Monitoring Carbon

Monitorama - Portland OR

Adrian Cockcroft - @adrianco - June 2022

Background images of lunar eclipse by Adrian just to make slides look slightly more interesting


We’re used to reporting and optimizing
throughput, latency, utilization, capacity, cost…


Carbon is just another metric for monitoring tools to report

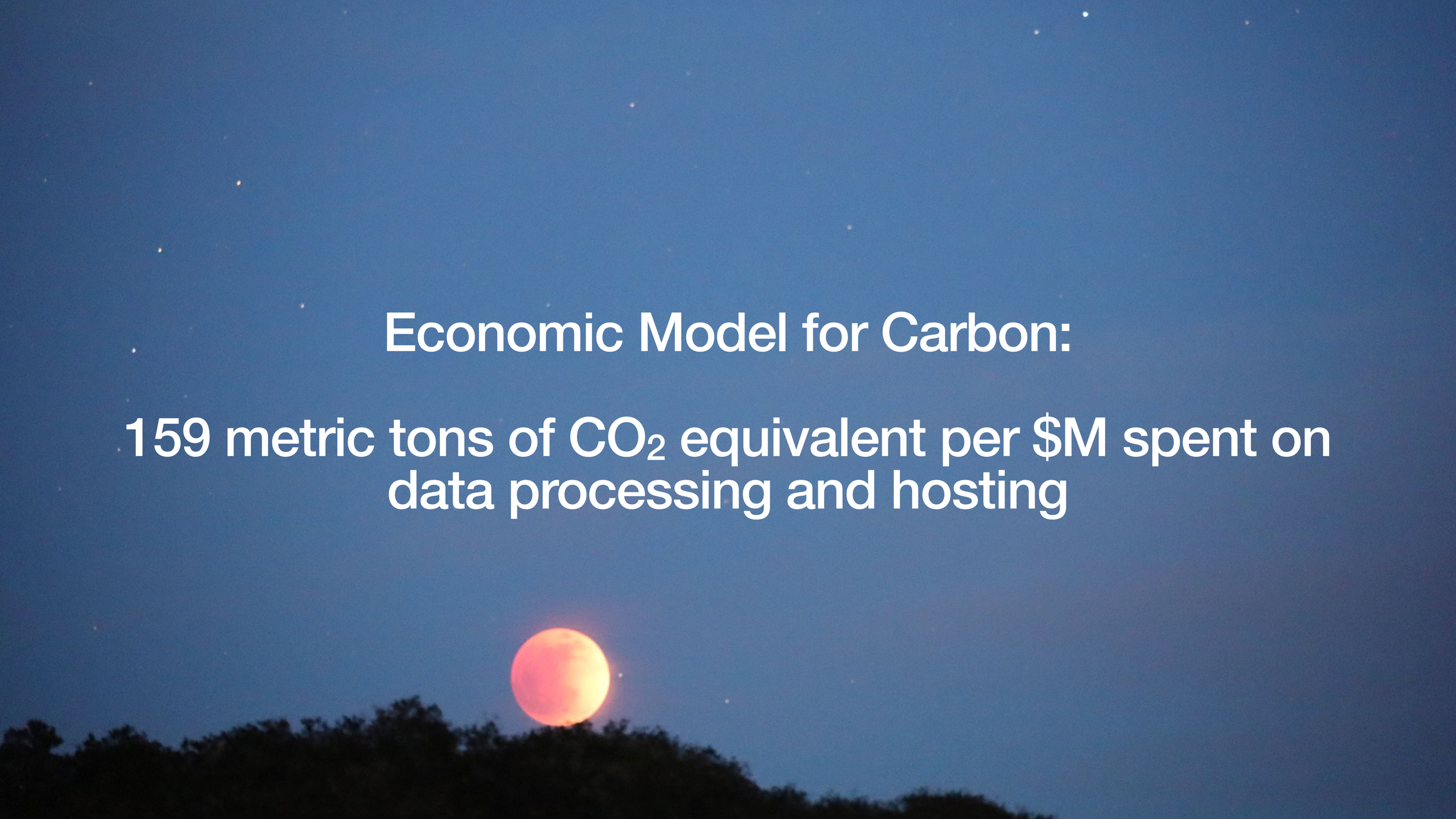

Regulators and market pressure are going to make everyone report carbon and decarbonize their products and services


How can we decarbonize our products and services?
First we need to know how much carbon we emit and where most of it is coming from


How much carbon does your company emit, for “data processing and hosting” per year?


How can we get to an answer?


How much $ does your company spend on
“data processing and hosting” per year?


Economic Model for Carbon:
159 metric tons of CO_2 equivalent per $M spent on data processing and hosting

Data processing and hosting	EPA	2020	United States	Information and Communication	Information and Communication Services

Emission intensity of supply chain (with margins i.e. cradle to shelf) in US dollars spend on: data processing and hosting. This factor is representative of the described commodity (equivalent to a goods or services category) and was calculated from 2016 data applying IPCC 4th Assessment Report conversion factors.

ID `communication_services-type_data_processing_hosting`

SOURCE EPA

YEAR RELEASED 2020

REGION United States (US)

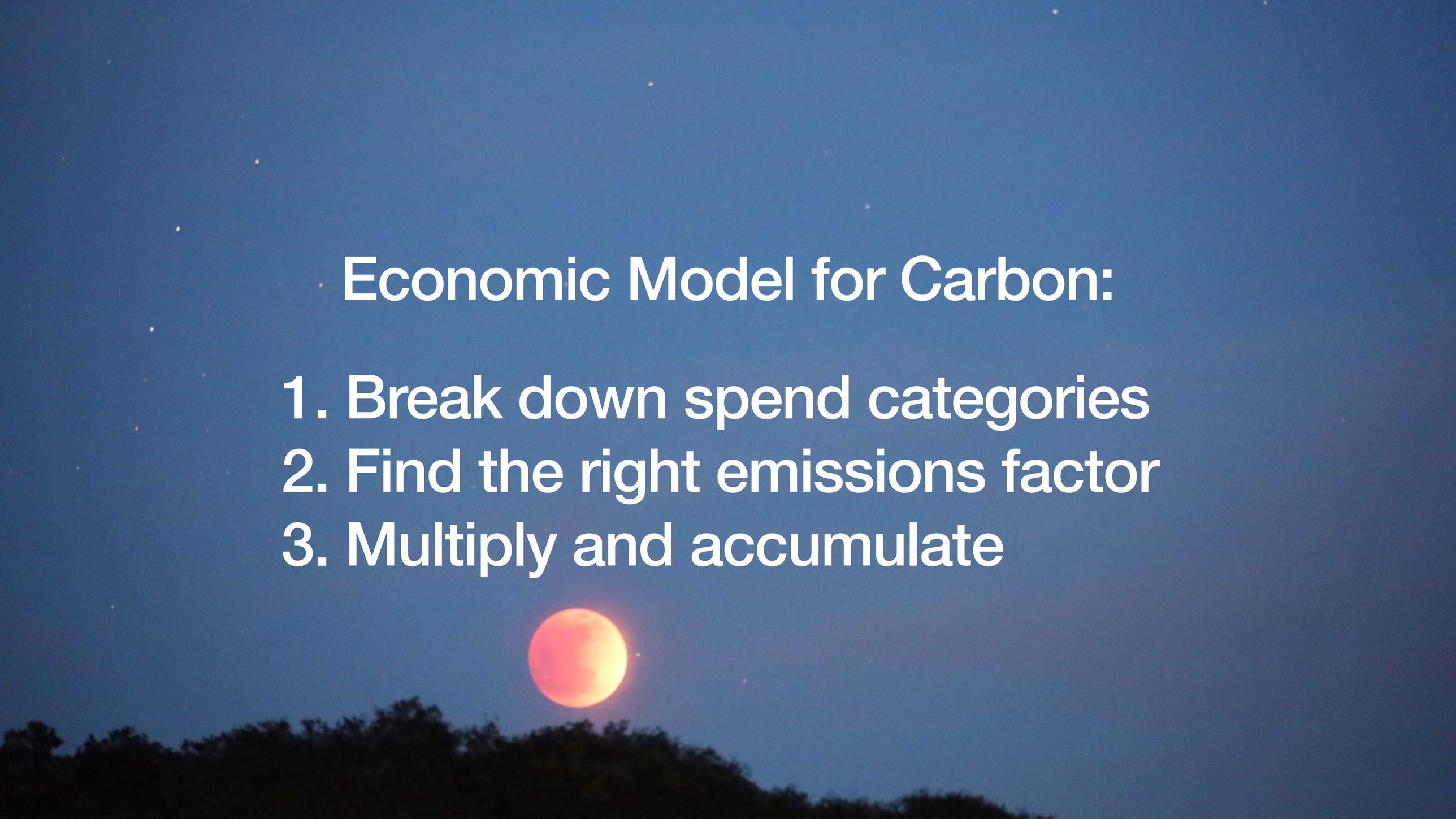
UNIT TYPE(S) Money

EMISSION FACTORS **CO_2e**: 0.159 kg/USD

CO_2e CALCULATION
Method applied: AR4
Methods supported: AR4
Origin: Source

LCA ACTIVITY Cradle_to_shelf

View examples in API Reference


Economic Model for Carbon:
1. Break down spend categories
2. Find the right emissions factor
3. Multiply and accumulate

Economic Model - The Good

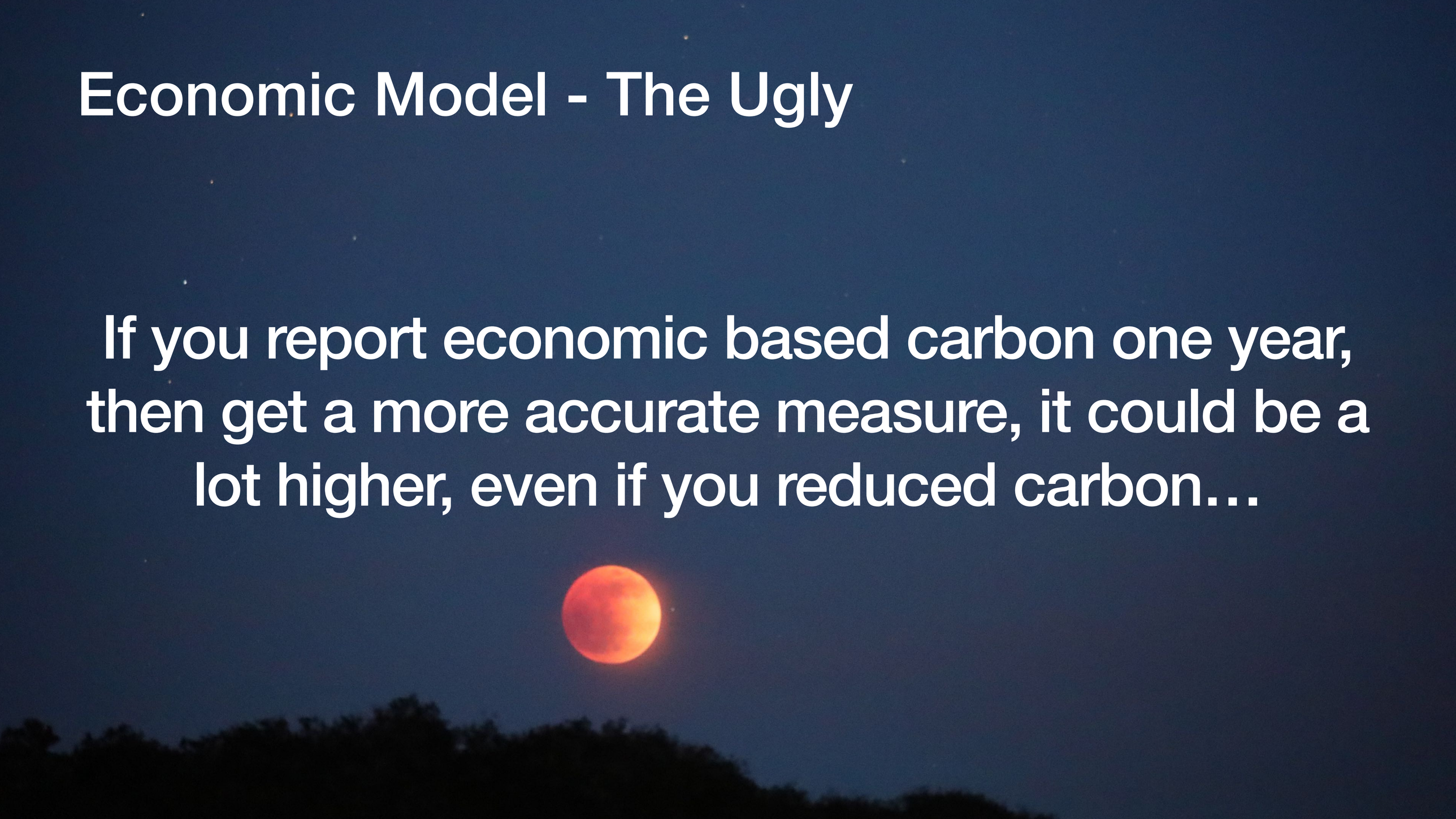
- Everyone uses economic models
- Big picture approximate view
- Input data is always available from finance
- Industry standard emissions factors that update regularly
- Auditors can trace the calculations easily
- Estimates entire life cycle

Economic Model - The Bad

- It’s a coarse model
- Emissions factors are based on old data
- It can be hard to pick the right factor
- If you spend more, reported carbon goes up
- Carbon optimizations have no effect

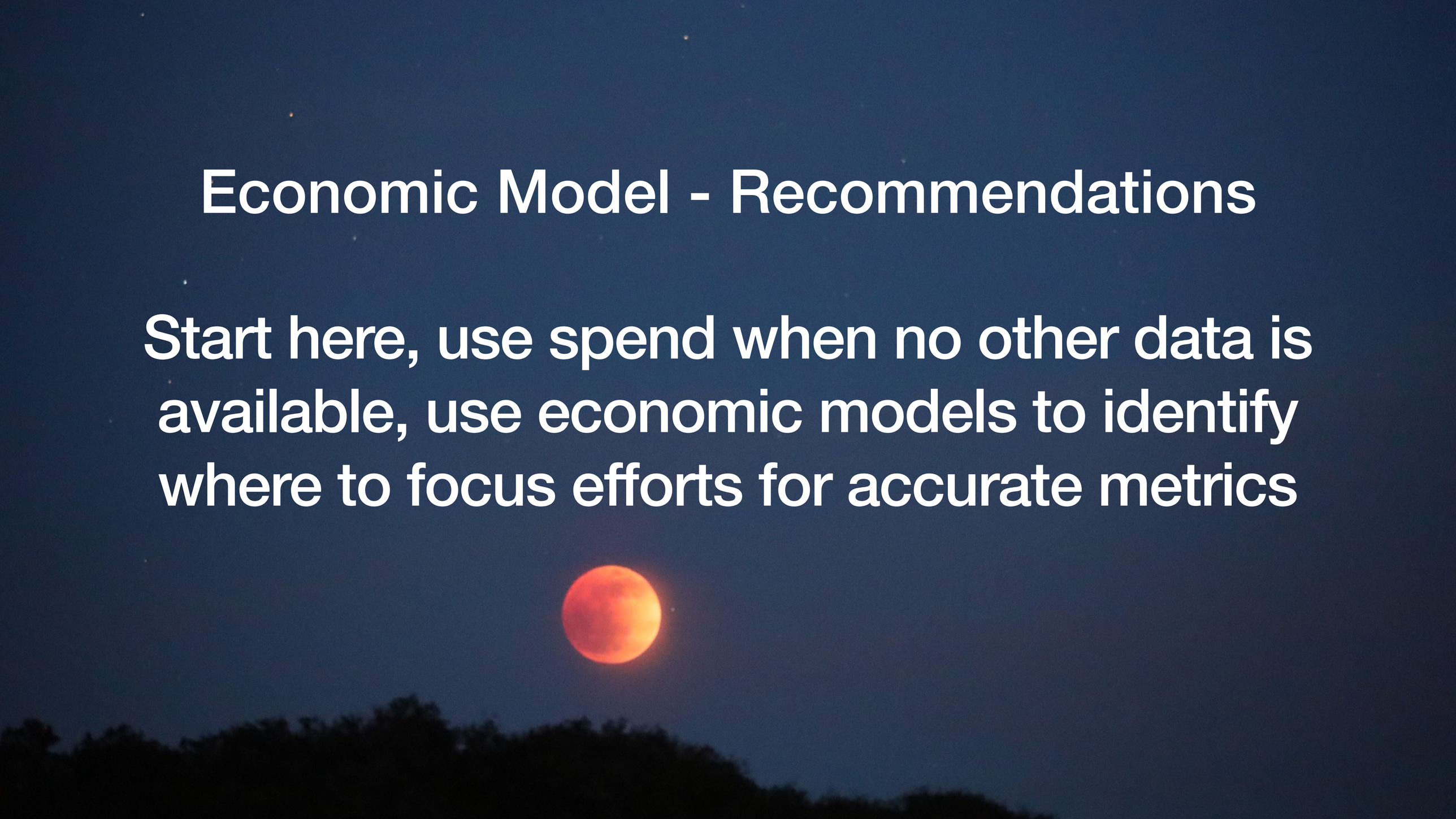
Economic Model - The Ugly

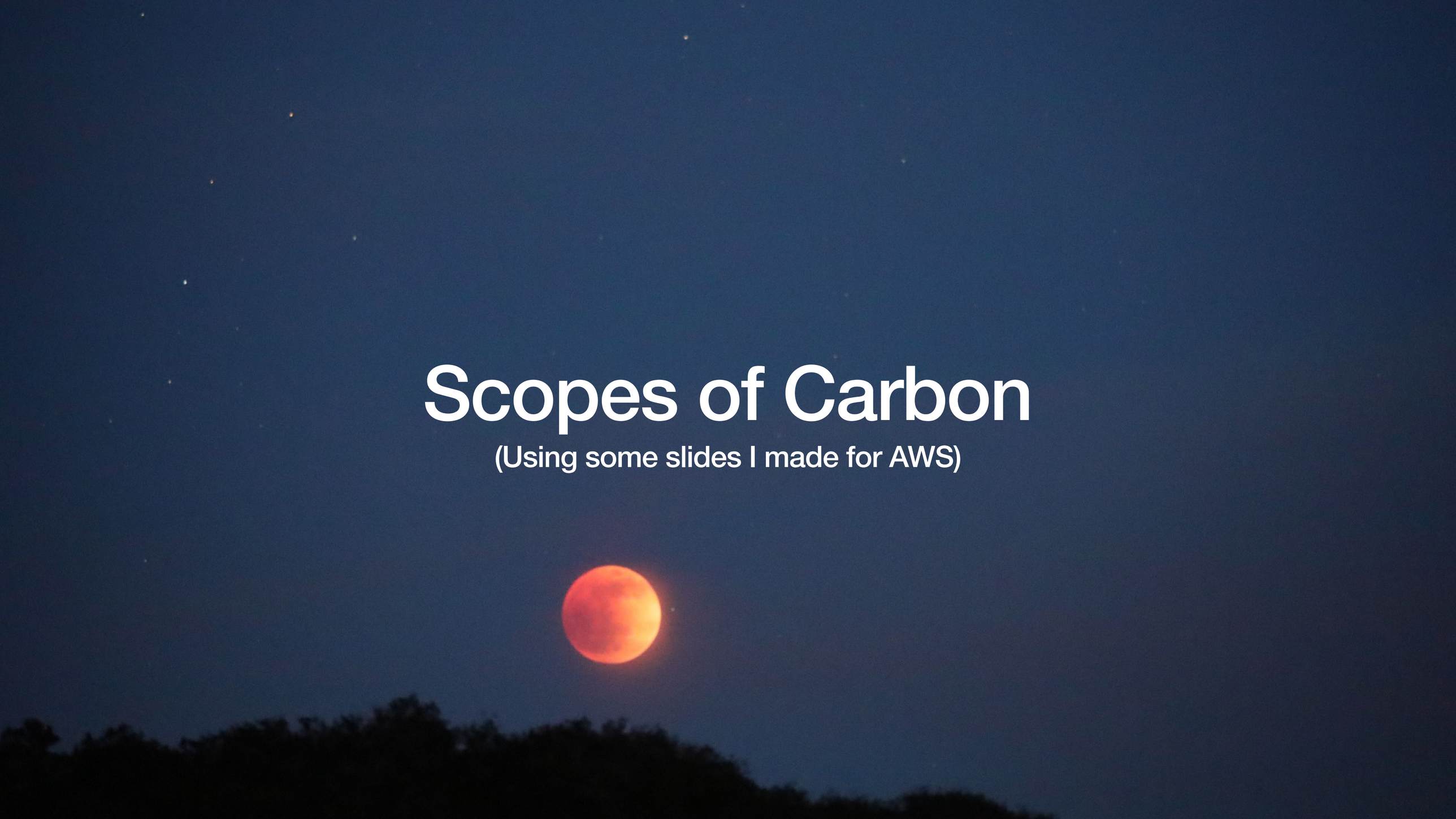
If you report economic based carbon one year, then get a more accurate measure, it could be a lot higher, even if you reduced carbon…



Economic Model - Recommendations

Start here, use spend when no other data is available, use economic models to identify where to focus efforts for accurate metrics



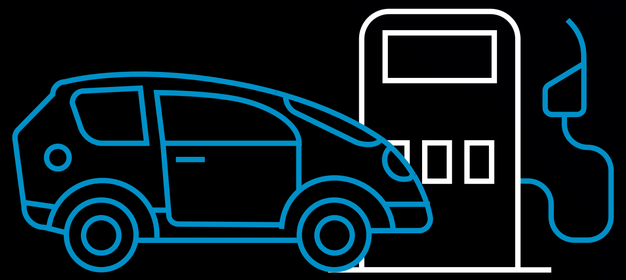


Scopes of Carbon

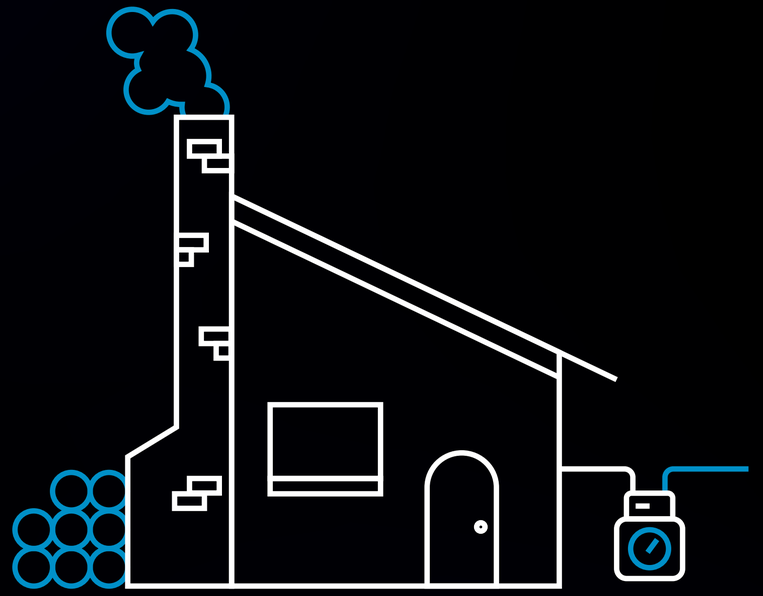
(Using some slides I made for AWS)

Scope 1—fuel consumed

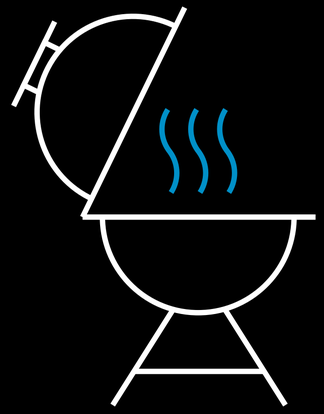
COUNTED BY WHOEVER OWNS THE FUEL WHEN IT BURNS



Car Gas pump



Fireplace Furnace Gas meter



Cooking

Electrify everything to take Scope 1 to zero

aws

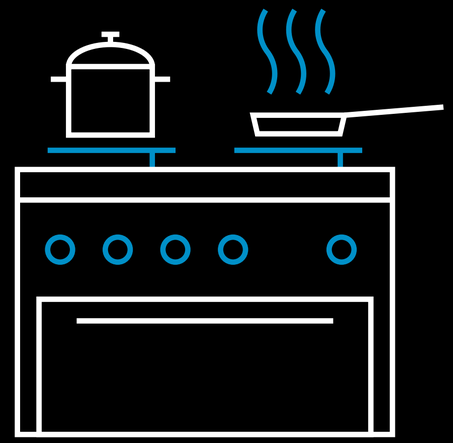
Scope 2—energy used

ELECTRICITY USE IS COUNTED ONLY ONCE WHERE IT IS CONSUMED

Windmill Power station

Grid mix

Heat pump Solar panels Batteries Electric car



Induction range

(gas ranges are also a big cause of indoor pollution that leads to asthma)

Change grid mix to renewable power and store renewable energy in batteries to reduce Scope 2

aws

Scope 3—everything else

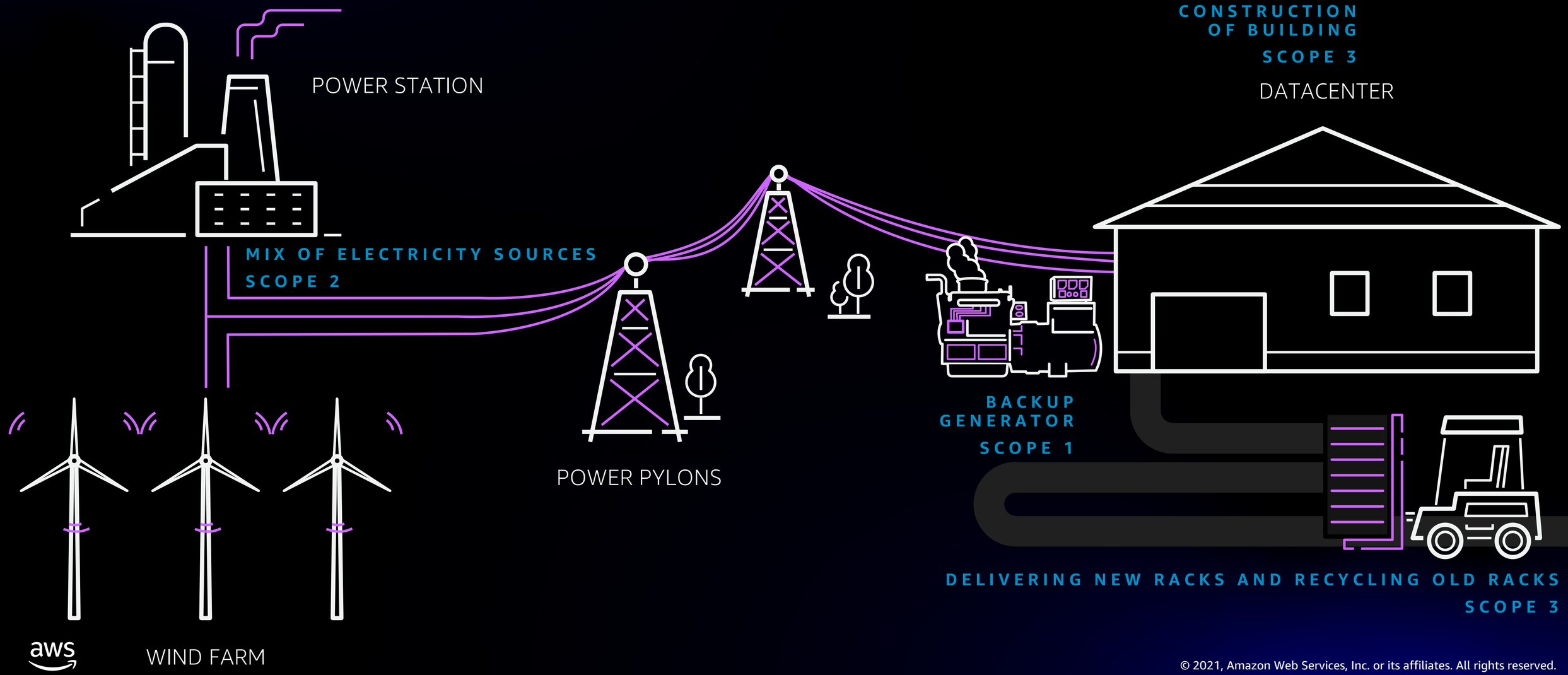
SUPPLY CHAIN AND INVESTMENTS

Scope 3 depends a lot on what kind of business you are in

aws

The carbon footprint of datacenters

TOP-DOWN CONTEXT



The carbon footprint of datacenters

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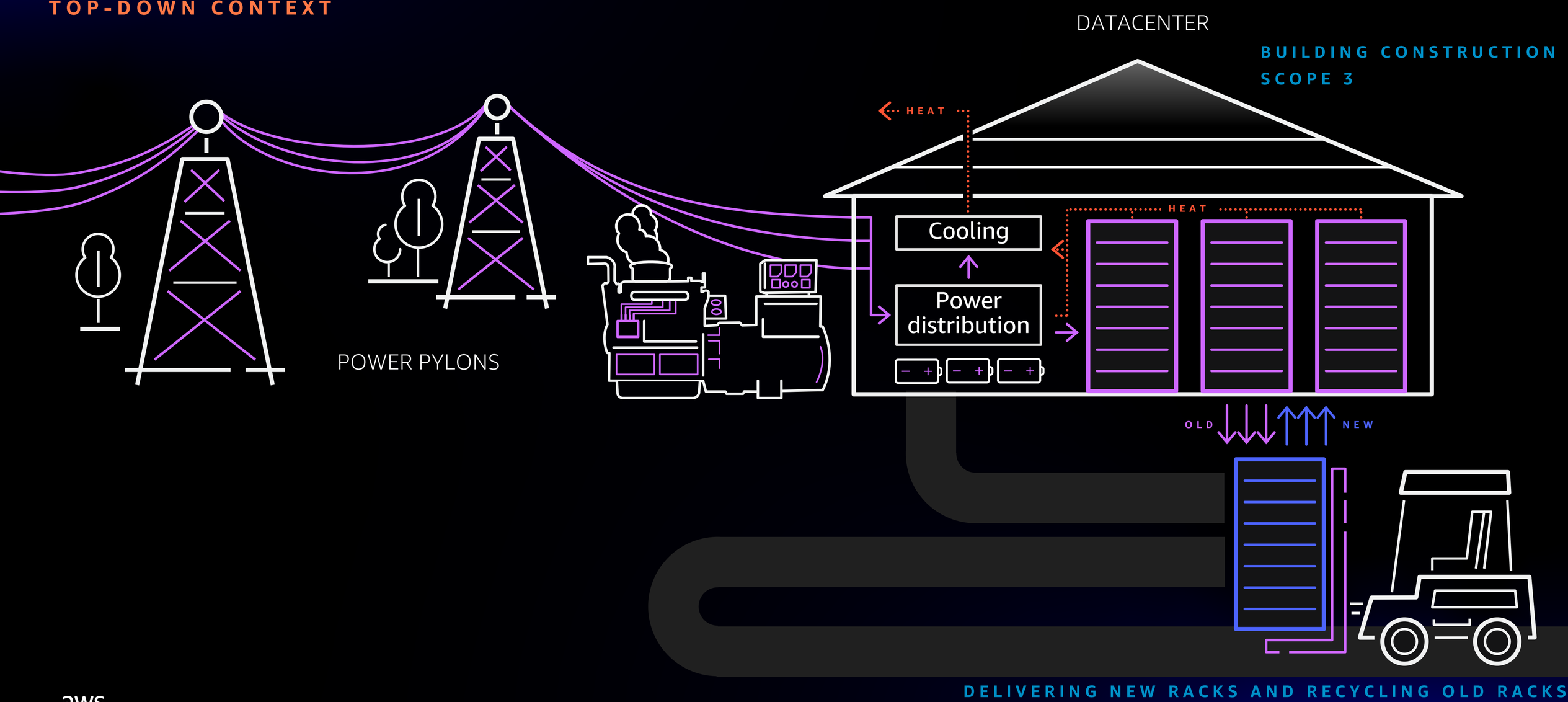
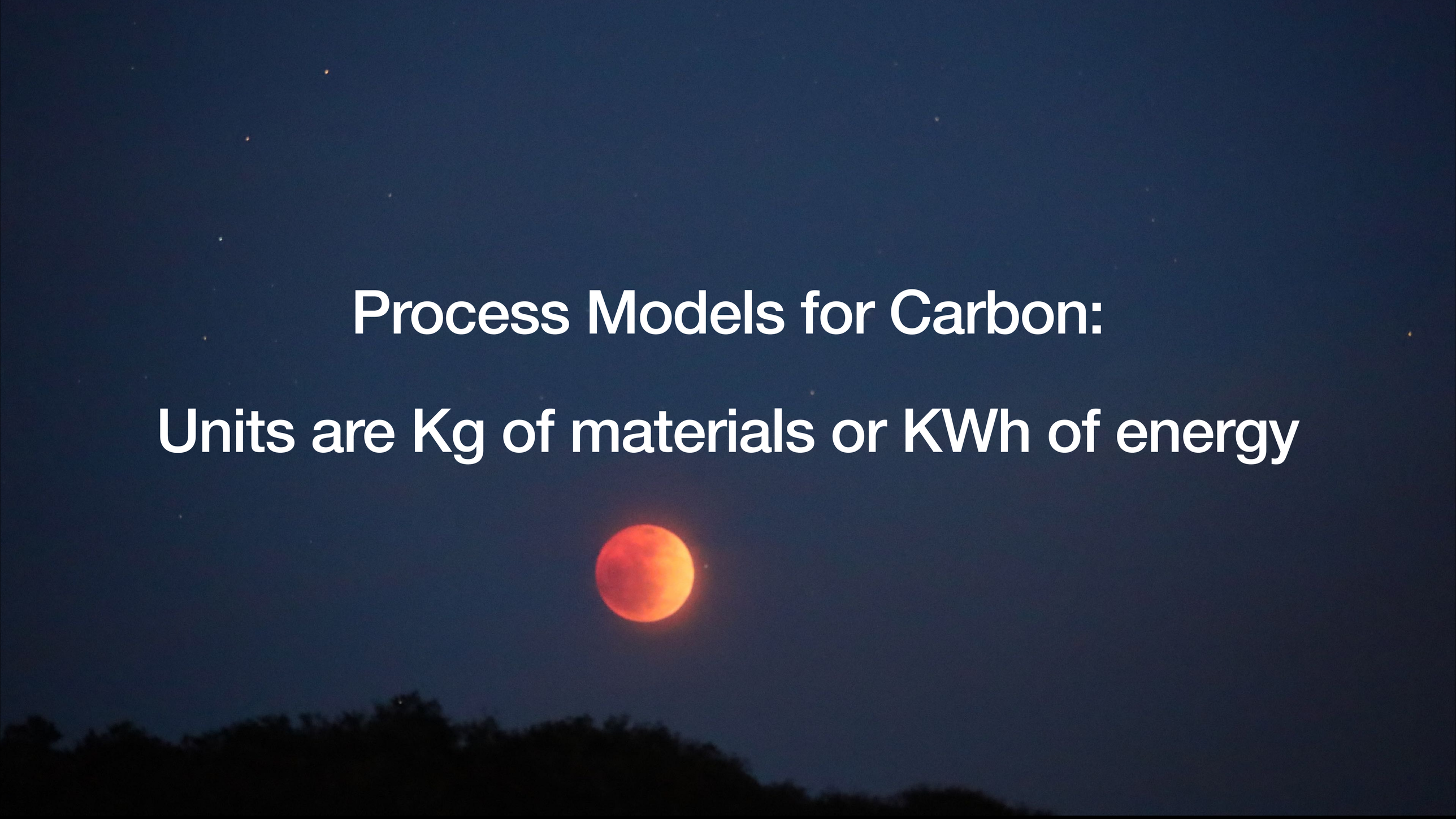



Your suppliers need to report scope 1,2,3 to you
You need to report scope 1,2,3 to your customers
Greenhouse Gas Protocol - https://ghgprotocol.org

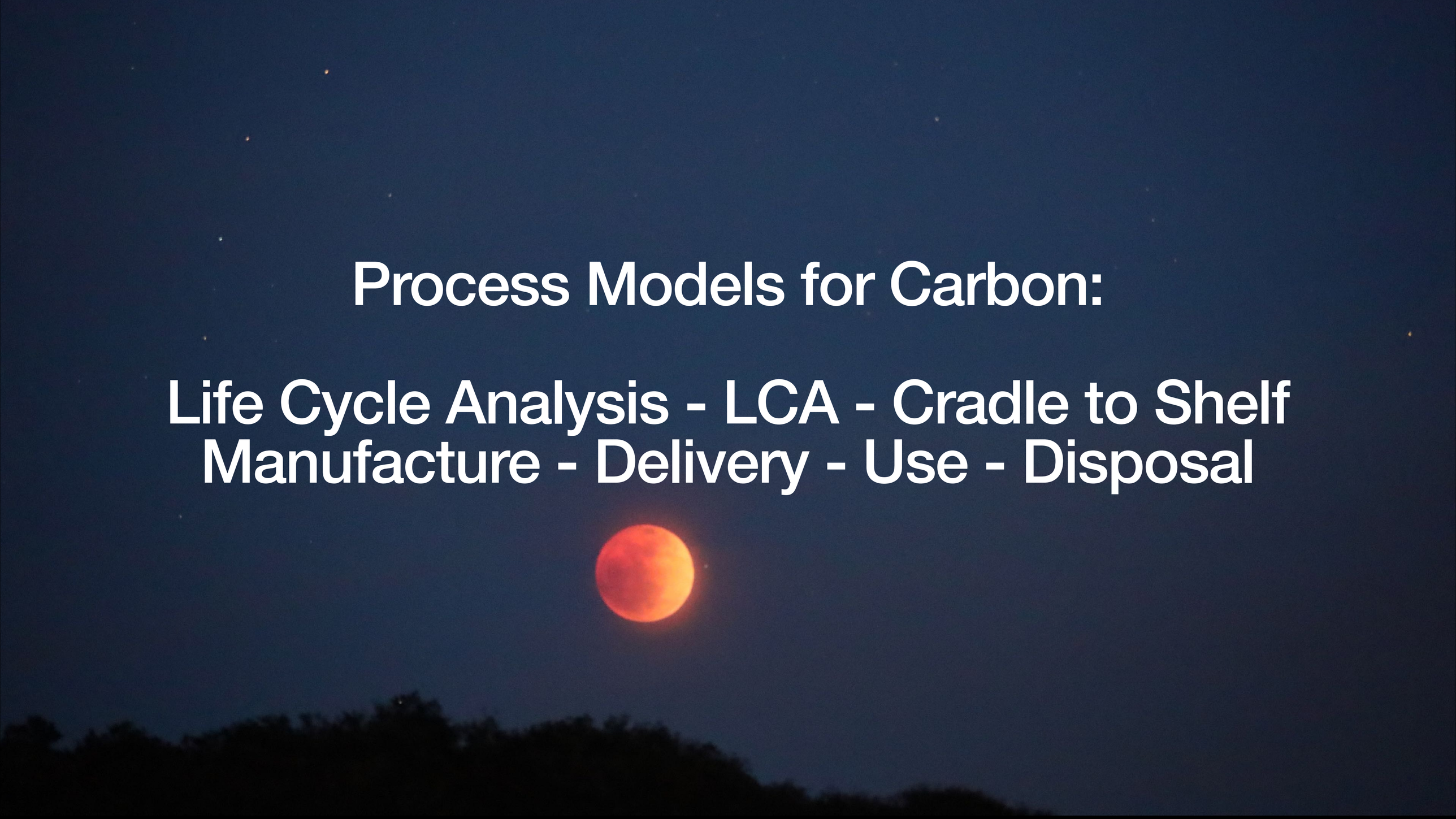

Process Models for Carbon:
Units are Kg of materials or KWh of energy

Process Model for Carbon:

1. Measure materials and energy
2. Find the right emissions factor
3. Multiply and accumulate

Process Models for Carbon:

Life Cycle Analysis - LCA - Cradle to Shelf
Manufacture - Delivery - Use - Disposal



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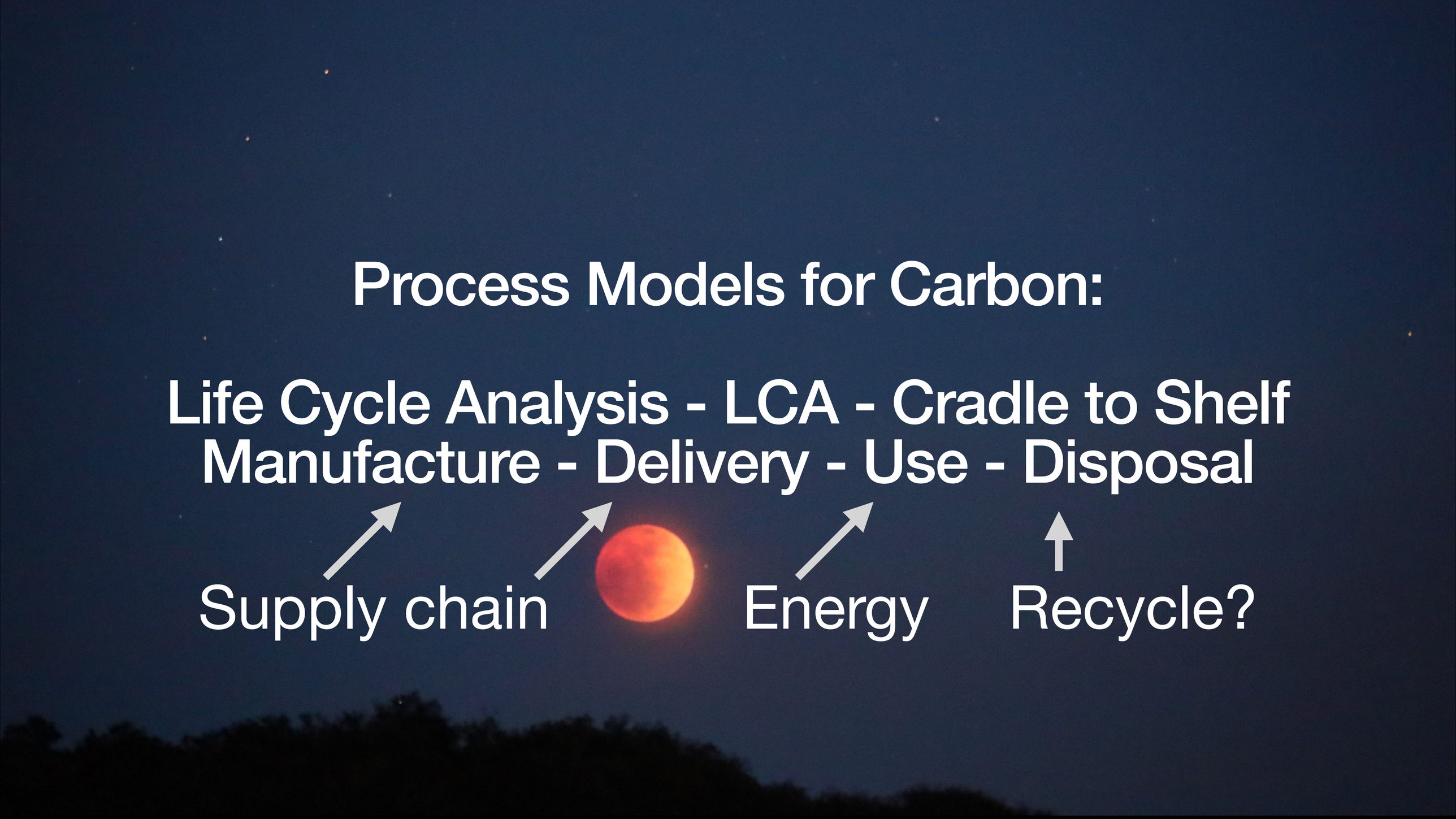


Process Model - The Good

- LCA models and expertise are available
- Reasonably detailed and accurate
- Energy data fairly easy to get for “Use phase”
- Optimizations reduce reported carbon
- Auditors can trace the calculations

Process Model - The Bad

- Models are averages for a business process
- Its a lot of work to build an LCA model
- Supply chain and recycle data is hard to get
- Scope 3 emissions are often left out

Process Model - The Ugly

Some people focus on reducing energy use, and ignore the life cycle, then get surprised when life cycle carbon ends up dominating…

Process Model - Recommendations

Build LCA process models for the areas that economic models tell you are dominating your carbon footprint. Start with energy, but don’t forget the rest of the life cycle

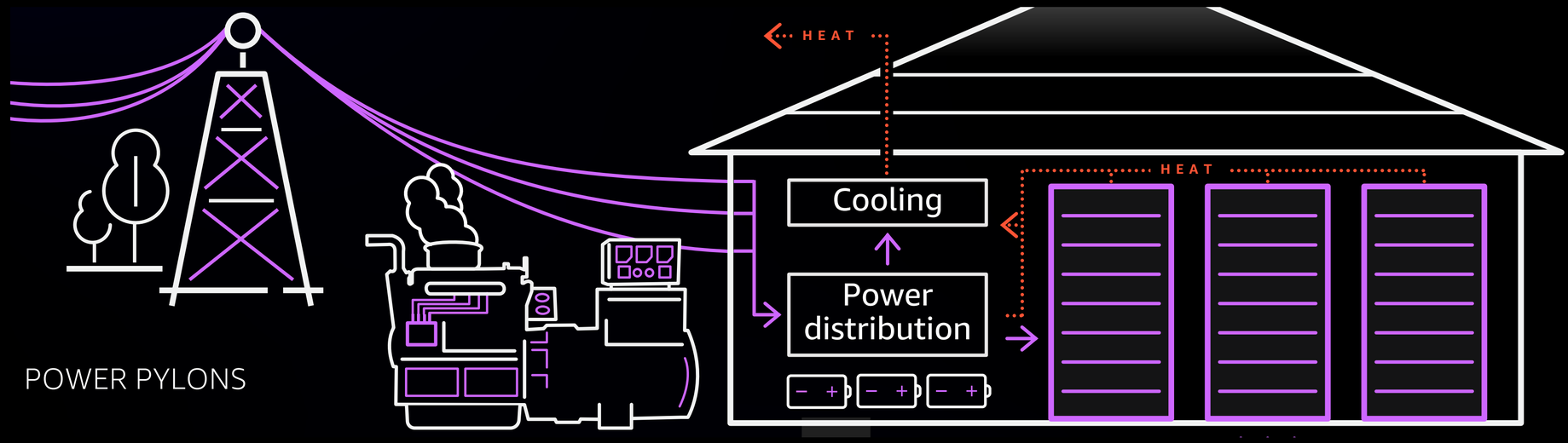
Measuring carbon emitted by a workload

How hard can it be?

Power Usage Efficiency (PUE) accounts for losses and cooling overhead but value depends on where it is measured

Power distribution and UPS batteries may be centralized or distributed in different datacenter architectures

Grid Mix is obtained from the local utility bill, usually a month or so in arrears, combined with any power purchase agreements (PPAs) or renewable energy credit (REC) purchases



Scope 2 Carbon = Power Mix * PUE * Capacity Used * Emissions factor per capacity

Problems…

Scope 2 Carbon = Power Mix * PUE * Capacity Used * Emissions factor per capacity

Utility bills delayed by a month or more, depending where in the world they are…

PPA - Power Purchase Agreements are contracts to build private power generation capacity
e.g. Amazon has over 15GW of PPAs (Solar, Wind, Battery) around the world

REC - Renewable Energy Credits are purchases of generation capacity on the open market, from existing generators, the energy can only be claimed once

RECs may be used to “top up” on top of PPAs, helps fund existing renewable capacity, but doesn’t create additional capacity, like PPAs do

Problems…

Scope 2 Carbon = Power Mix * PUE * Capacity Used * Emissions factor per capacity

Grid mix changes every month but is mostly getting better over time

Hourly data for 24/7 grid mix starting to appear for some suppliers in some parts of the world

GCP and Azure publicly working towards 24/7

cloudcarbonfootprint.org open source tool estimates are wrong, don’t include PPAs

Also see FlexiDAO.com

Problems…

Scope 2 Carbon = Power Mix * PUE * Capacity Used * Emissions factor per capacity

Power Usage Efficiency is not well standardized. Values can be compared for similar datacenter designs, but some good efficiency improvements may move components from the infrastructure to the equipment, and make PUE look worse. See:

https://perspectives.mvdirona.com/2009/06/pue-and-total-power-usage-efficiency-tpue/

Problems…

Scope 2 Carbon = Power Mix * PUE * Capacity Used * Emissions factor per capacity

Dedicated compute and storage capacity is relatively easy to account for, but sliced instances, shared services, network equipment etc. are a challenge to allocate

If you are operating a multi-tenant service and want to report carbon, then you have a problem figuring out how much capacity to allocate to each customer, and how much is overhead that you should own yourself…

Problems…

Scope 2 Carbon = Power Mix * PUE * Capacity Used * Emissions factor per capacity

Need to know how much power each instance type, storage class or service uses
This varies based on utilization and other overheads confuse measurements

Some data is available for some systems…


What can you do today?

For carbon audits:

Cloud vendor reports

On-prem economic models

More accurate but not useful

Cloud Vendor Reports

AWS - Customer Carbon Footprint - Billing Console - Free
Market based scope 1 & 2, audited but currently very low resolution
Europe and US regions near zero carbon today, global zero by 2025

Azure - Microsoft Sustainability Manager - Dynamics - $$
Market based scope 1 & 2, audited, high resolution
Europe and US regions report near zero carbon today

GCP - Carbon Footprint - Tool, API - Free
Location based scope 1 & 2, not audited, high resolution
Easiest place to build workload optimization products today

Market vs. Location

CO_2 is globally mixed
So saving carbon anywhere helps, but that gets harder over time

Power grids are markets for energy
Power generation and use occur in different locations
but adding renewable capacity reduces fossil capacity in that market

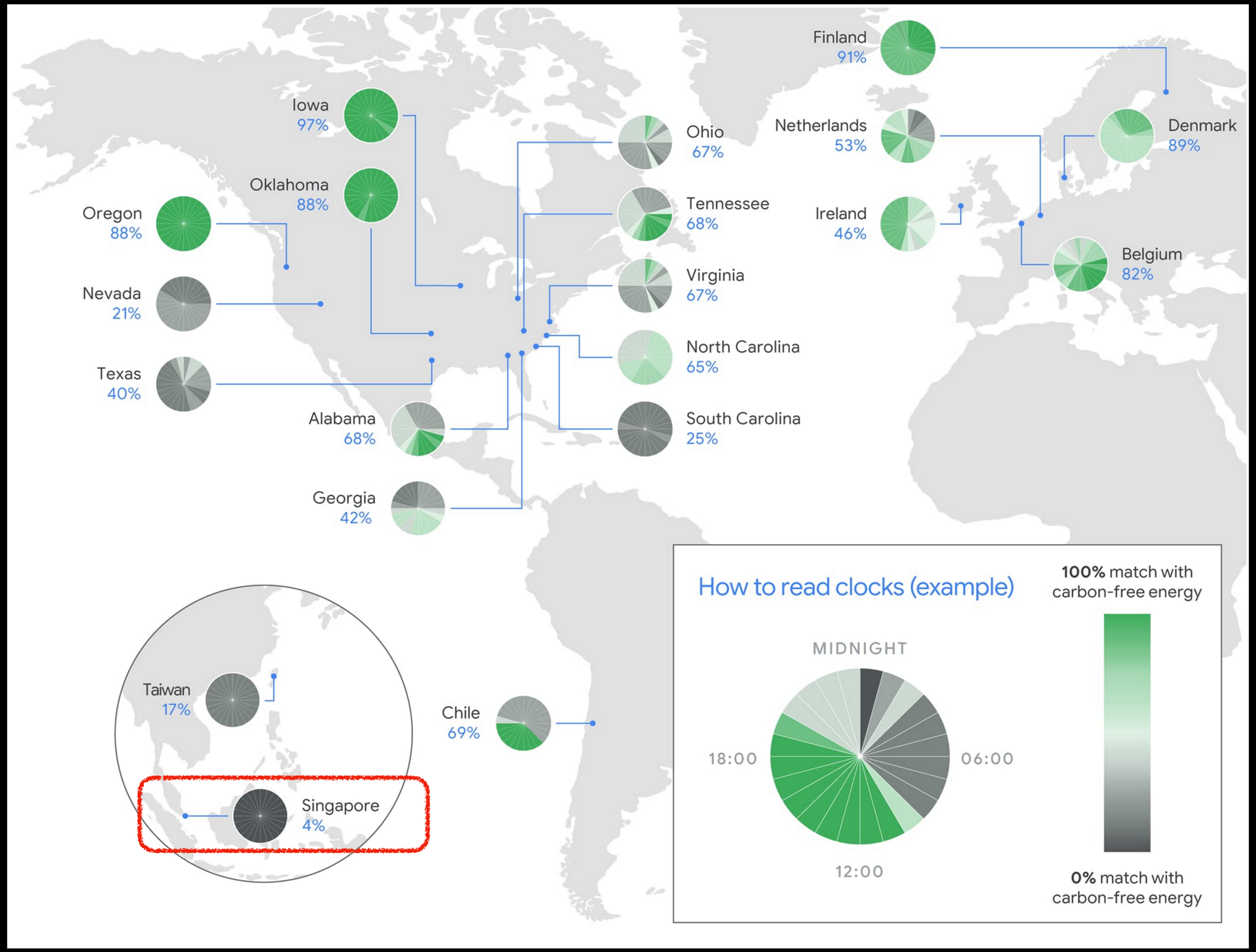
Google's location based reports don't include their PPAs
AWS and Azure market based reports do include PPAs and RECs…

What about offsets that remove carbon?
Differing policies and opinions

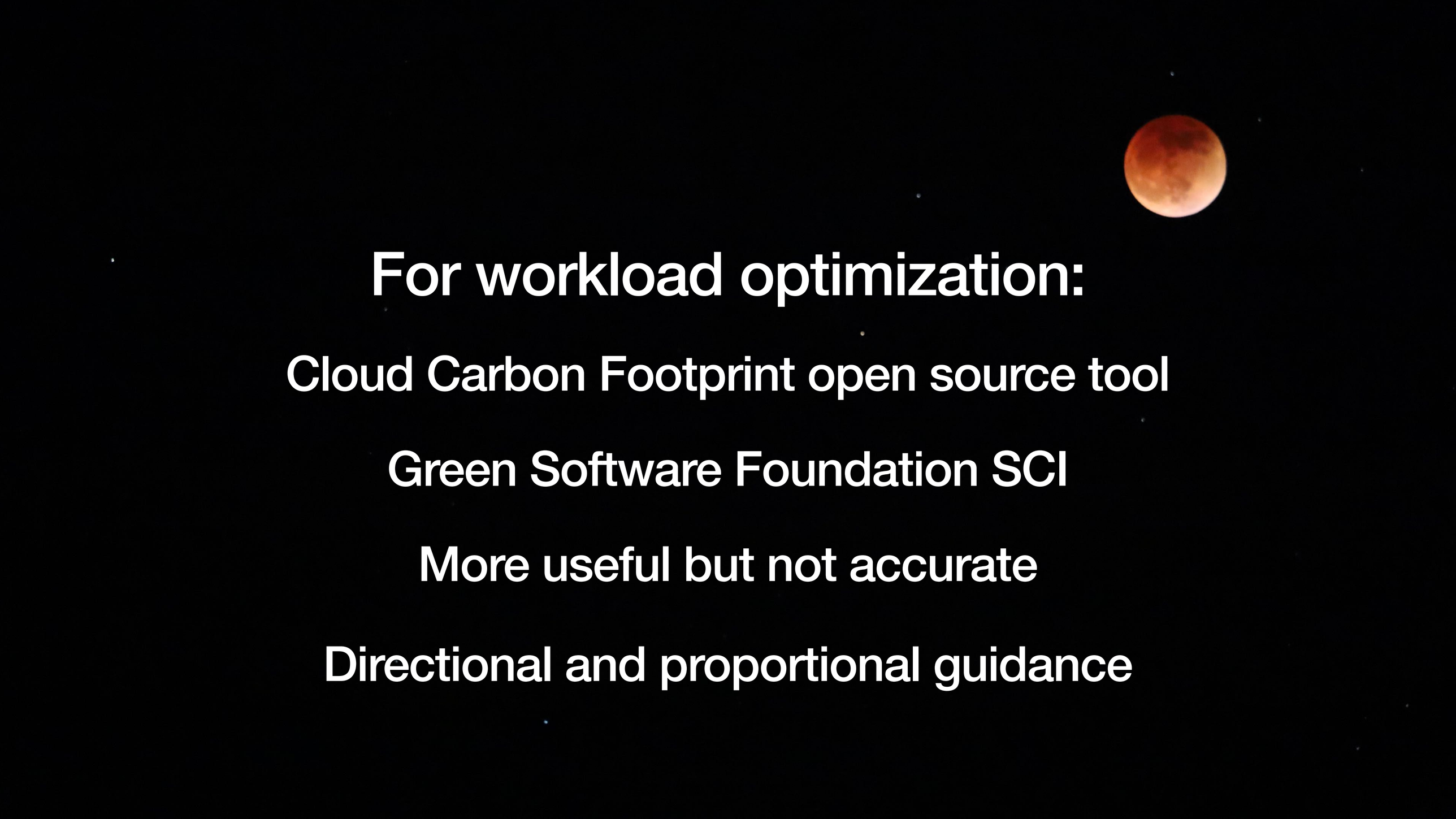
Google Cloud Regions

% carbon free energy by location and time of day

Asia is the problem for everyone



https://sustainability.google/progress/energy/



For workload optimization:

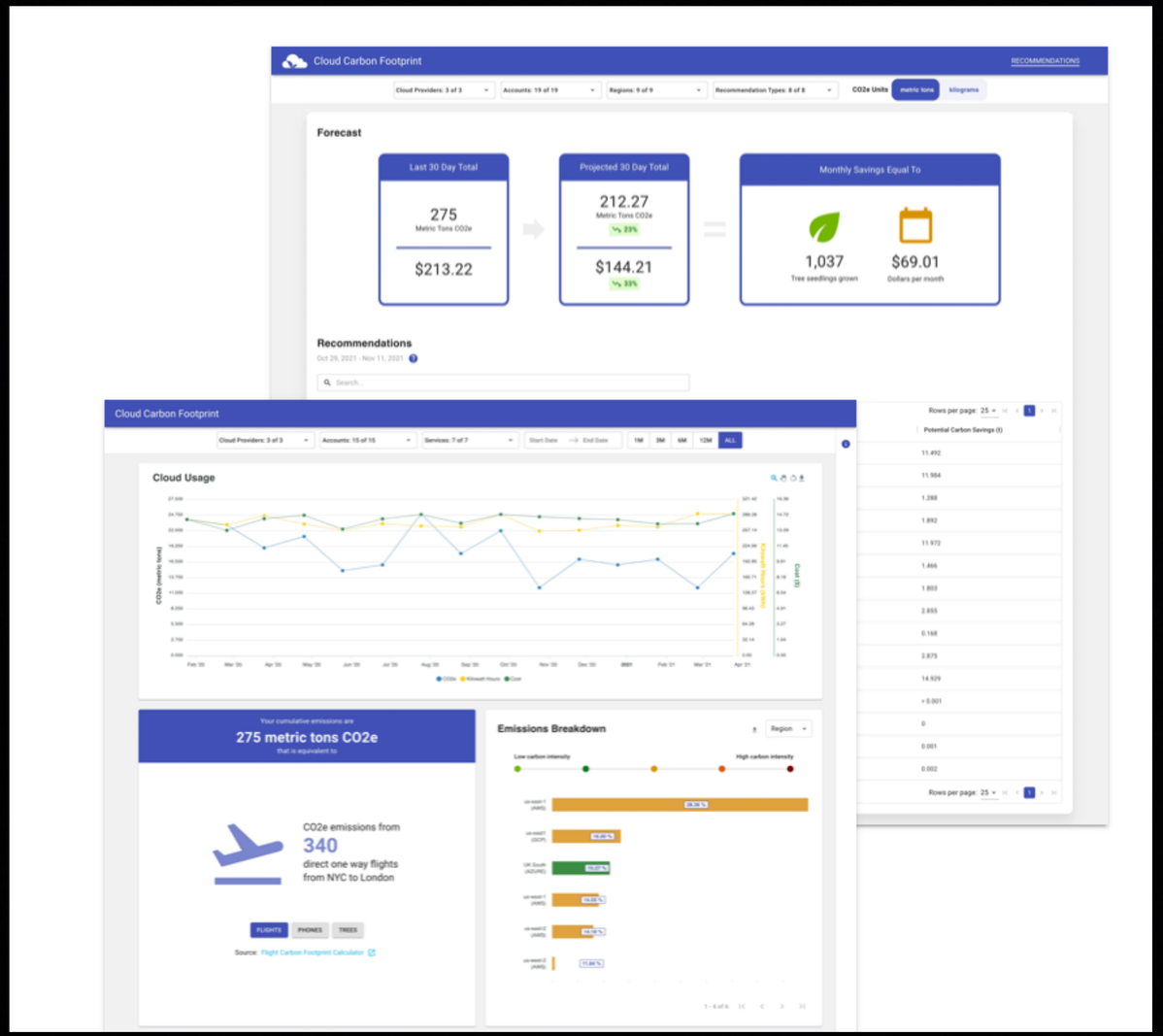
Cloud Carbon Footprint open source tool

Green Software Foundation SCI

More useful but not accurate

Directional and proportional guidance

Cloud Carbon Footprint tool



cloudcarbonfootprint.org

Use for tuning exercises within a region, to find where to focus on optimizing workloads

Comparisons across regions and vendors don't have access to enough underlying data to be useful

Green Software Foundation

SCI is a model for carbon per unit of work
e.g. carbon per API call or transaction

https://greensoftware.foundation/projects/software-carbon-intensity-sci-specification

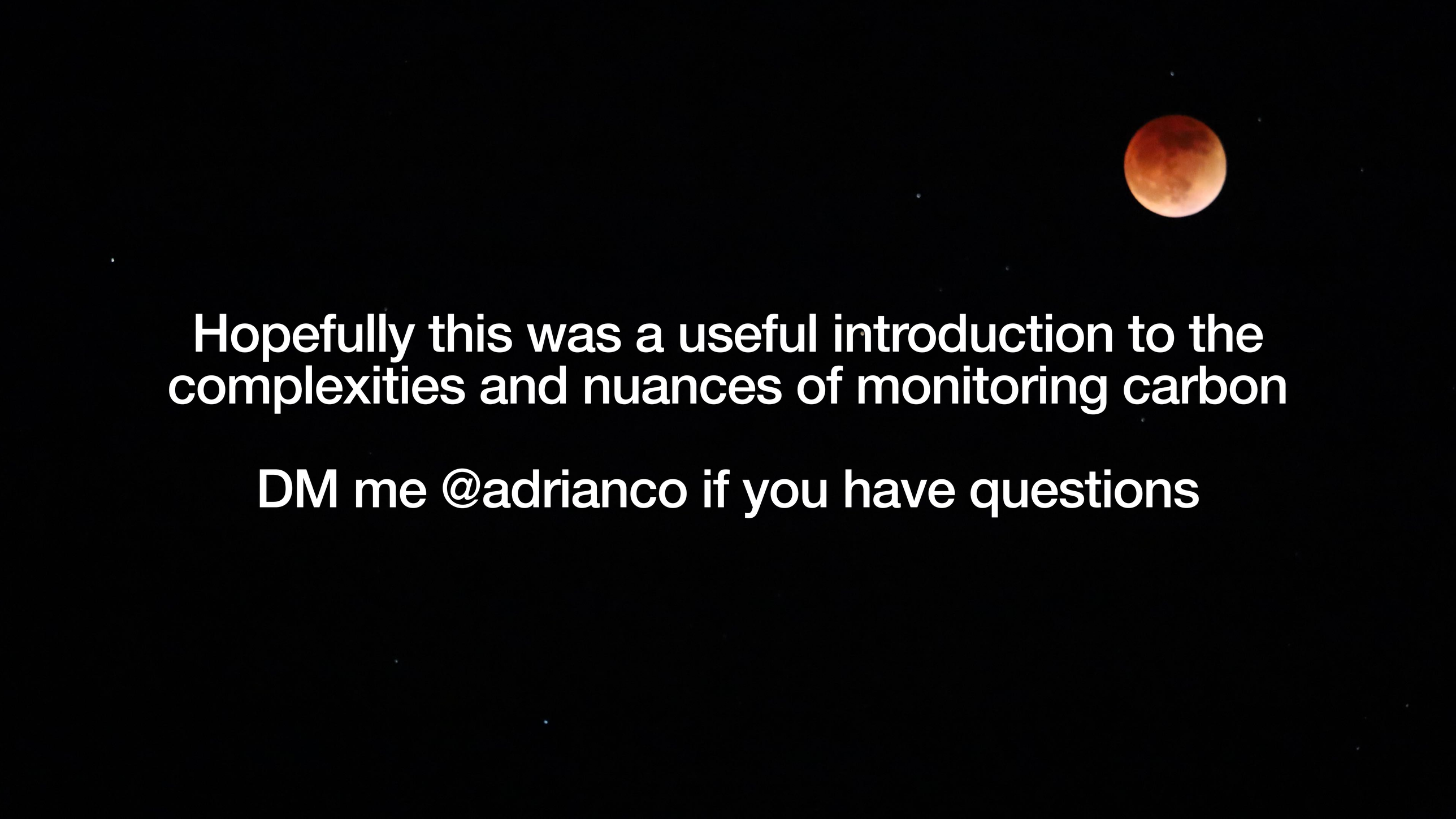
https://github.com/Green-Software-Foundation/software_carbon_intensity

Cloud Provider Comparison - My Opinions

Not much difference in carbon emissions between providers, they all have lots of PPAs and are all much better than datacenters

Big differences in tooling and transparency

Lots of opportunity for monitoring tools vendors


Hopefully this was a useful introduction to the complexities and nuances of monitoring carbon
DM me @adrianco if you have questions

Moonitoring Carbon

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Adrian Cockcroft @adrianco — June 2022