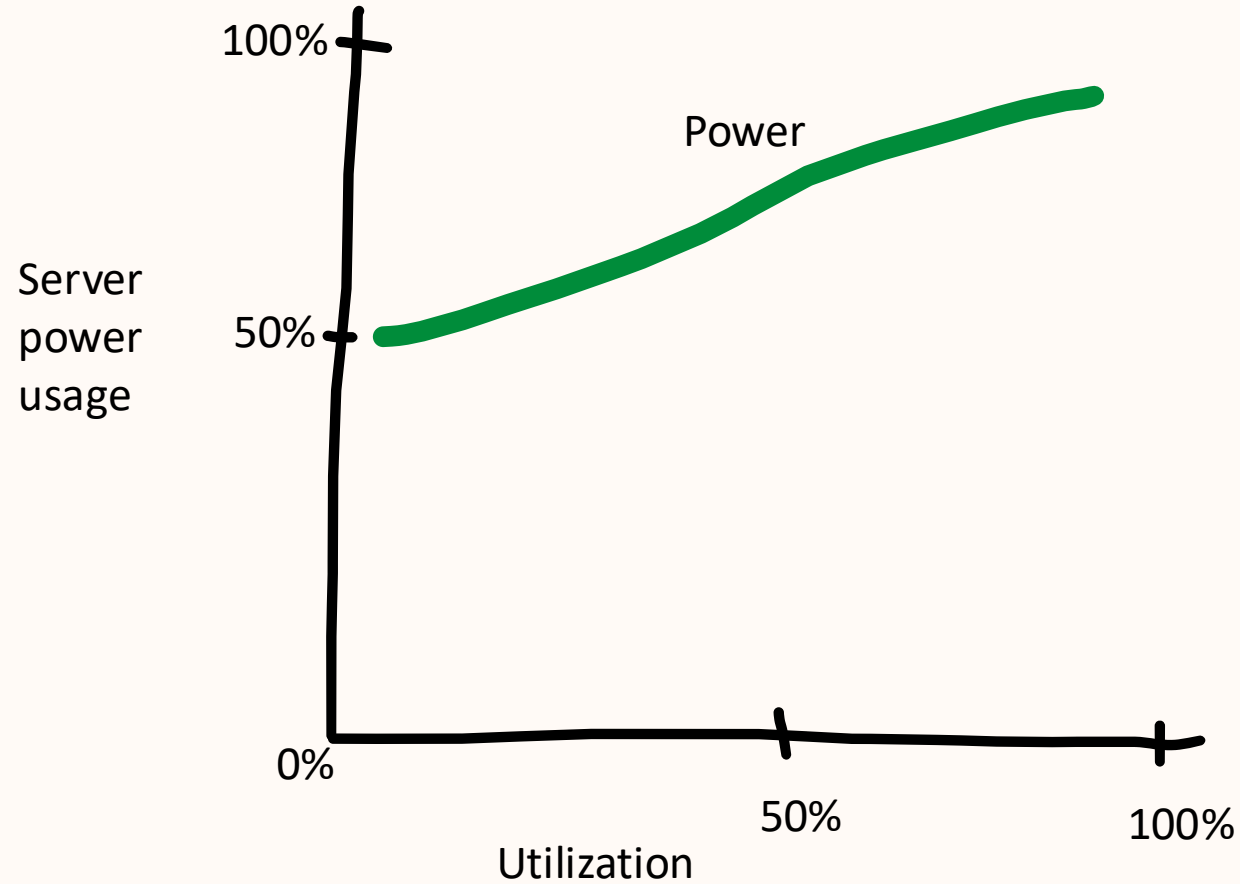
Carbon
efficiency

Emit the least amount
of carbon possible.

What makes software green?



Energy proportionality

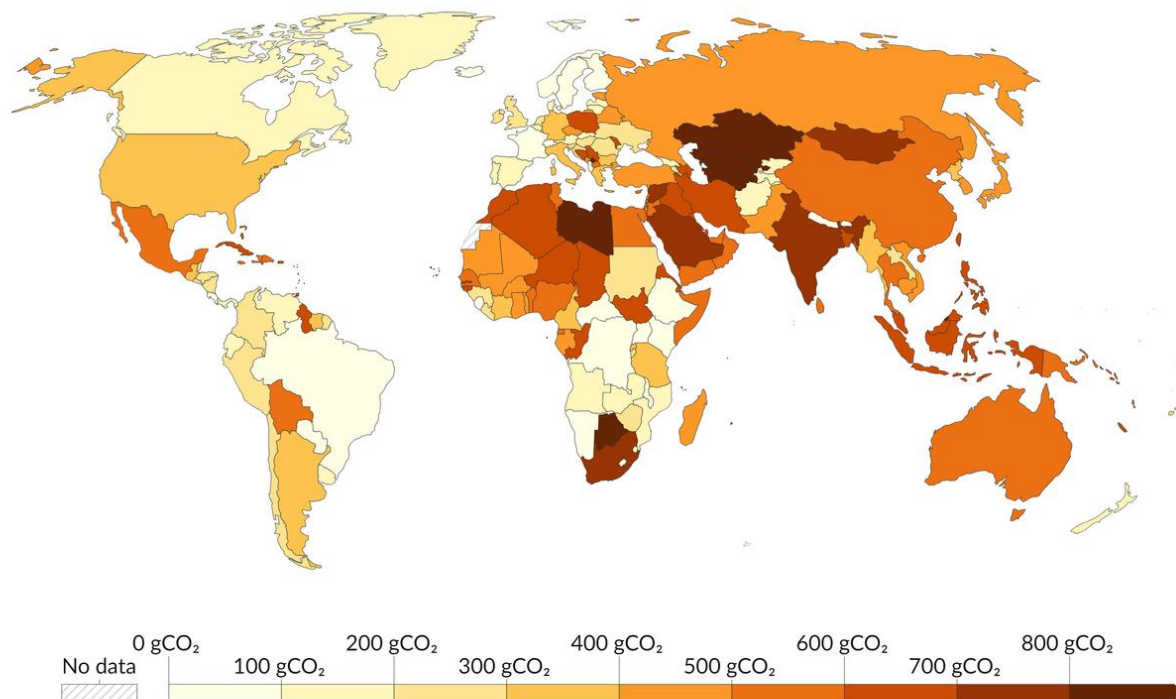


Energy market

Carbon intensity of electricity generation, 2023

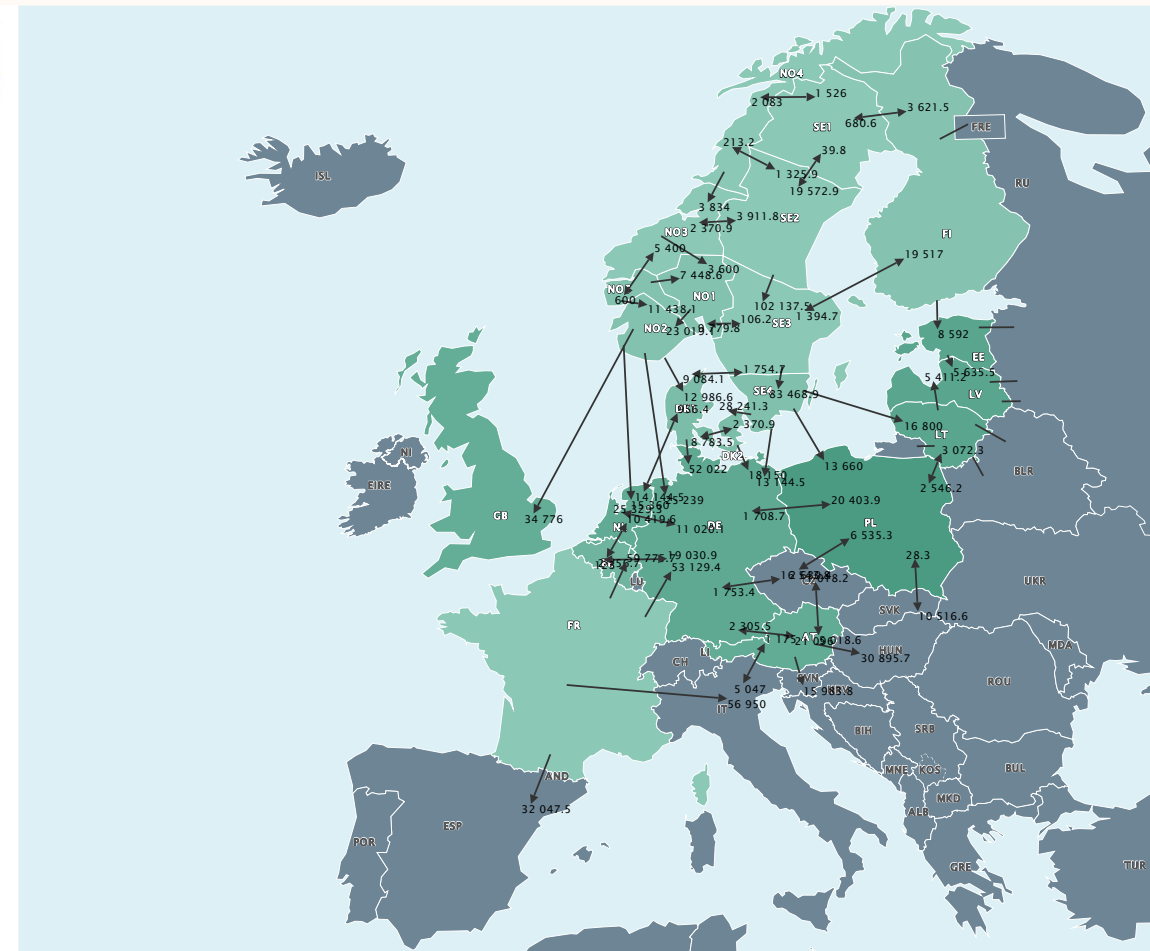
Carbon intensity is measured in grams of carbon dioxide-equivalents emitted per kilowatt-hour of electricity generated.

Our World
in Data



Data source: Ember (2024); Energy Institute - Statistical Review of World Energy (2023)

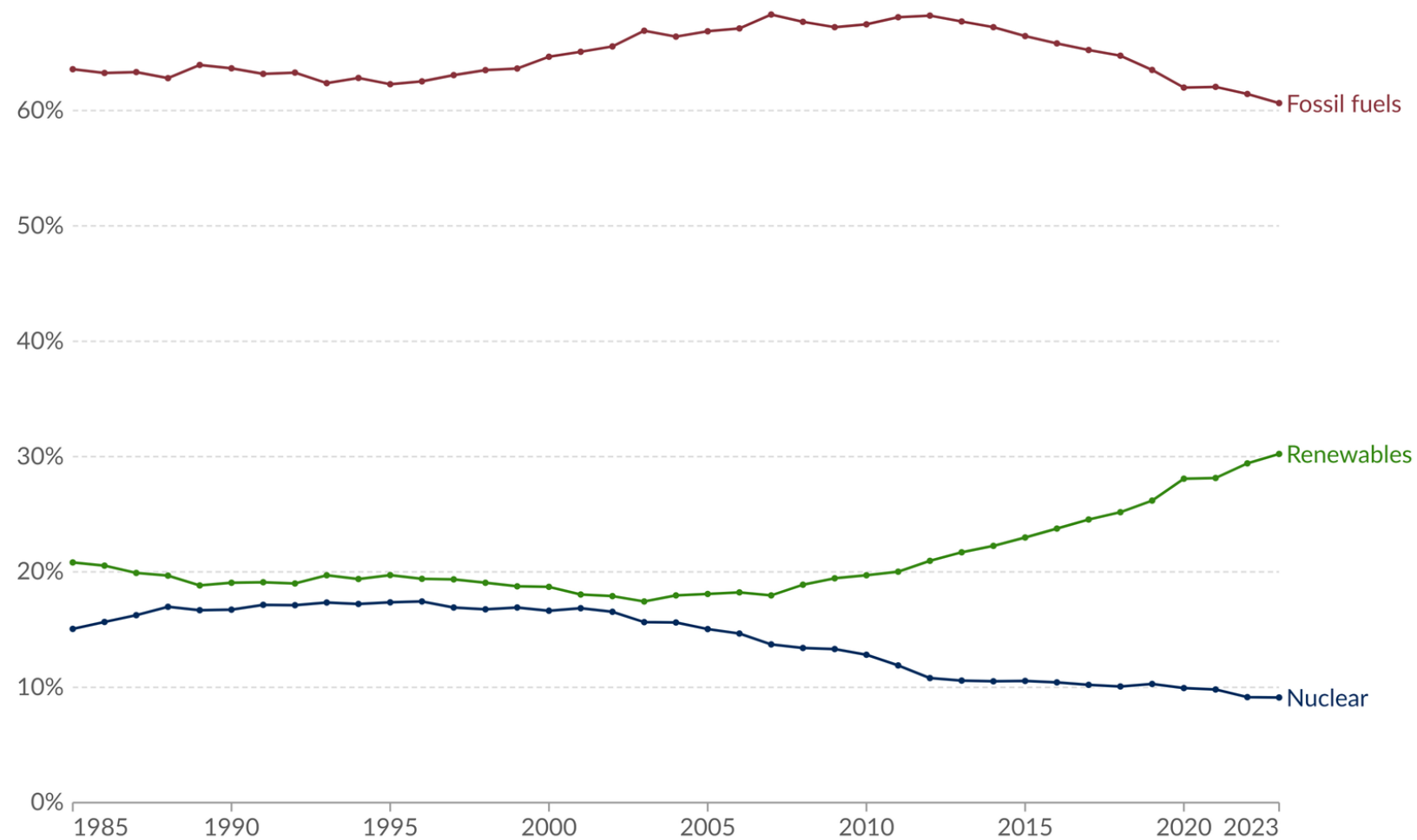
OurWorldInData.org/energy | CC BY



Source: Nord Pool

Share of electricity generation from fossil fuels, renewables and nuclear, World

Our World
in Data

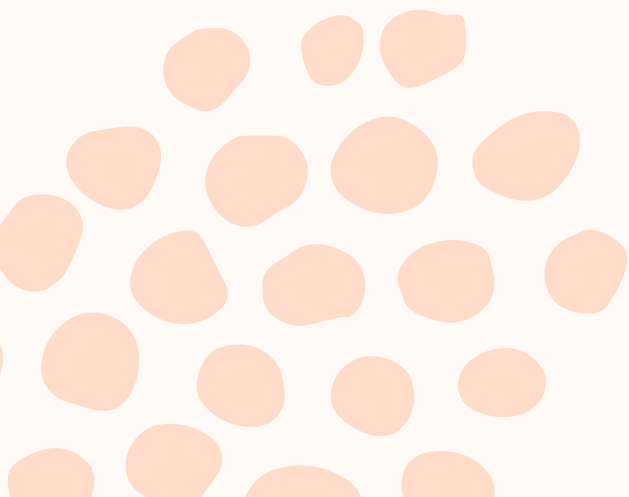


Data source: Ember (2024); Energy Institute - Statistical Review of World Energy (2023)











OurWorldInData.org/energy | CC BY

Hannah Ritchie and Pablo Rosado (2020) - "Electricity Mix" -
<https://ourworldindata.org/electricity-mix>

What can you
do?



Green Software Maturity Matrix

	ASPIRING	AWARE	ACTING	AWESOME	INSPIRING
 commitments					
 footprint					
 metrics					
 carbon ops	none	manual	lightswitch ops	auto-rightsizing	carbon SRE
 energy	none	green hosting	dynamic management	demand shaping	Electricity
 devices					
 utilization					
 products					
 training					

I read all the cloud
providers Well Architected
Framework's sustainability
sections, so you didn't
have to!

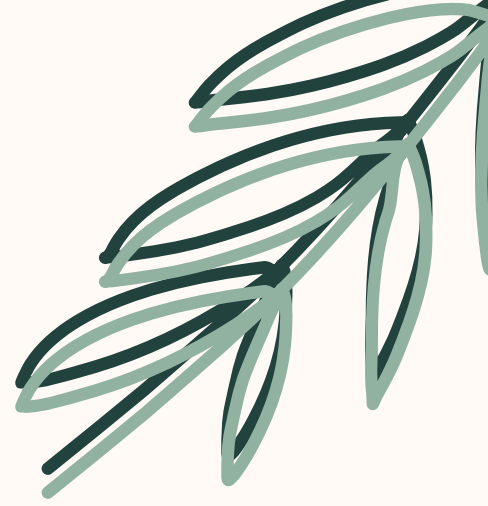


Cloud Native Computing Foundation



TAG ENVIRONMENTAL
SUSTAINABILITY

Carbon Ops



Server resource
management

Don't be Smaug



Avoid hoarding!

Delete:

- Unused or idle resources
- Old logs
- Unused data



LightSwitchOps



Decouple compute and storage



Use services that
decouple compute and
storage for data
processing and analytics.

Google Cloud examples: Spanner, BigQuery or Dataproc

Use the most suited tech



Use storage technologies that best support how your data is accessed and stored to minimize the resources provisioned.

AWS examples: Amazon S3 Glacier for archive, Amazon DynamoDB for key-value database

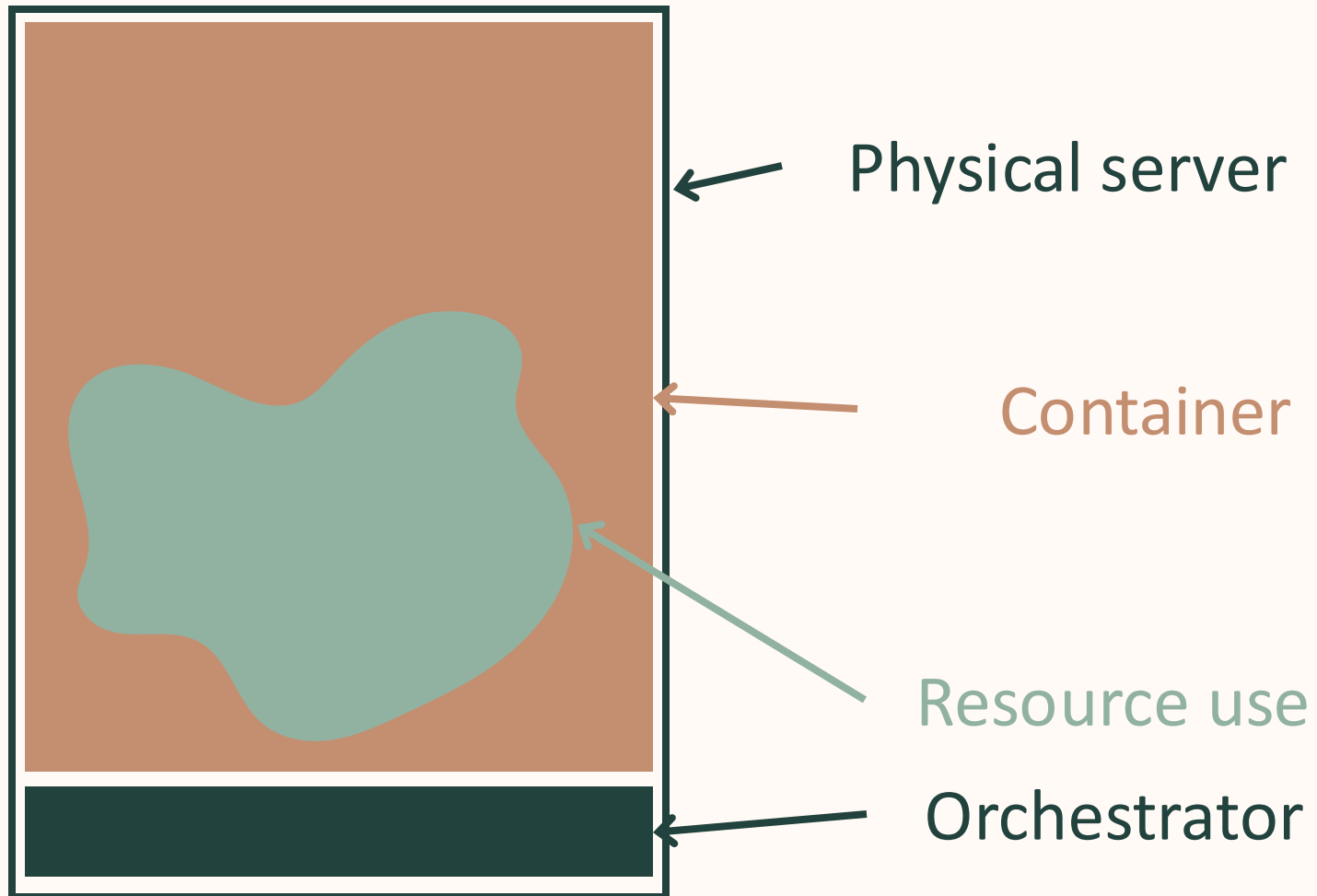
Backup



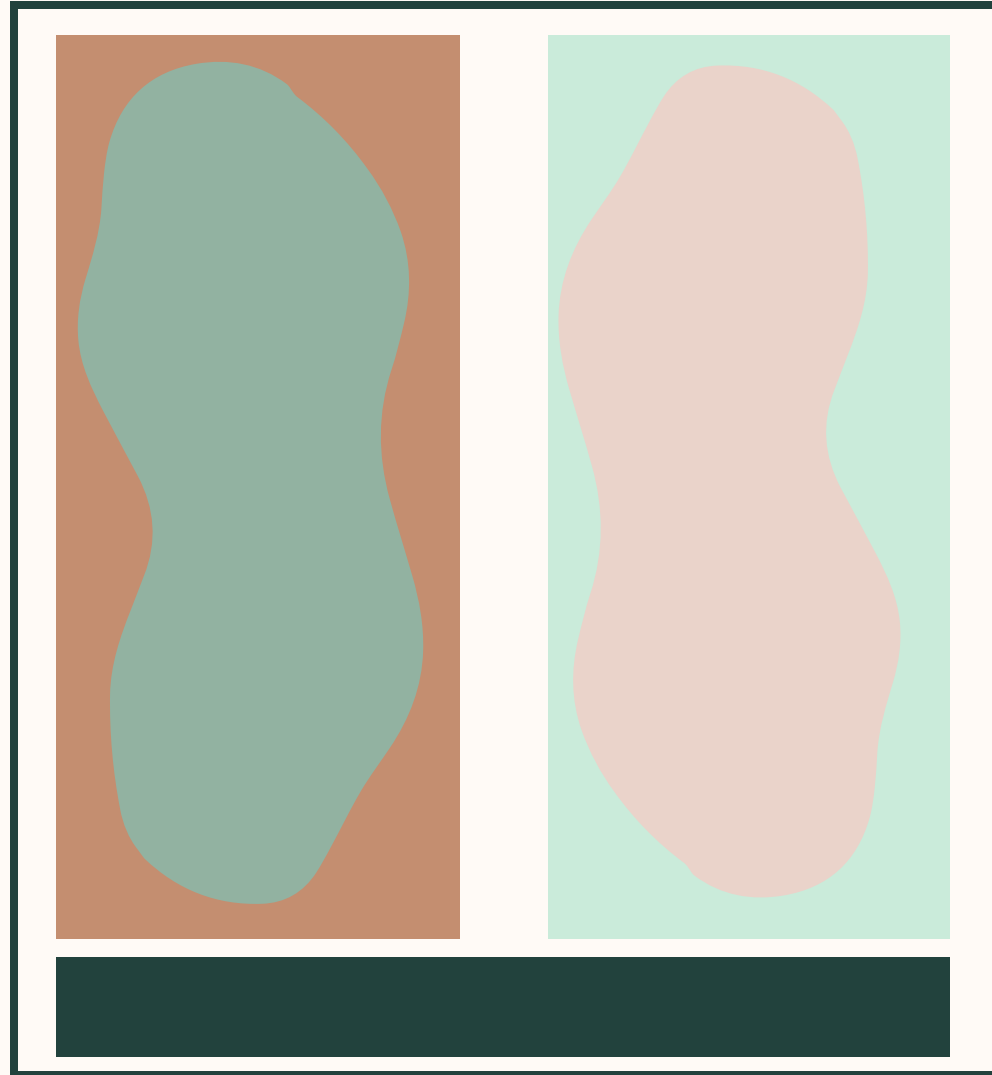
Only store what is relevant.
Storing backups indefinitely
can quickly allocate much
unnecessary disk space.

Azure example: Use Microsoft Purview to label data and add time-based purging

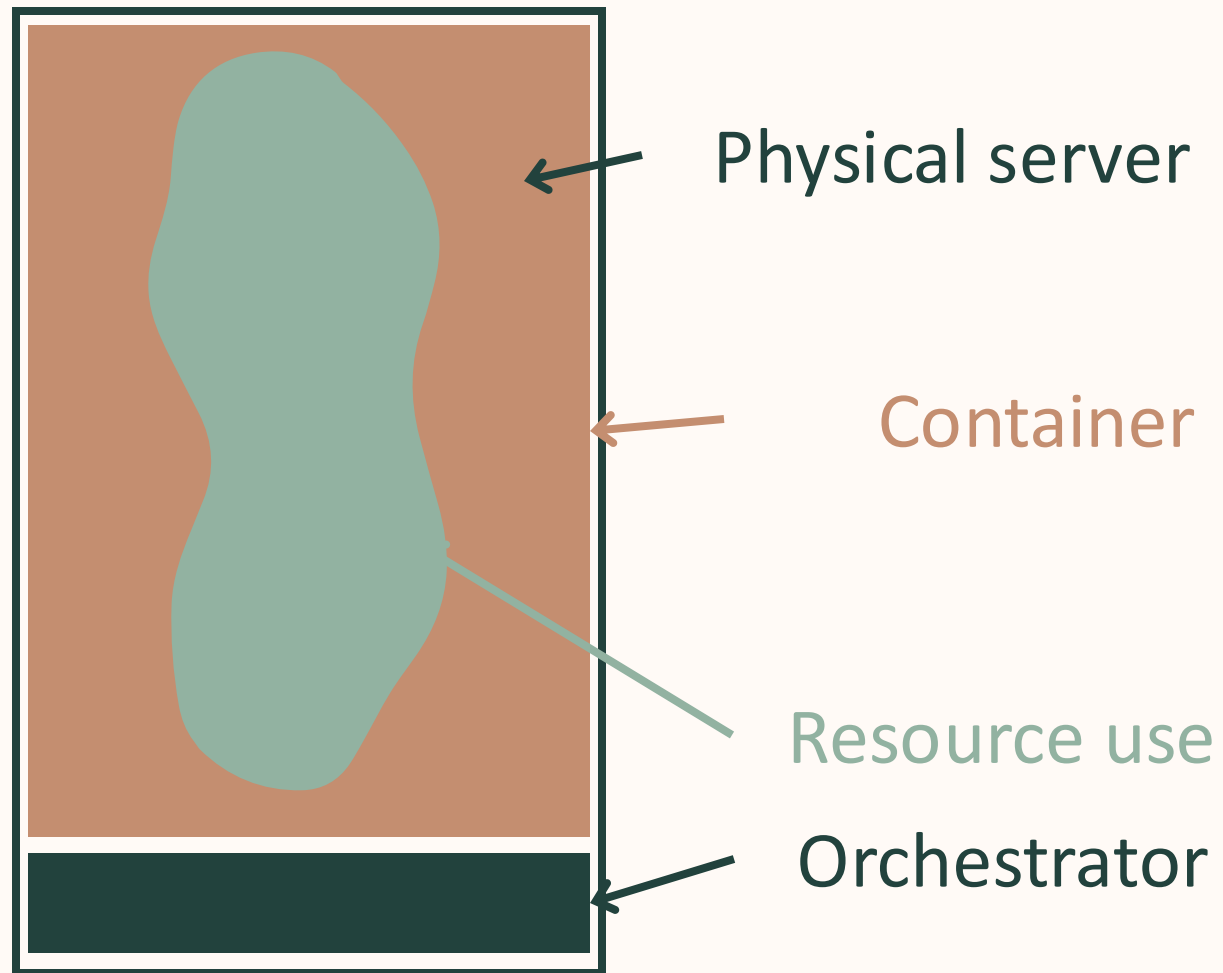
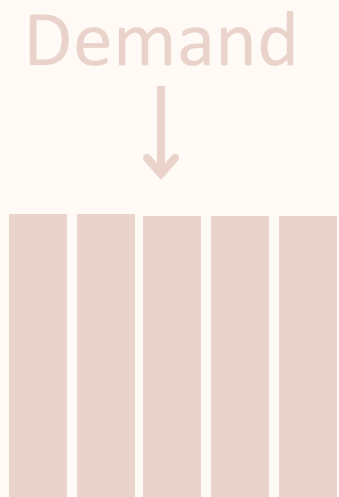
Right sizing



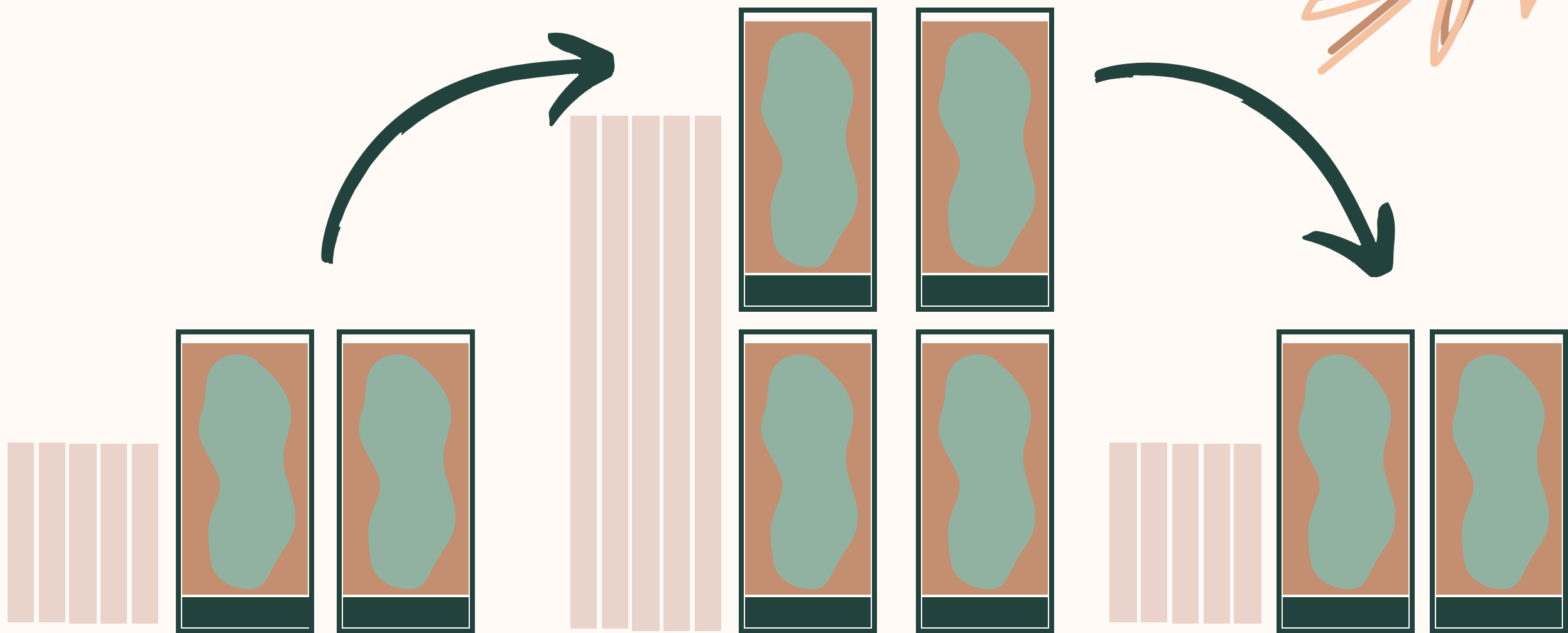
Right sizing



Auto-scaling



Auto-scaling



Serverless containers



Software without the
infrastructure

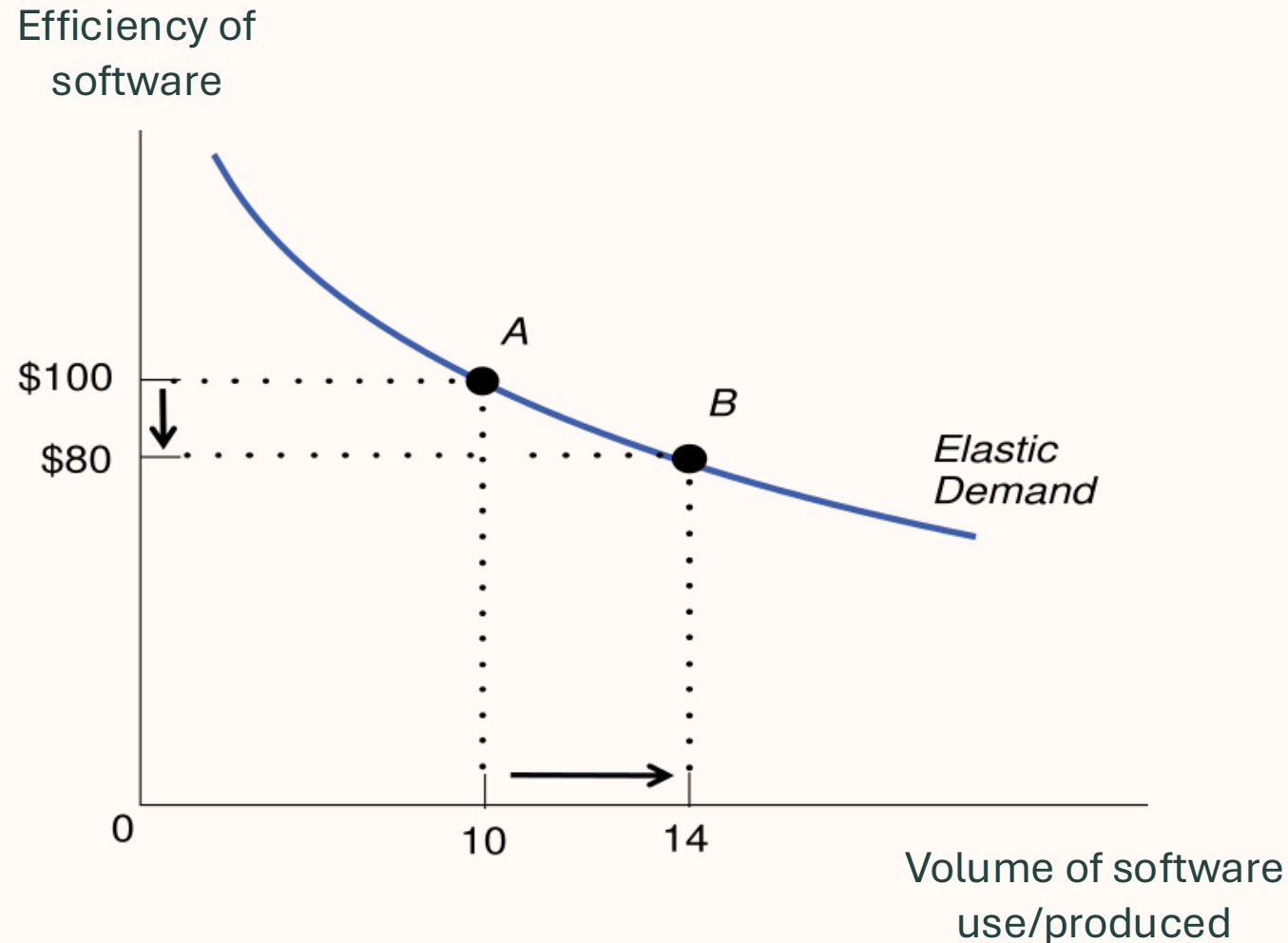
Examples: Google Cloud Run, Google Cloud Function, AWS Fargate, AWS
Lambda, Azure Container Apps or Azure Kubernetes Service

Use the most efficient hardware



Examples: AWS Graviton, Azure's Ampere Altra Arm-based VMs, Google's
Tensor Processing Unit (TPU)

A note on the Jevons Paradox



Lawrencekhoo - Own work. CC BY-SA 4.0

Energy



Carbon aware energy
resource management

Greenhouse Gas Protocol Scope 2 emission



Market-based



Location-based

Location shift



Market-based

AWS Renewable energy
projects

Google Cloud Region
picker

AWS or Azure emissions
impact tooling

Location-based

Google emissions impact
tooling

ElectricityMaps

WattTime API

Cloud Carbon Footprint
tool

Time shift

Move to a greener time

Use burstable / flexible /
spot instances when
applicable



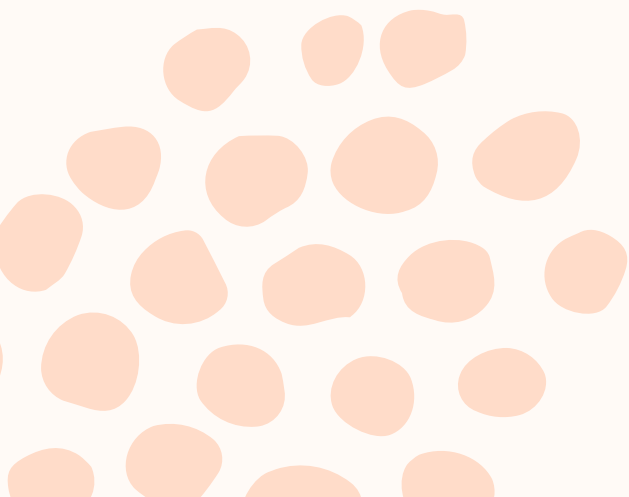
Location shift

Move to a greener place

Suitable when network cost is
minimal and privacy allows for
it



Where does this
take us?



Sustainability



Cost



Resilience



Key learnings

Software will benefit from carbon efficiency

Building green is cheaper, more performant, and more resilient



Resources

<https://maturity-matrix.greensoftware.foundation/>

<https://cloud.google.com/architecture/framework/system-design/sustainability>

<https://cloud.google.com/architecture/reduce-carbon-footprint>

<https://docs.aws.amazon.com/wellarchitected/latest/sustainability-pillar/best-practices-for-sustainability-in-the-cloud.html>

<https://learn.microsoft.com/en-us/azure/well-architected/sustainability/>



Thank you!



Questions?