Getting to a fossil free internet by 2030

A tour of the tech and policy changes to get us there

GREENWEBFOUNDATION.ORG

Chris Adams

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Hello!

I'm Chris. My background:

Loco2 - Low CO2 Travel in Europe by train

A.M.E.E (Avoid Mass Extinction Engine) - CO2 calculation as an API

Icebreaker One - data infrastructure for a net zero future

Spend Network - direct public spending for net zero

Green Web Foundation - make the web green

Green Software Foundation - Policy WG chair

Branch Magazine - climate / tech magazine

Environment Variables - podcast on green software

Contact: chris@thegreenwebfoundation.org | @mrchrisadams

What we’ll cover today

1. Why a fossil free internet by 2030

2. A framework to think about it - *Consumption, Intensity, Direction*

3. Using the framework to look ahead at policy and tech changes

1

Why a fossil free internet by 2030

Why a fossil free internet by 2030

We are in a climate crisis largely because we keep burning fossil fuels, instead of finding a path off them

1.

Why a fossil free internet by 2030

1. **Achievable** - Big firm buy in already, but doable at small scale too.
2. **Save carbon** - climate emergency, remember?
3. **Save lives** - 5m+ avoidable deaths / year from poor air quality globally, primarily from burning fossil fuels
4. **Save money** - fossil fuels are expensive with volatile prices
5. **Improve retention among staff** - ppl 💚 greener firms
6. **Energy security** - geopolitics and local resiliency

A framework to think about digital sustainability: *Consumption, Intensity, Direction*

2

A model for thinking about digital sustainability - **CID**

Consumption	Intensity	Direction
Can I change how much we need?	Can I change how much harm is done?	Can I change where we are headed?

A model for thinking about digital sustainability - **CID**

Consumption	**Intensity**	**Direction**
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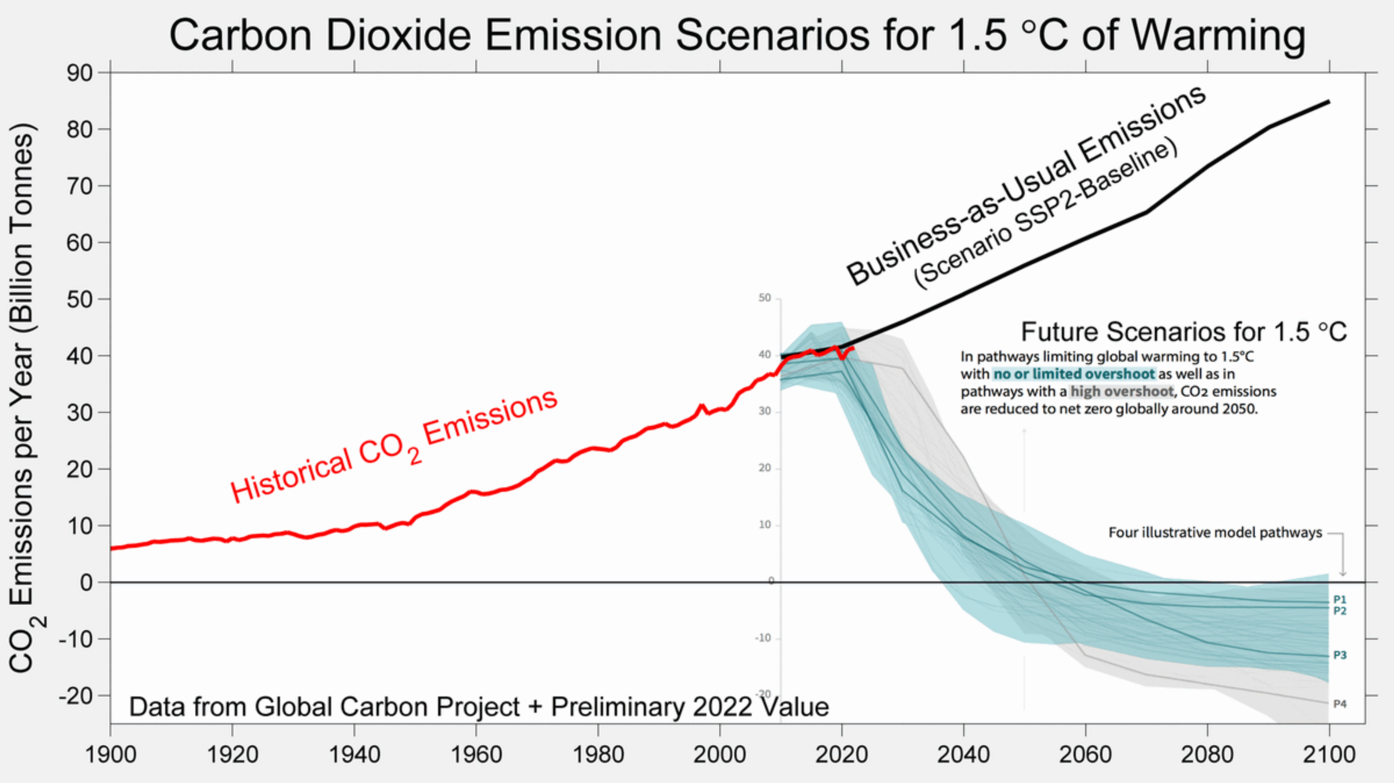


Image: Dr. Robert Rohde / Data: Global Carbon Project & IPCC

 | Source: https://twitter.com/RARohde/status/1596797941557366784

“ the Paris Agreement will require the information and communication technology (ICT) industry to reduce greenhouse gas (GHG) emissions by 45 per cent from 2020 to 2030

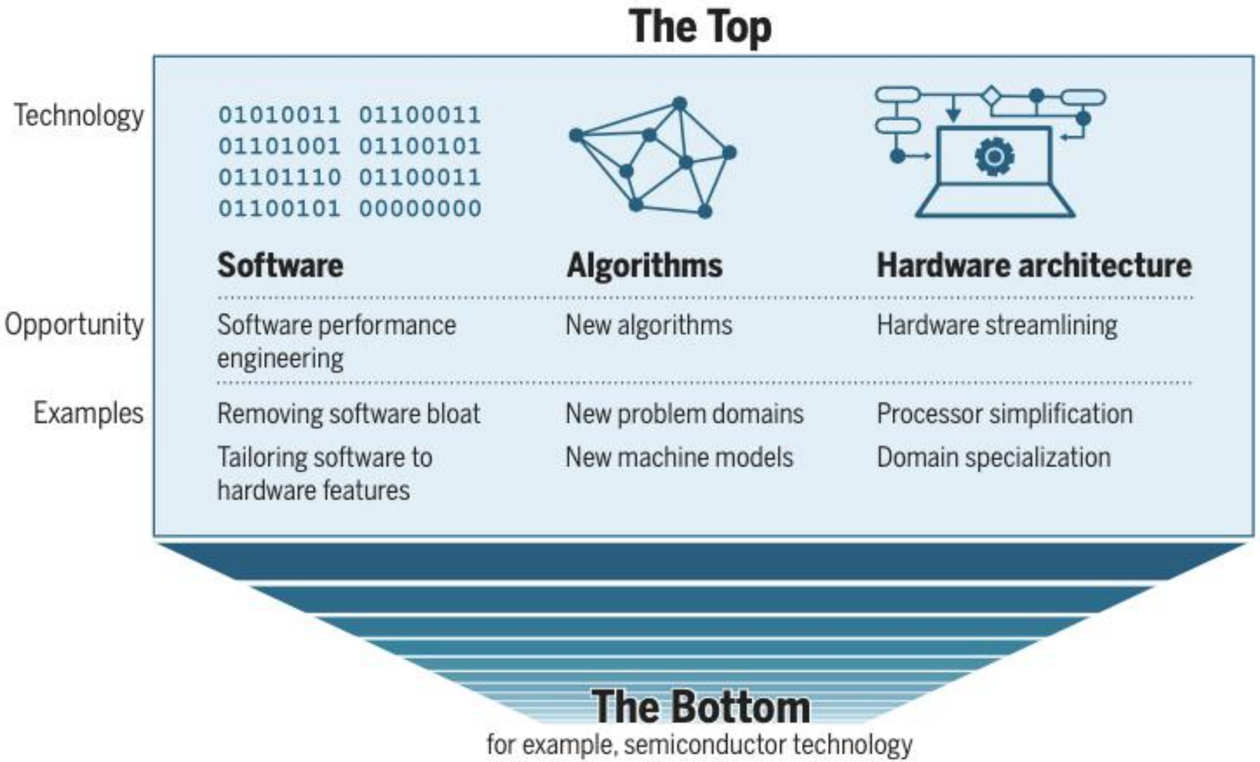
2020 - ITU, GeSI, GSMA & SBTi set science-based pathway in line with Paris Agreement - ICT industry to reduce greenhouse gas emissions by 45 per cent by 2030

Source: https://www.itu.int/en/mediacentre/Pages/PR04-2020-ICT-industry-to-reduce-greenhouse-gas-emissions-by-45-percent-by-2030.aspx

How are we doing so far?

	2015	2021	Change
Internet users	**3 billion**	**4.9 billion**	**+ 60 %**
Internet traffic	**0.6 ZB**	**3.4 ZB**	**+ 440 %**
Data centre workloads	**180 million**	**650million**	**+ 260 %**
Data centre energy use (excluding crypto)	**200 TWh**	**220 - 320 TWh**	**+ 10-60%**
Crypto mining energy use	**4 TWh**	**100 - 140 TWh**	**+ 2,300 - 3,300%**
Data transmission network energy use	**220 TWh**	**260 - 340 TWh**	**+ 20 - 60%**

Source: https://www.iea.org/reports/data-centres-and-data-transmission-networks



Performance gains after Moore's law ends. In the post-Moore era, improvements in computing power will increasingly come from technologies at the "Top" of the computing stack, not from those at the "Bottom", reversing the historical trend.

A model for thinking about digital sustainability - **CID**

Consumption

Can I change how much we need?

Intensity

Can I change how much harm is done?

Direction

Can I change where we are headed?

High carbon intensity

Mining coal, burning it to create steam, to turn turbines to generate electricity.

Typical carbon intensity:

~ 1001g CO2eq / KWh

Source: NREL: Life Cycle Emissions Factors for Electricity Generation Technologies

Lower carbon intensity

Harvesting energy to generate power directly.

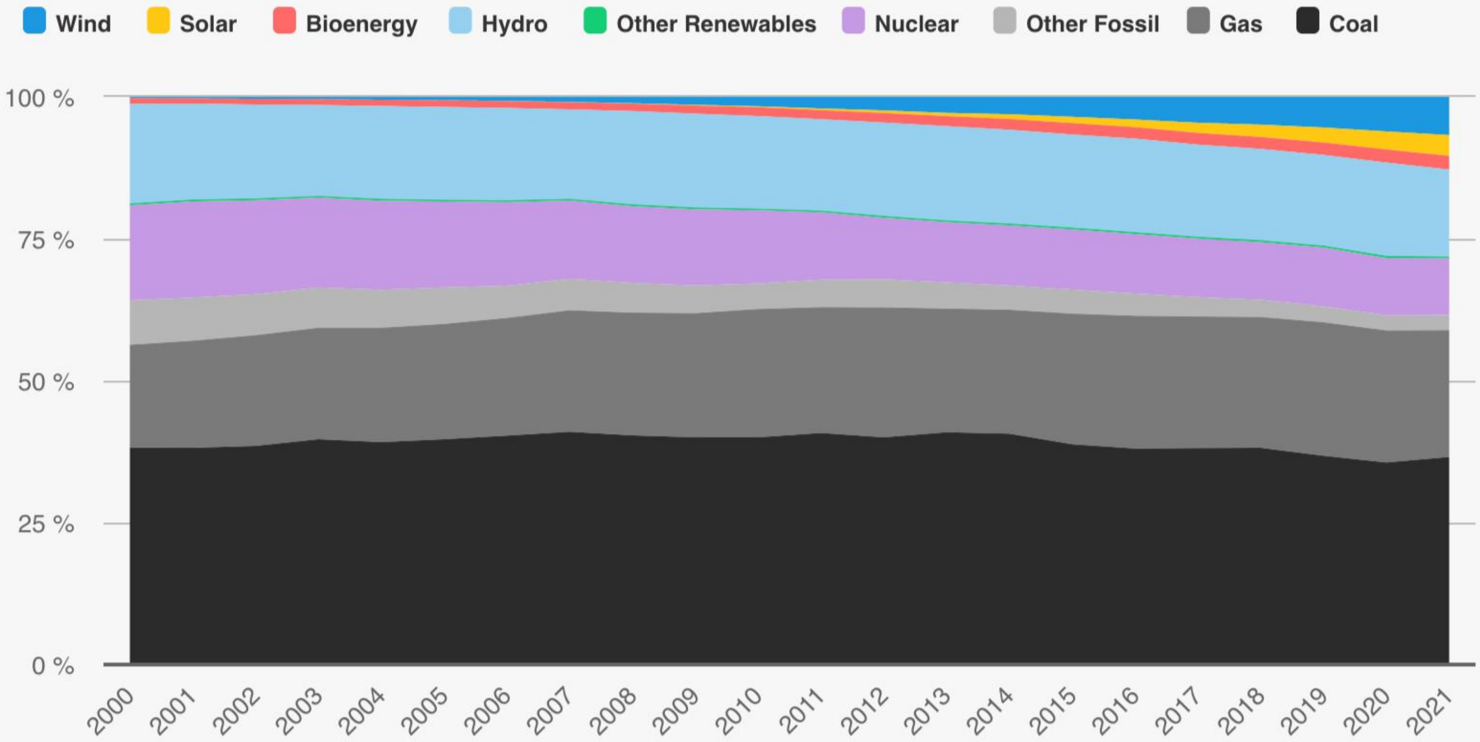
Typical carbon intensity:

~ 57g CO2eq / KWh

Source: NREL: Life Cycle Emissions Factors for Electricity Generation Technologies

World electricity generation by source

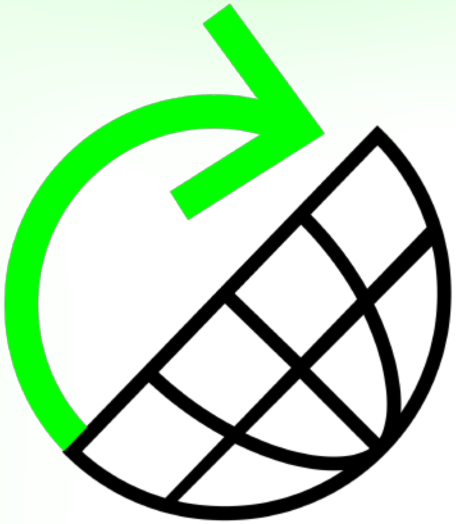
Percentage share



Source: https://ember-climate.org/data/data-explorer/

Common strategies for improving carbon intensity of compute

1. **geographic migration**: move workloads *through space* to where more clean energy is on the grid
2. **temporal migration:** move workloads *through time* to when more clean energy is on the grid



A model for thinking about digital sustainability - **CID**

Consumption	Intensity	Direction
Can I change how much we need?	Can I change how much harm is done?	Can I change where we are headed?

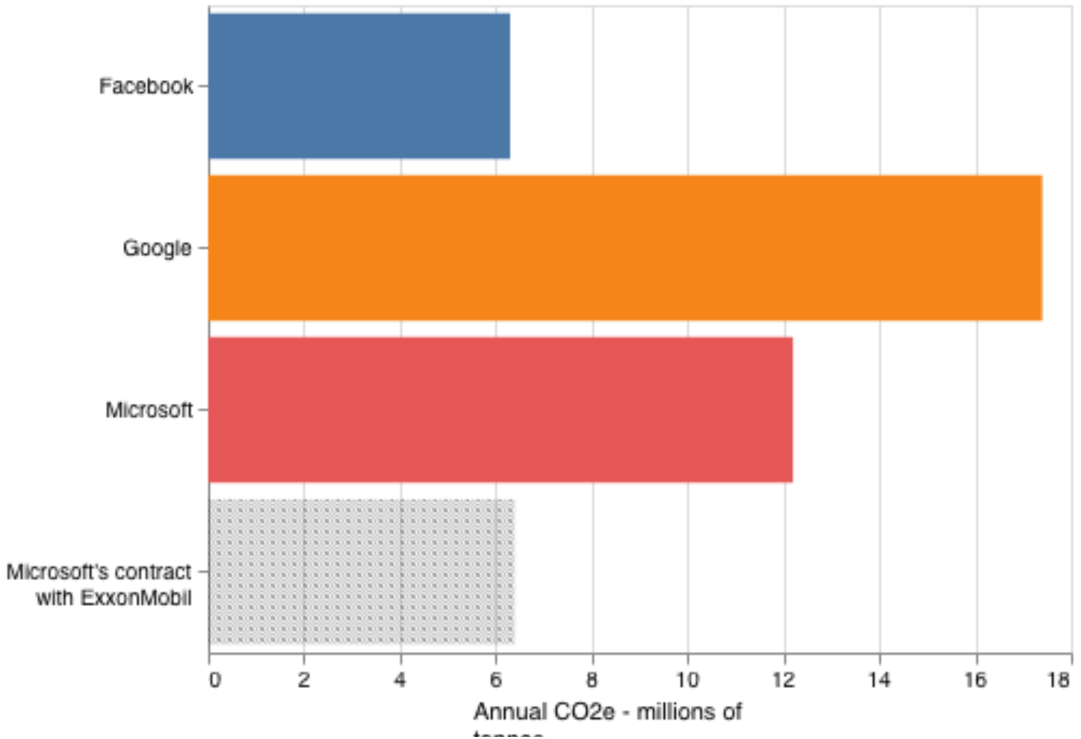
“

TECHNOLOGY IS A SOCIAL, POLITICAL AND ENVIRONMENTAL ACCELERANT

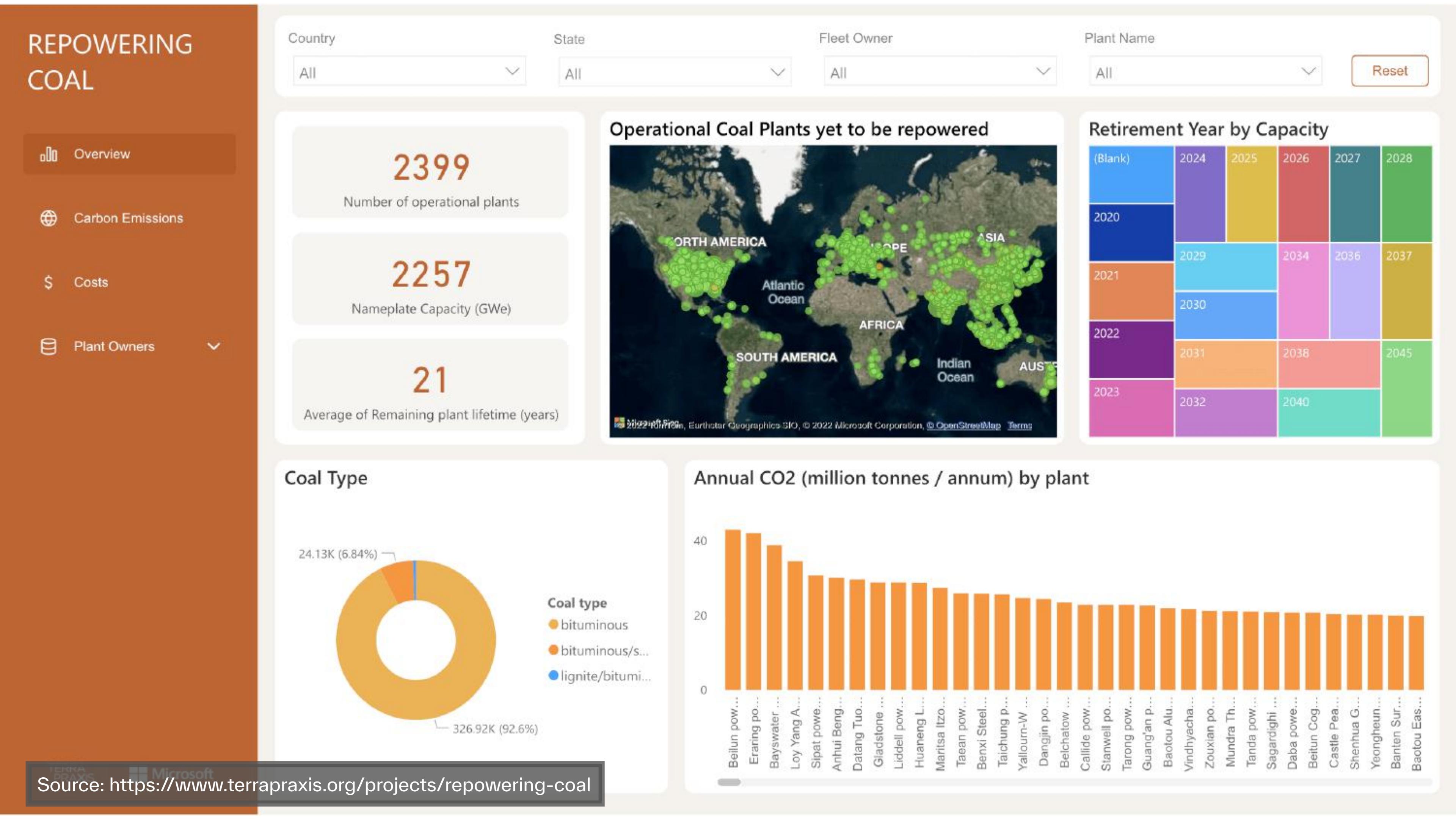
CADE DIEHM, *New Design Congress*

What's the carbon footprint of that oil and gas contract?

Reported corporate emissions for 2019, compared to estimated annual emissions from single oil and gas contract



Source: https://nextjournal.com/greenweb/whats-the-carbon-footprint-of-that-oil-and-gas-ai-contract

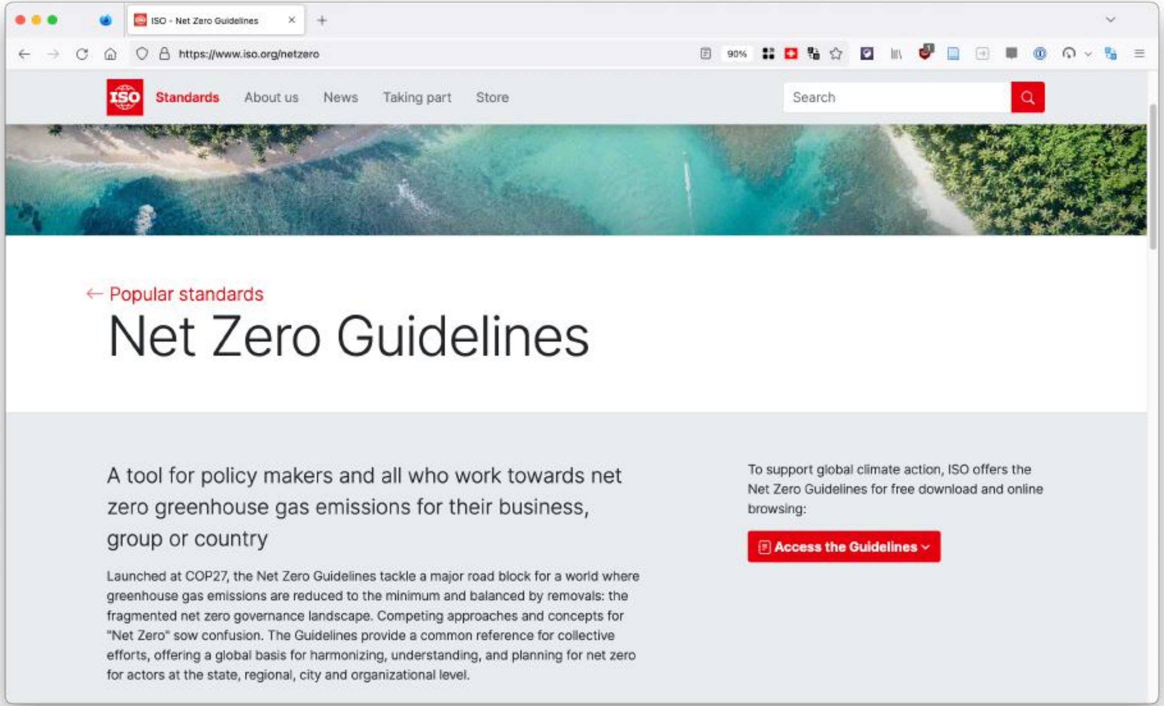


Source: https://www.terrapraxis.org/projects/repowering-coal

Using the framework to look ahead at policy and tech changes

3

Emerging sustainability reporting standards



Emerging corporate reporting standards

ISO Net Zero Guidelines: Net zero claims are no longer considered credible without halving emissions by 2030, if they don't include all supply chain, and if they don't have interim targets every 3-5 years.

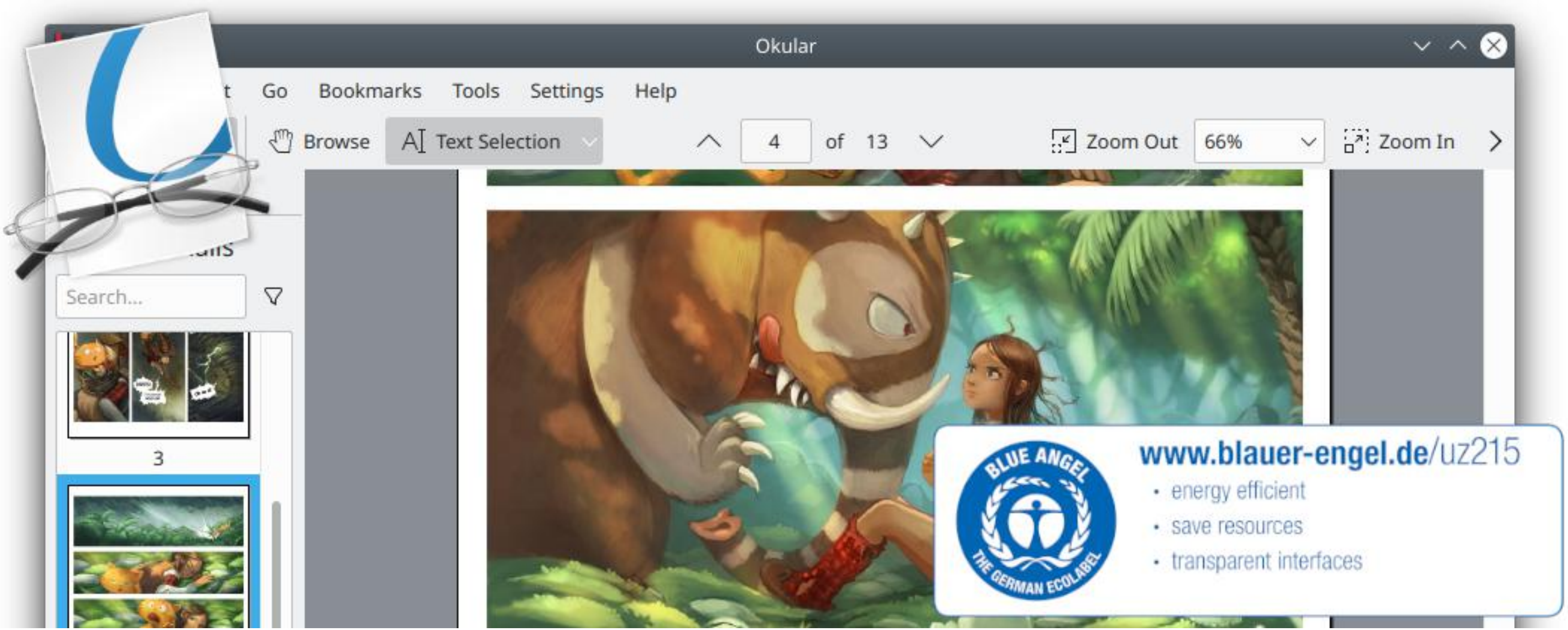
EU CSRD (European Union Corporate Sustainability Reporting Directive): Comes into force in 2024, for every company with more than 250 employees. *You need to start collecting data in 2023 to report for 2024!* 😱

IFRS (International Financial Reporting Standards) Foundation: voted unanimously to require company disclosures on Scope 1, Scope 2 and Scope 3 greenhouse gases (i.e. entire supply chain).

Consumption

Can I change how much we need?

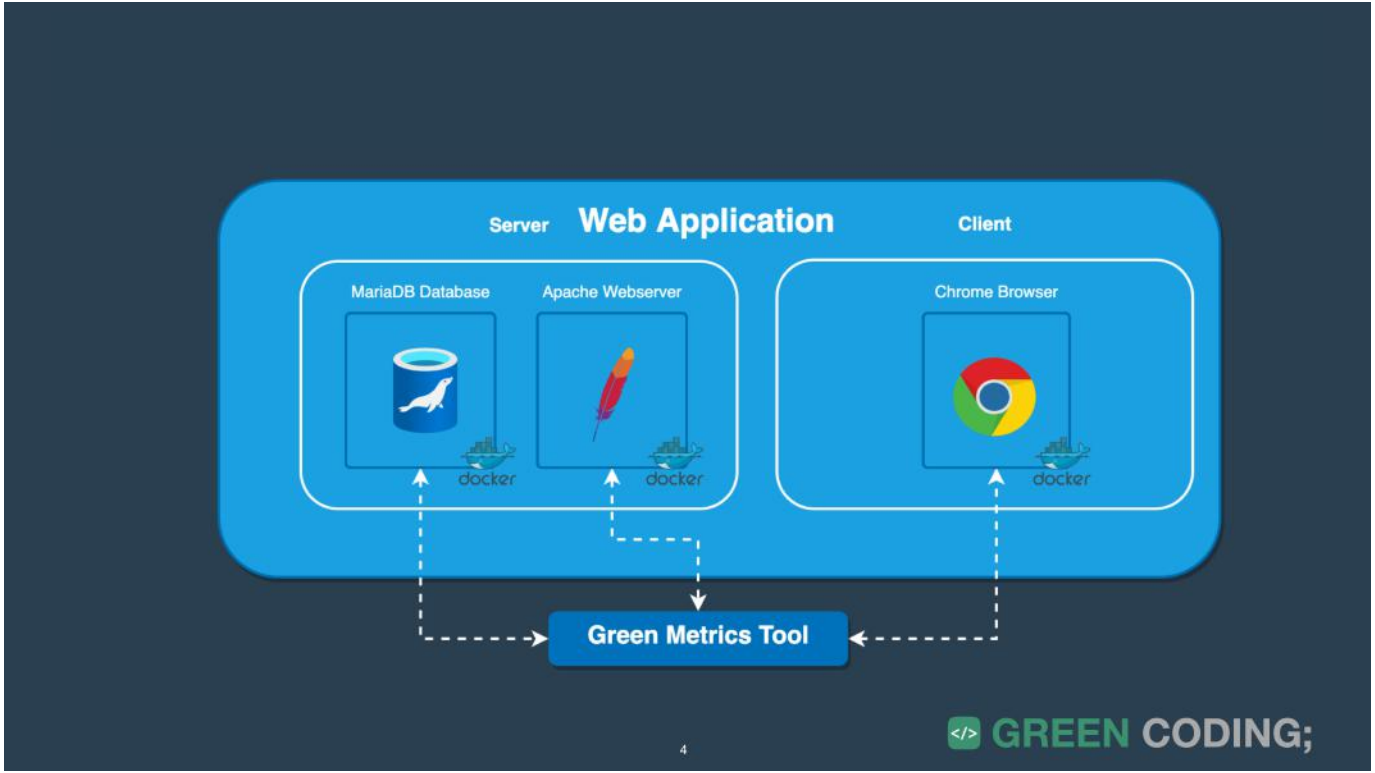
Emerging sustainable software standards



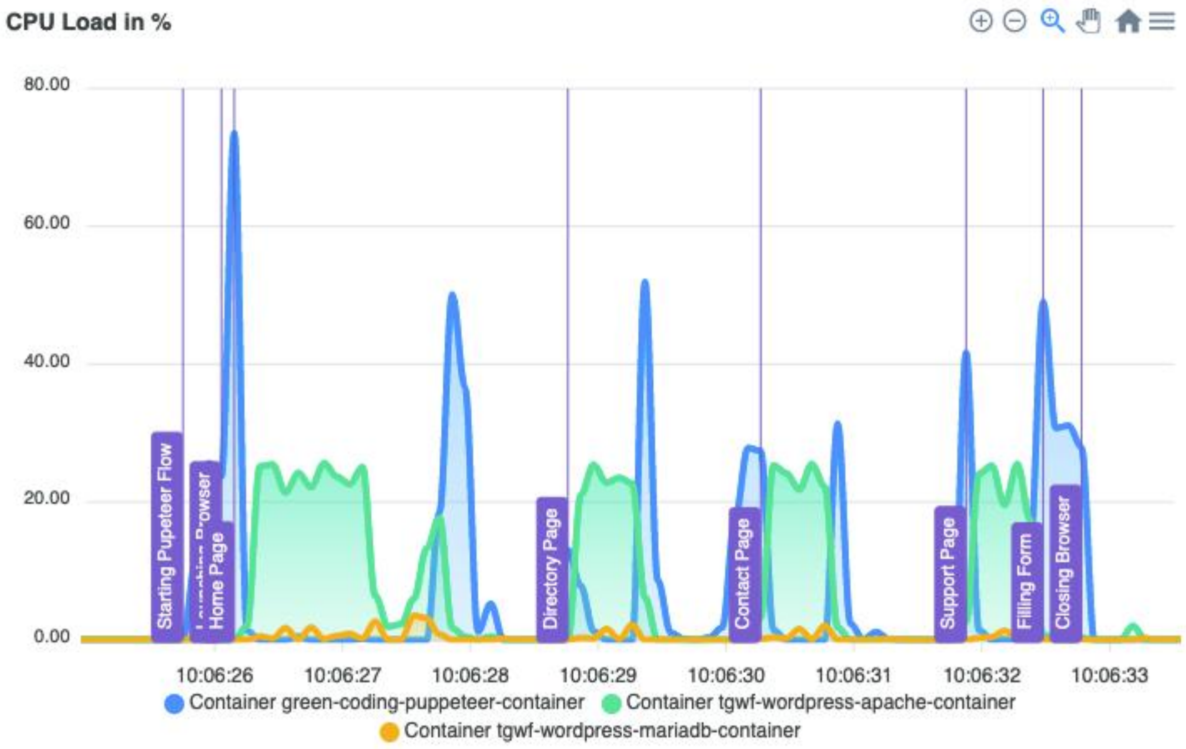
Source: https://eco.kde.org/blog/2022-09-28_okular_blue-angel-award-ceremony/

Green Metrics tool - end to end measurement

Measuring from the outside with the AGPL licensed Green Metrics Tool (GMT)



Green Metrics tool - output

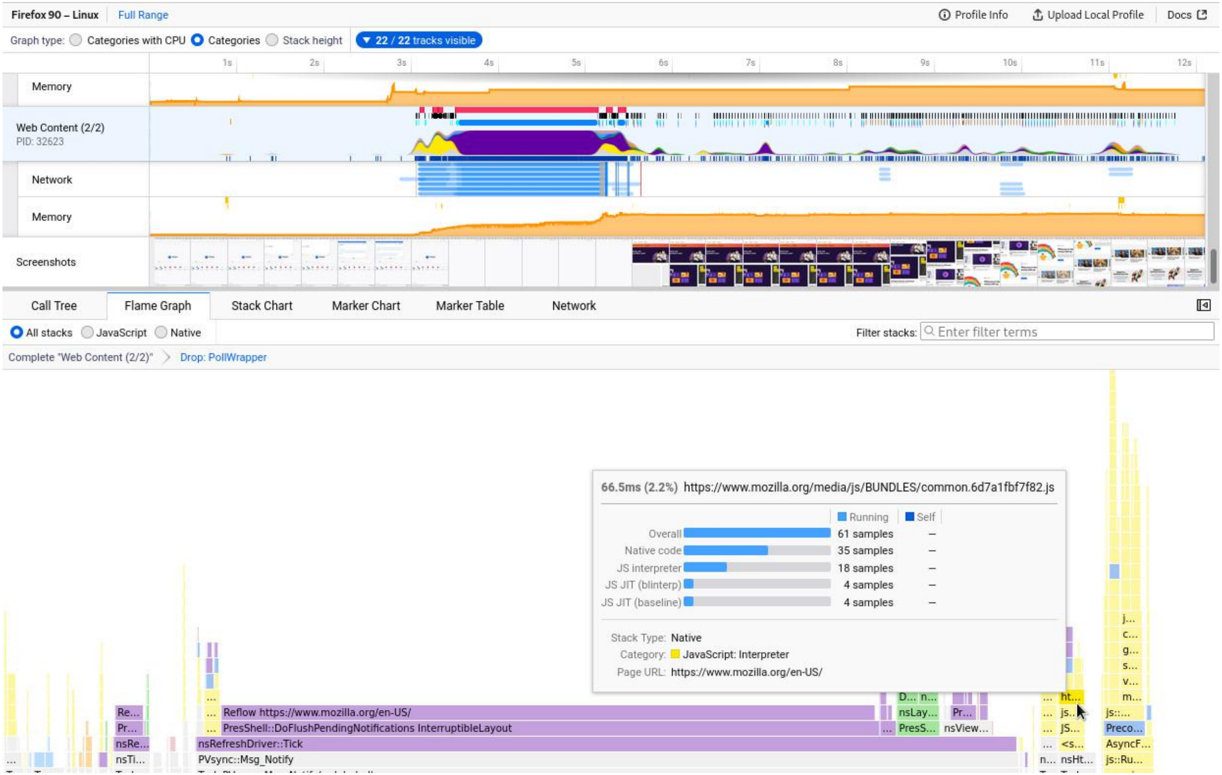


Source: https://www.green-coding.berlin

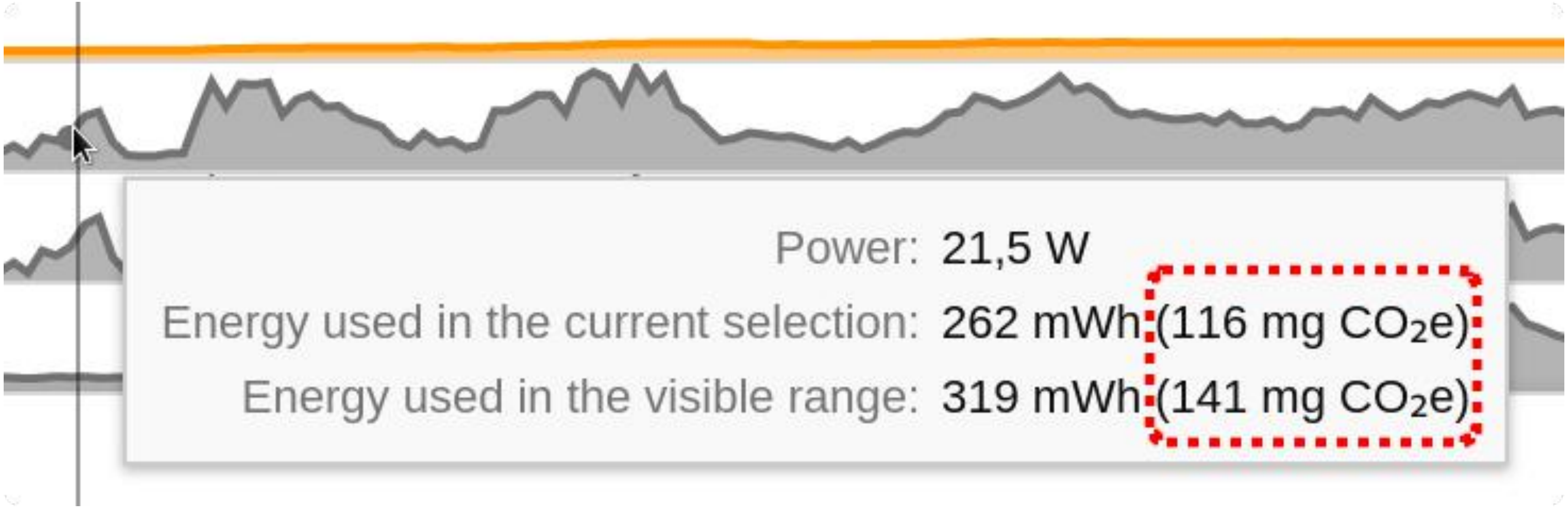
Tracking direct usage with Firefox profiler

You can measure from the inside too!

If you have used profiler or perf tool, you can measure to optimise for consumption of resources.



Adding carbon metrics with CO2.js



Optimising the right parts for consumption

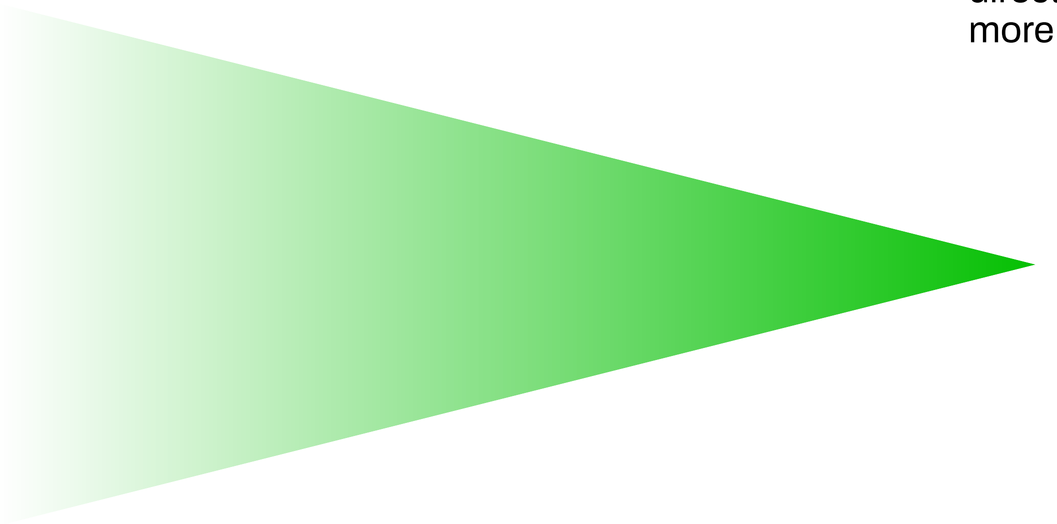
Table 5. Pareto optimal sets for different combination of objectives.

Time & Memory	Energy & Time	Energy & Memory	Energy & Time & Memory
C • Pascal • Go	C	C • Pascal	C • Pascal • Go
Rust • C++ • Fortran	Rust	Rust • C++ • Fortran • Go	Rust • C++ • Fortran
Ada	C++	Ada	Ada
Java • Chapel • Lisp • Ocaml	Ada	Java • Chapel • Lisp	Java • Chapel • Lisp • Ocaml
Haskell • C#	Java	OCaml • Swift • Haskell	Swift • Haskell • C#
Swift • PHP	Pascal • Chapel	C# • PHP	Dart • F# • Racket • Hack • PHP
F# • Racket • Hack • Python	Lisp • Ocaml • Go	Dart • F# • Racket • Hack • Python	JavaScript • Ruby • Python
JavaScript • Ruby	Fortran • Haskell • C#	JavaScript • Ruby	TypeScript • Erlang
Dart • TypeScript • Erlang	Swift	TypeScript	Lua • JRuby • Perl
JRuby • Perl	Dart • F#	Erlang • Lua • Perl	
Lua	JavaScript	JRuby	
	Racket		
	TypeScript • Hack		
	PHP		
	Erlang		
	Lua • JRuby		
	Ruby		

All models are wrong, some are useful

Top down, faster, modelled, more lightweight

Bottom up, slower, directly measured, more detailed

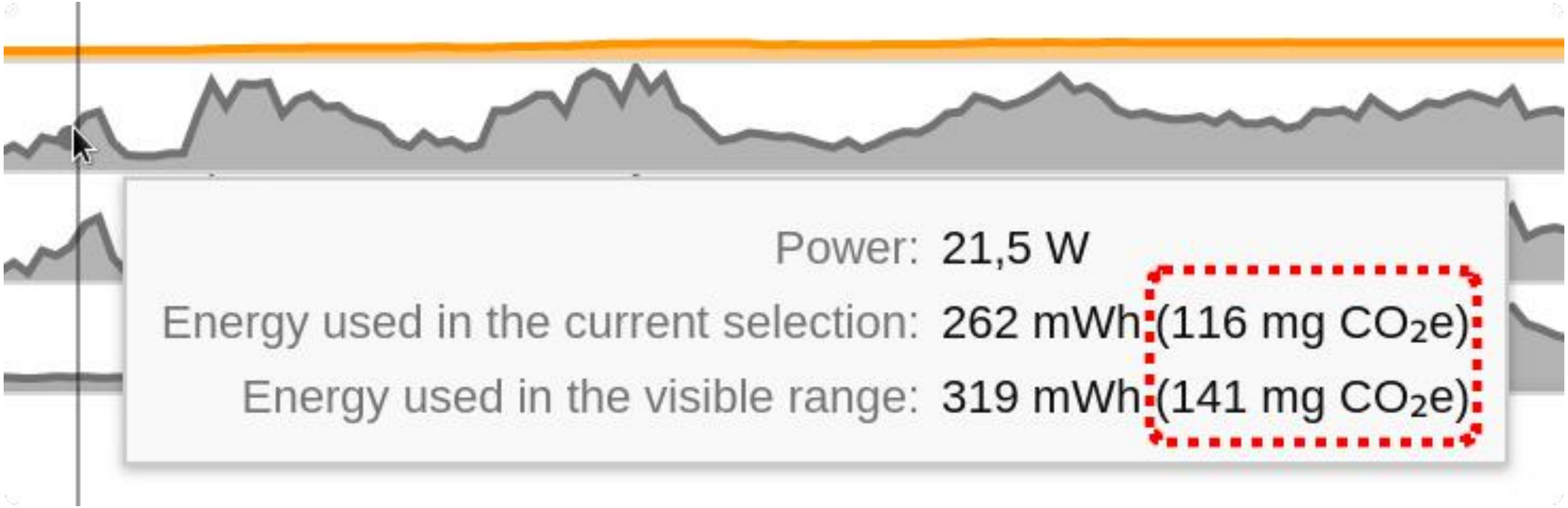


More likely to overestimate

More likely to underestimate

Emissions Distribution

Adding carbon metrics with CO2.js



Intensity

Can I change how much harm is done?

Green energy - annual vs hourly

FIG. 2

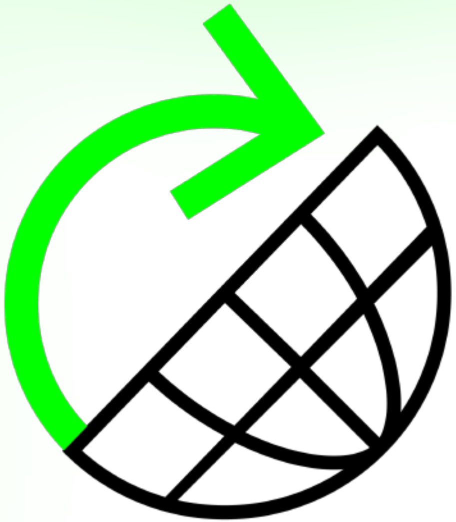
Hourly carbon-free energy performance at an example data center

While Google buys large amounts of wind and solar power (symbolized by green spikes below), these resources are variable, meaning that our data centers still sometimes rely on carbon-based resources.

Source: https://www.google.com/about/datacenters/cleanenergy/

Common strategies for improving carbon intensity of compute

1. **spatial migration**: move workloads *through space* to where more clean energy is on the grid
2. **temporal migration:** move workloads *through time* to when more clean energy is on the grid



kubernetes

low carbonetes

For more: see the Carbon Intensity Aware Scheduling in Kubernetes session at FOSDEM 2023.

What our computers run on

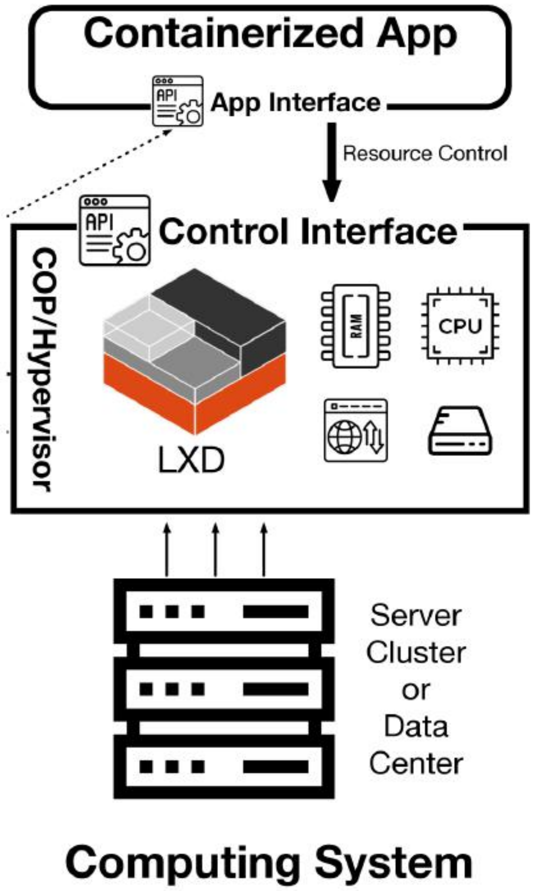
Type	Carbon intensity	Dispatchable	Supply limited by
On-site renewables	Very low	No (in most cases)	Local environment
Energy storage (usually batteries)	Derived from source	Yes	Local storage capacity
Grid Energy	Variable	Yes	Local grid capacity THE COST OF GAS THESE DAYS HOLY MOLY

Hypervisors

We can use virtualisation to take a big physical machine, and abstract the hardware into resources like compute, network, ram and storage.

Once we done this we have fine grained control over how we allocate the resources, to compose into sets of smaller virtual machines.

This allows for more efficient use of the hardware, and respond to

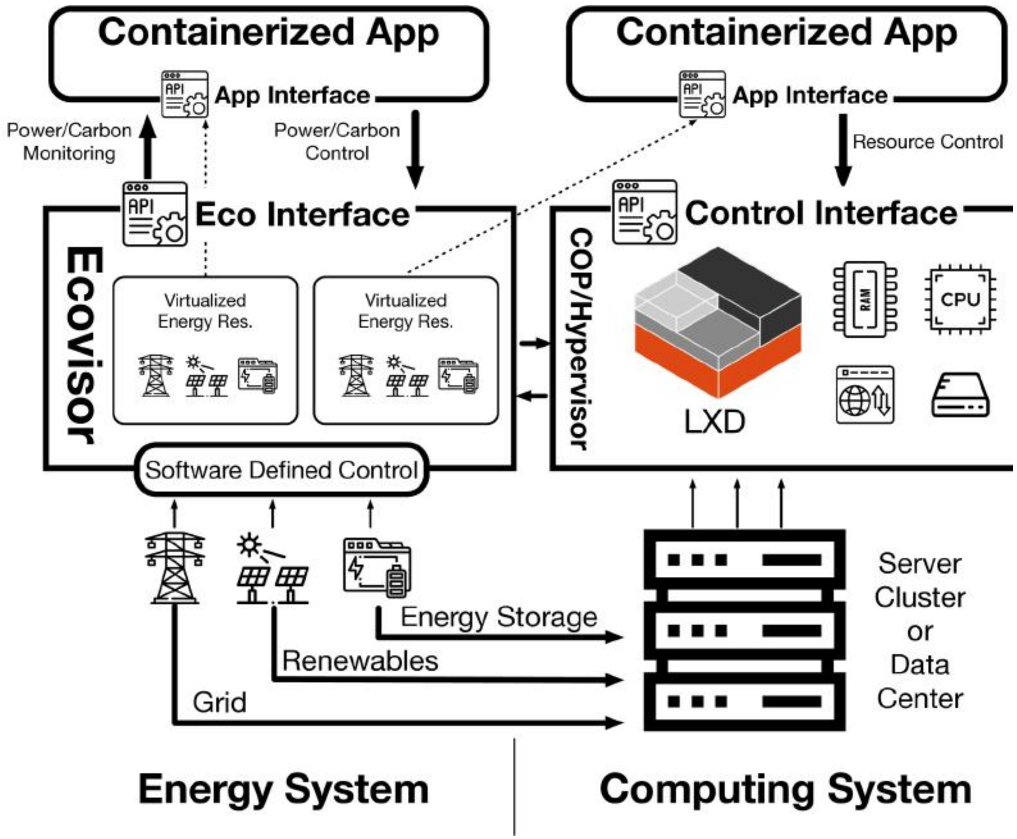


Source: https://ar5iv.labs.arxiv.org/html/2210.04951

Ecovisors

You can do the same with the *power computers use*. Power is usually presented as a single stream, even when we have batteries built in laptops.

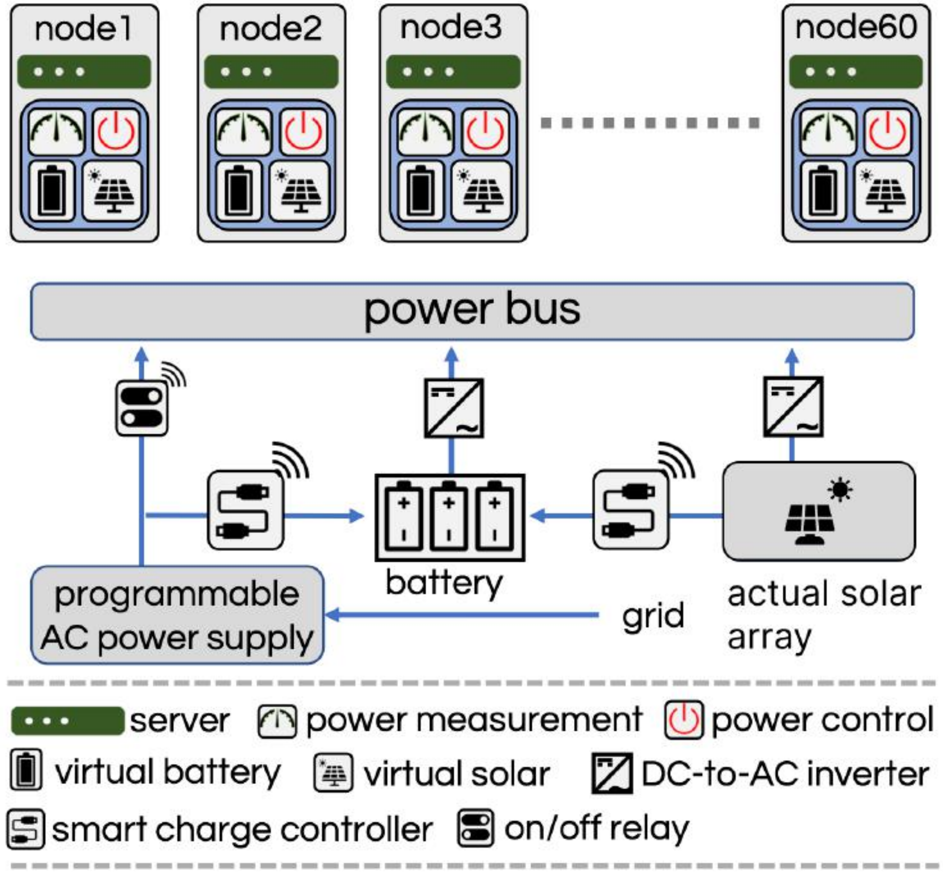
But if you virtualise the power as *grid*, *renewables* and *energy storage*, then you can allocate these resources the like how you allocate compute, memory, storage, and network with virtual machines



Ecovisors

Virtual machines and other kinds of containers are allocated set amounts of each kind of power in addition to the usual resources, and given visibility into the amounts they have, on a schedule.

Applications can do more when there is more green energy available, and do less when there less available, to maximise the use of green energy and reduce carbon intensity.



Source: https://ar5iv.labs.arxiv.org/html/2210.04951

A sample Ecovisor API for an application to implement

Function Name	Type	Input	Return Value	Description
`set_container_powercap()`	Setter	ContainerID, kW	N/A	Set a container's power cap
`set_battery_charge_rate()`	Setter	kW	N/A	Set battery charge rate until full
`set_battery_max_discharge()`	Setter	kW	N/A	Set max battery discharge rate
`get_solar_power()`	Getter	N/A	kW	Get virtual solar power output
`get_grid_power()`	Getter	N/A	kW	Get virtual grid power usage
`get_grid_carbon()`	Getter	N/A	$g \cdot CO_2/kW$	Get current grid carbon intensity
`get_battery_discharge_rate()`	Getter	N/A	kW	Get current rate of battery discharge
`get_battery_charge_level()`	Getter	N/A	kWh	Get energy stored in virtual battery
`get_container_powercap()`	Getter	ContainerID	kW	Get a container's power cap
`get_container_power()`	Getter	ContainerID	kW	Get a container's power usage
`tick()`	Notification	N/A	N/A	Invoked by ecovisor every Δt

Table 1: *Ecovisor's narrow API that provides application's visibility and control over their virtual energy system.*

Ecovisor: A Virtual Energy System for Carbon-Efficient Applications

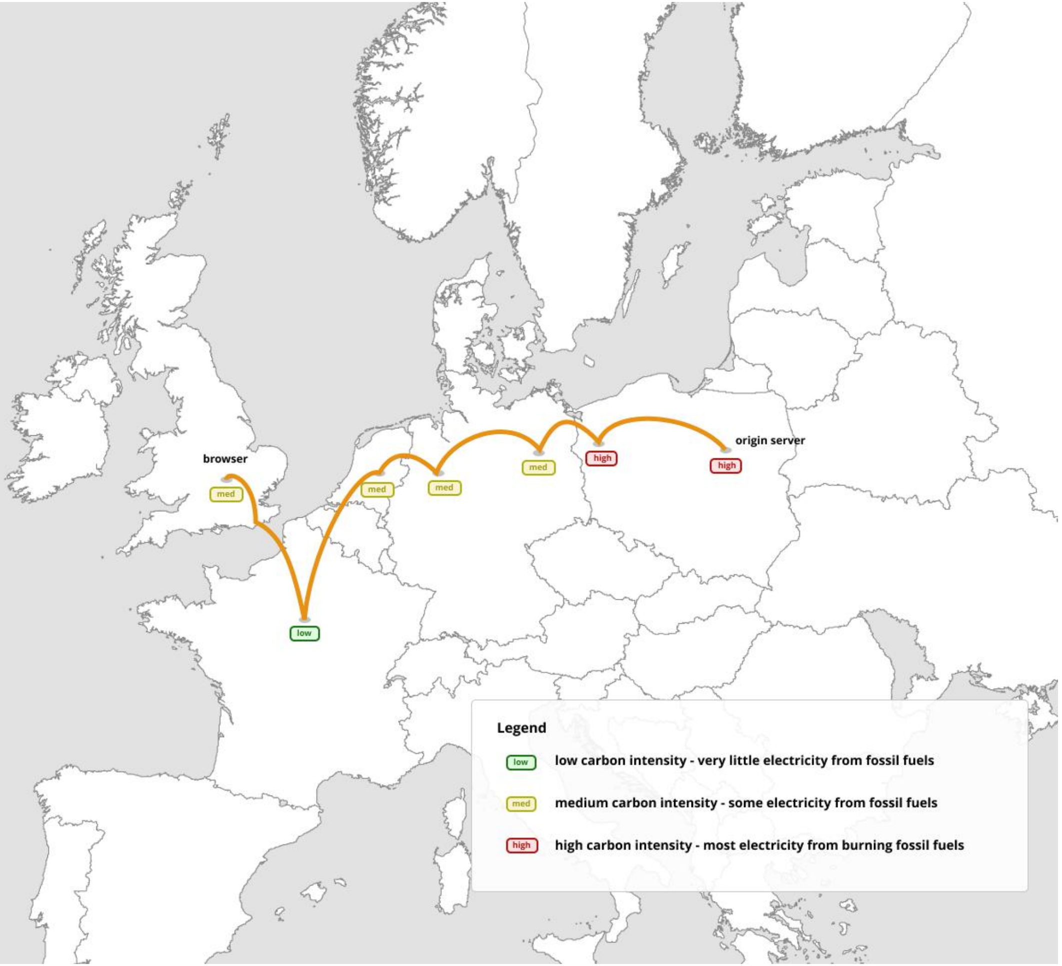
Abel Souza, Noman Bashir, Jorge Murillo, Walid Hanafy, Qianlin Liang, David Irwin, Prashant Shenoy

When we fetch data from servers, we rely on routers to route it to the next ‘hop’ along the way, as well as from the origin server.

This adds up - data transfer for the internet uses around 250 TWh of electricity each year - this is more than Spain uses!

Also when routes pass through areas where electricity mainly comes from burning fossil fuels, we have a higher carbon footprint for this transfer.

Because most electricity globally is still generated by burning fossil fuels, these emissions are hard to avoid with the design of the current internet.



If we know the carbon intensity of energy on the grid, we can tailor the way we serve traffic to match moments of over-supply on sunny or windy days, when energy is particularly cheap and green.

As long as the nodes are close enough, we can still serve quick responses, and save hops reducing the carbon footprint, but we also help actively balance the grid, making it easier to integrate more renewables into our energy system.

Even when some content can't be cached, we can still optimise for the greenest routes that serves the request in time.

Carbon aware networks

1. **IETF / internet architecture board e-impact**: recent workshop in December, 26 papers, full recorded workshop
2. **SCION:** clean slate, path aware networking protocol, with carbon awareness being built in
3. **Extending ipv6 for carbon aware networking**: our paper outlining an approach, in collaboration with University of Rome and independent consultants

Direction

Can I change where we are headed?

“The Green Web Foundation is working towards a fossil-free internet by 2030.

The internet should be a global public good—healthy for the planet and for the people who use it.

A fossil free internet in the UK is doable

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Who we are | Electricity explained | A net zero future | Industry information | Our strategy | Research & publications

Great Britain on track for periods of zero carbon electricity in 2025

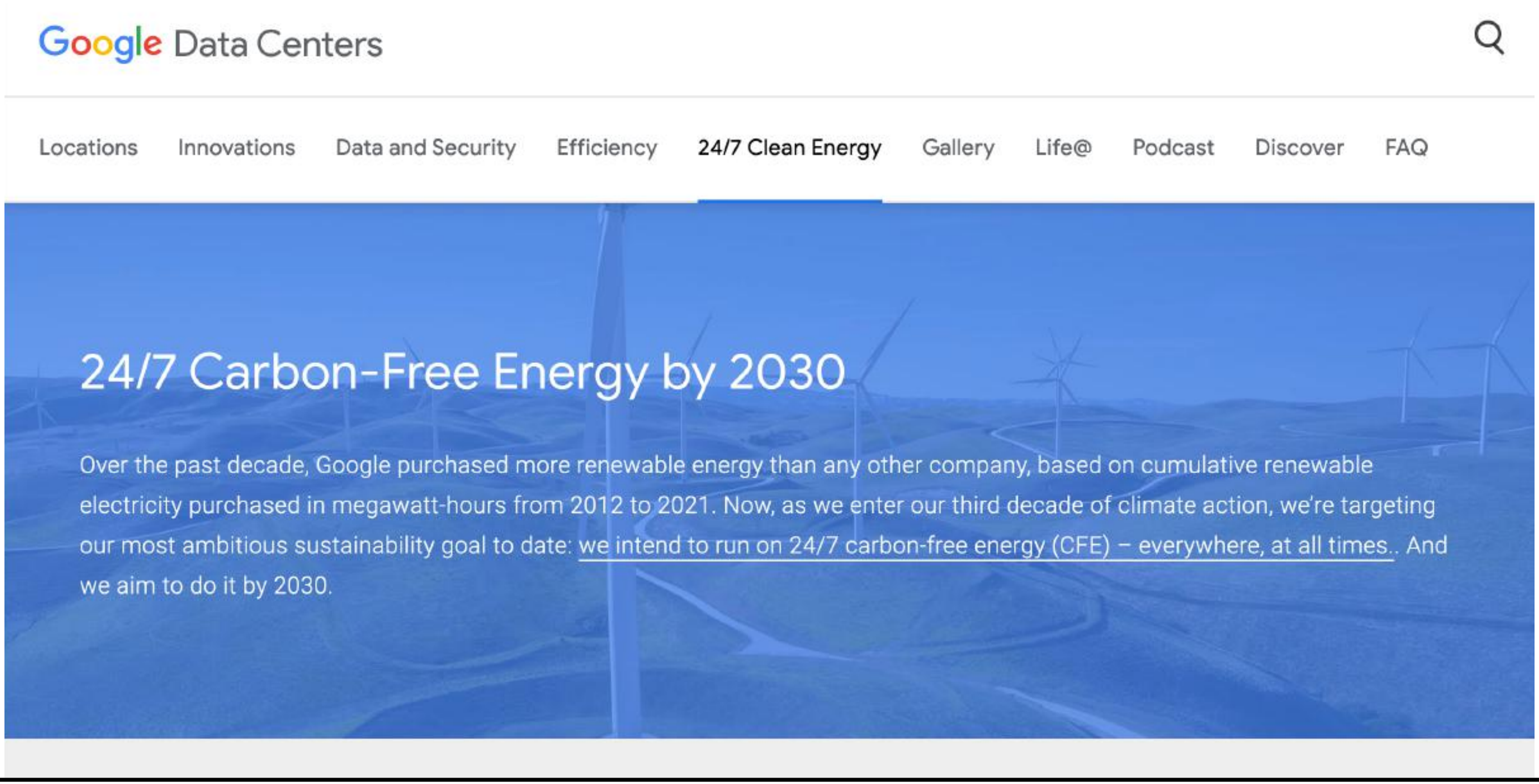
New report charts progress in decarbonising the country's grid ahead of COP26 summit

15th June 2021 - *Future of energy*

Great Britain's electricity system is on track to be powered free of fossil fuels and at 100% zero carbon in just four years' time according to a new National Grid Electricity System Operator (ESO) report. This is a key enabler for a zero carbon electricity system by 2035, in line with the sixth Carbon Budget.

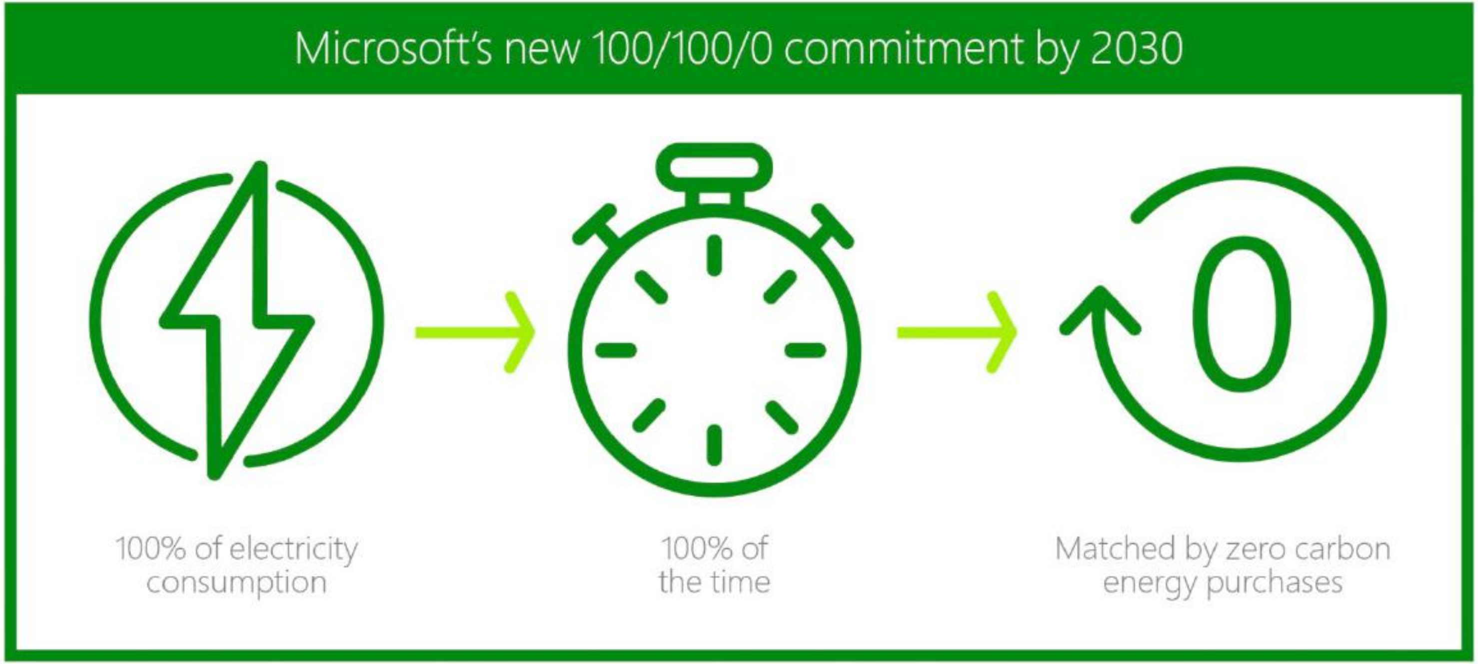
Data released ahead of the COP26 climate summit in November, along with recent electricity records, illustrates the growth

Ambitious corporate targets (cont)



 | Source: https://www.google.com/about/datacenters/cleanenergy/ |

Ambitious corporate targets (cont)

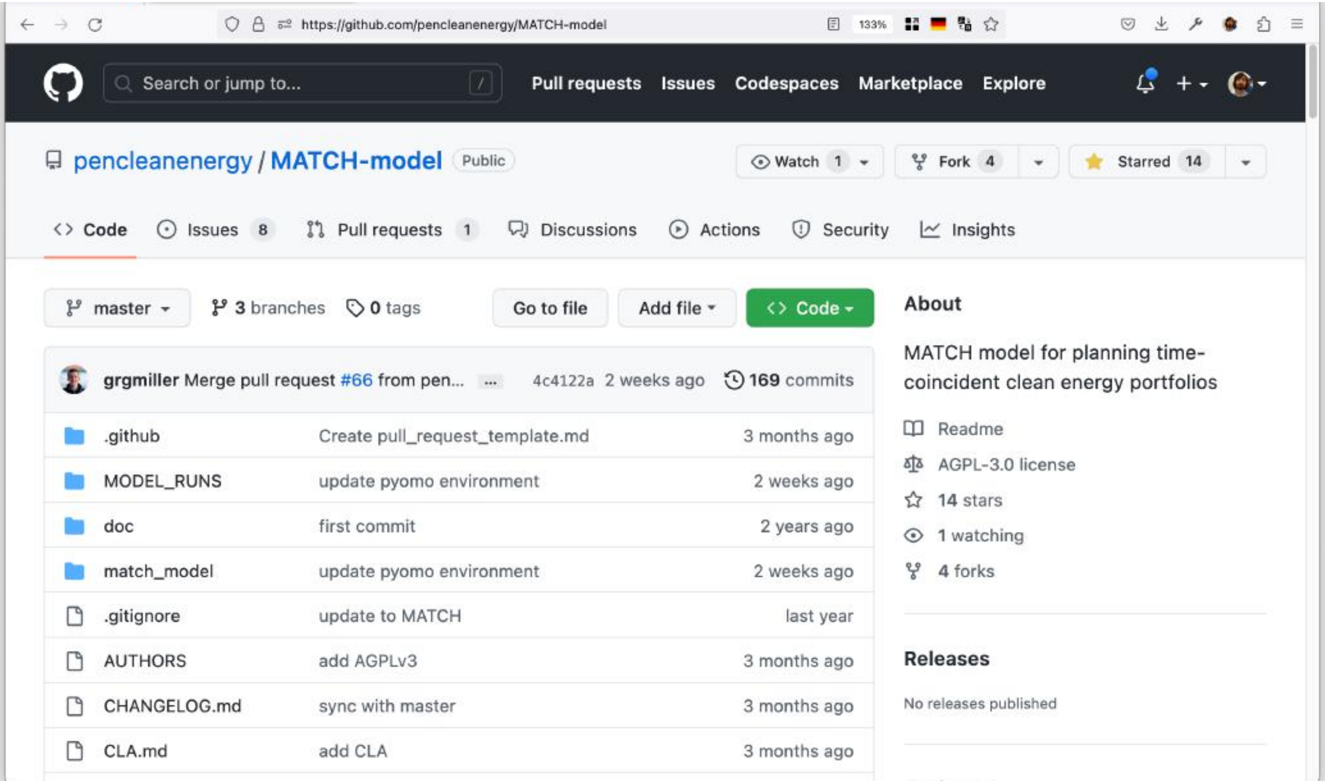


Source: https://blogs.microsoft.com/blog/2021/07/14/made-to-measure-sustainability-commitment-progress-and-updates/

Building targets into your governance

Source: https://www.peninsulacleanenergy.com/wp-content/uploads/2021/11/Whitepaper-OUR-PATH-TO-247-RENEWABLE-ENERGY-BY-2025.pdf

Open sourcing the way to set direction



"We have completely got rid of our dependency on Russian fossil fuels. It went much faster than we expected...

So we have the possibility to redirect or reorient the additional funding of REPowerEU – ≈€250 billion – to our net-zero industries."

European Commission President Ursula von der Leyen, 1st Feb 2023

RECAP

4

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6. **Energy security** - geopolitics and local resiliency

Thanks!

If you want know more: we publish open source code and open data in this field, and if you want help we offer training and consulting.

https://www.thegreenwebfoundation.org/fosdem/

Chris Adams | **@mrchrisadams / @mrchrisadams@mastodon.social**

chris@thegreenwebfoundation.org

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