# Global Hive Summit
# September 2024 – Day 1

# Welcome & Intro

# Welcome & Intro

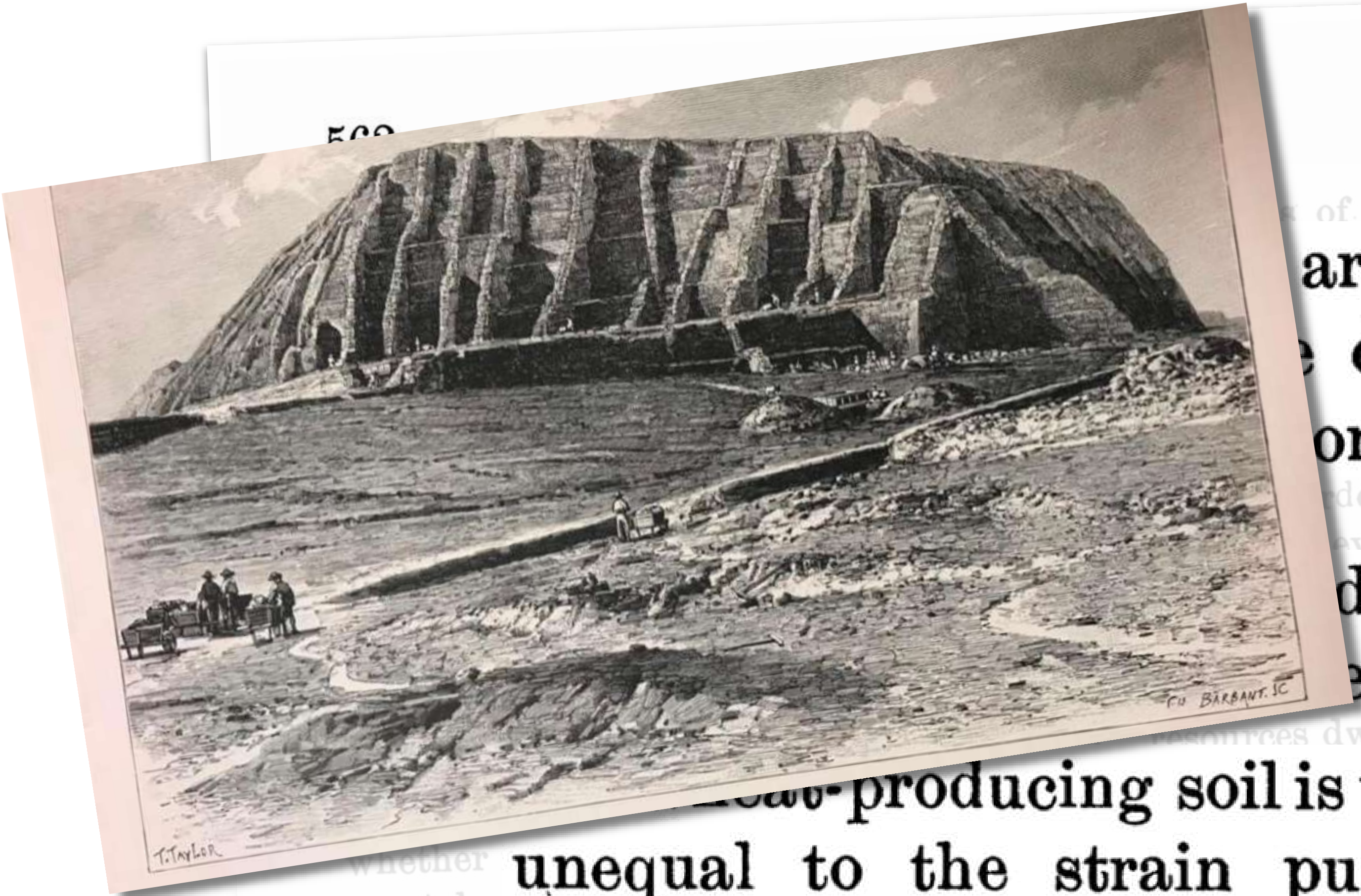
Larry Zitnick

# Modeling atoms to address our climate crisis

Larry Zitnick

Research Director

Meta




are of the
depress-
orn facts.

d in deadly peril
eat.

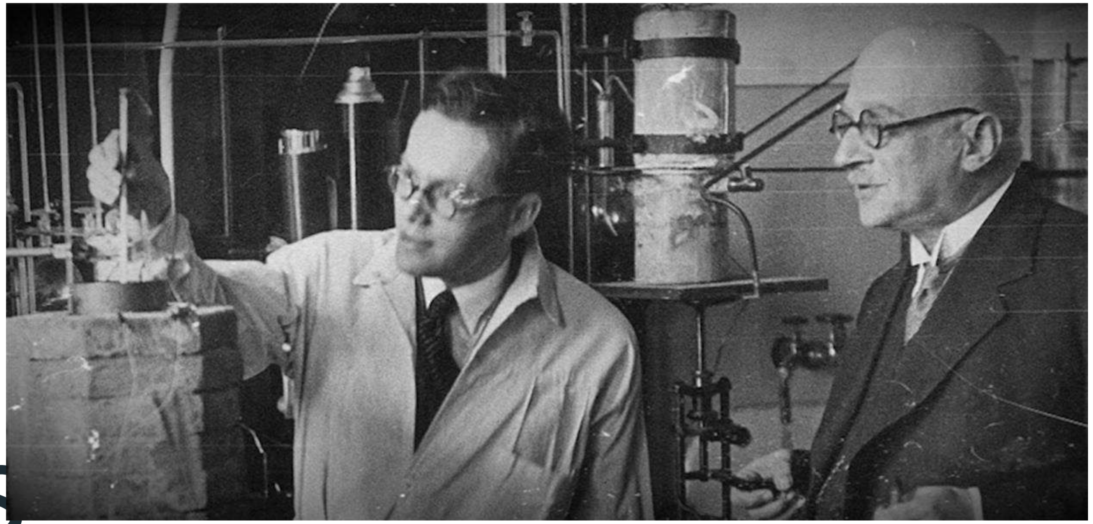
-producing soil is totally
unequal to the strain put upon it.

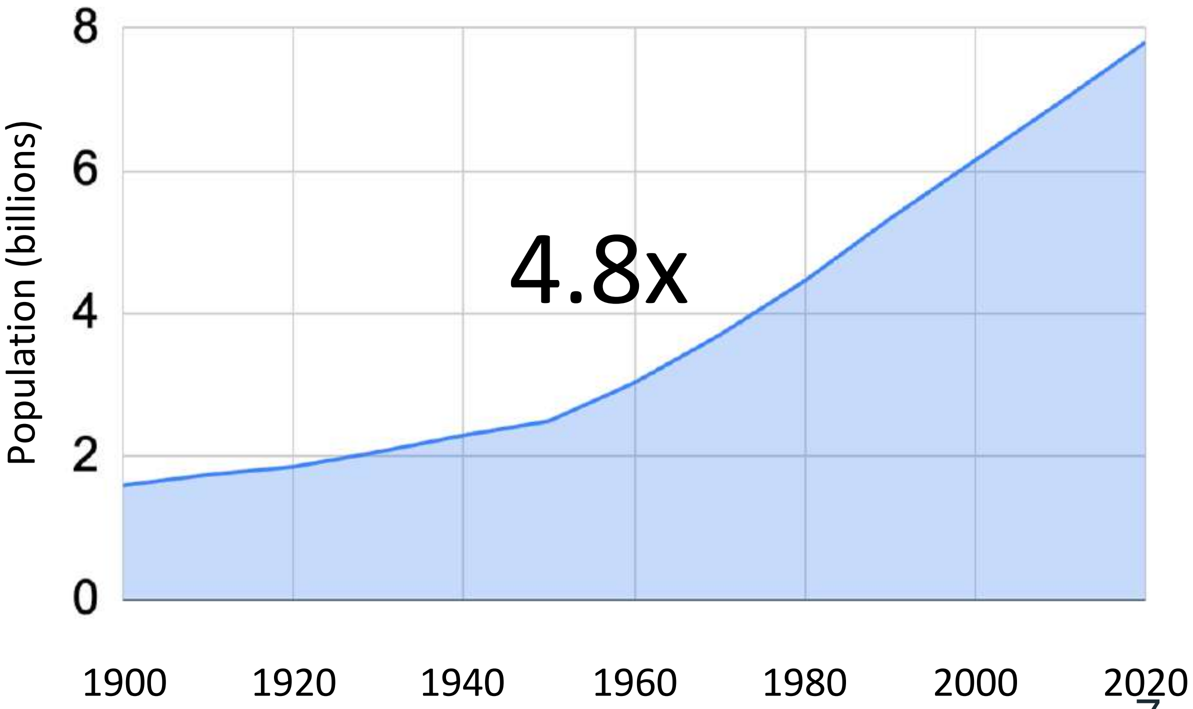
It is the chemist who must come to the rescue of the threatened communities. It is through the laboratory that starvation may ultimately be turned into plenty.

# Haber-Bosch Process

(ammonia fertilizer)

$$N_2 + 3H_2 \longrightarrow 2NH_3$$





# The Mittasch approach

*Uranium Osmium*

$$$

Oesper, R. E. "Alwin Mittasch." *Journal of Chemical Education* 25.10 (1948): 531.

# The Mittasch approach

*Uranium Osmium*

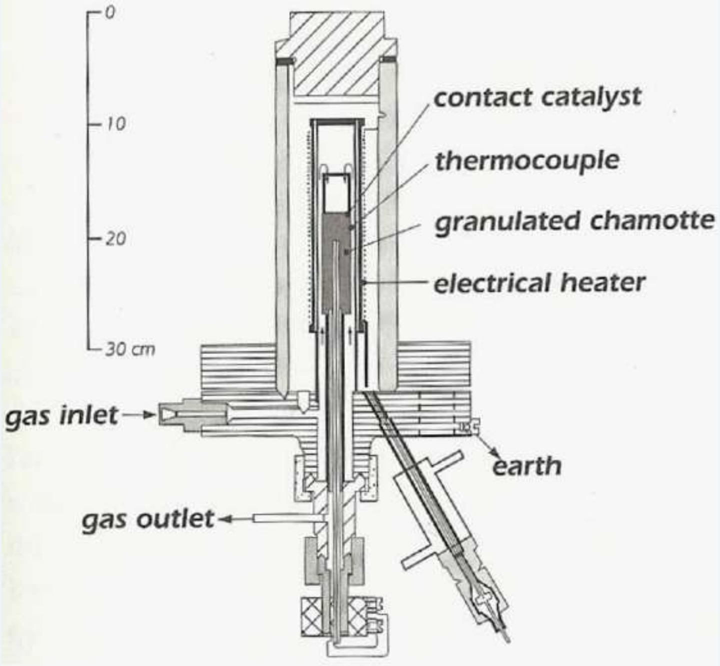
$$$

**Catalyst Screening**

*Magnetite*

$

**20,000** experiments
**>2500** compositions



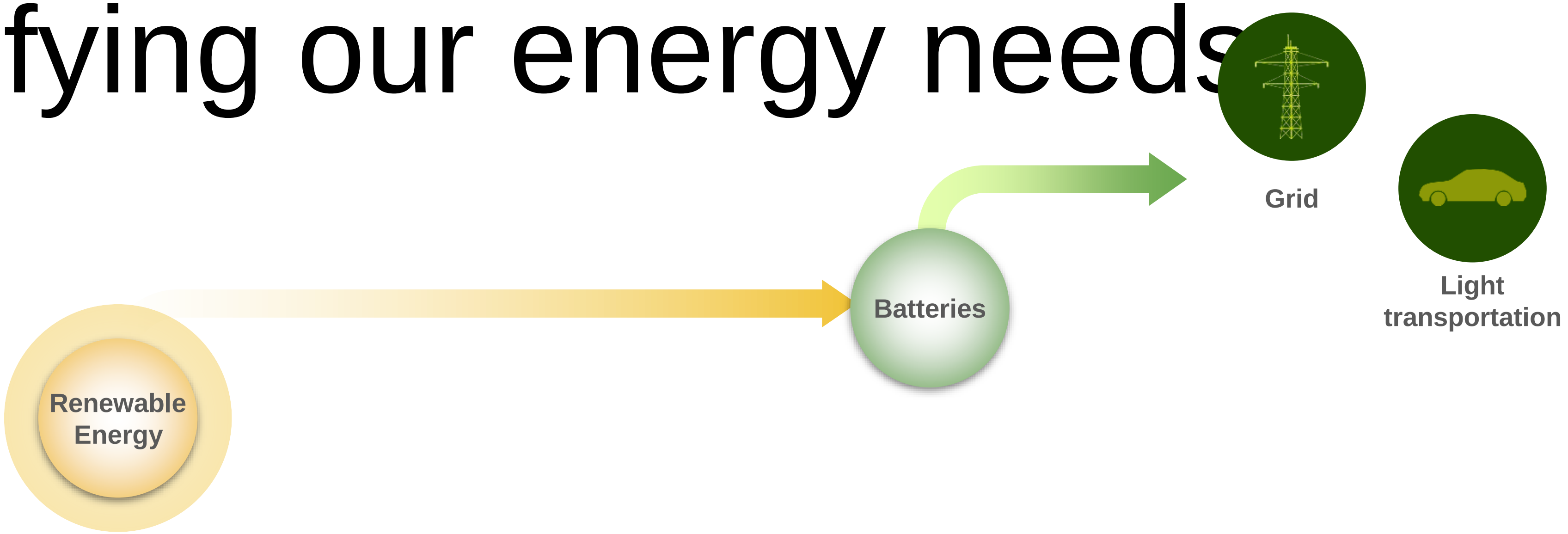

Laboratory apparatus used
by Alwin Mittasch
for testing catalyst (1910)

Oesper, R. E. "Alwin Mittasch." *Journal of Chemical Education* 25.10 (1948): 531.

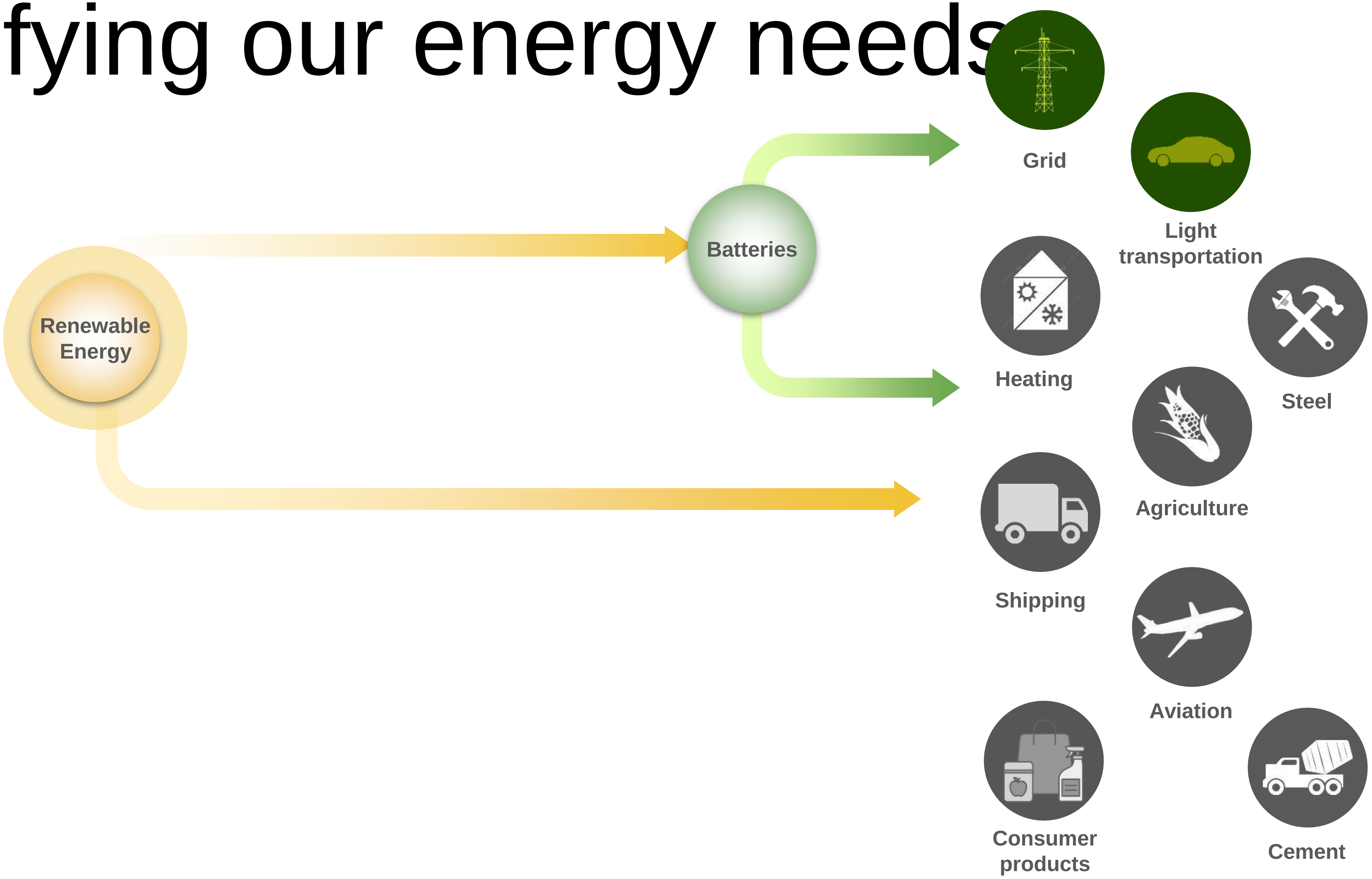
1900 …

… 2024

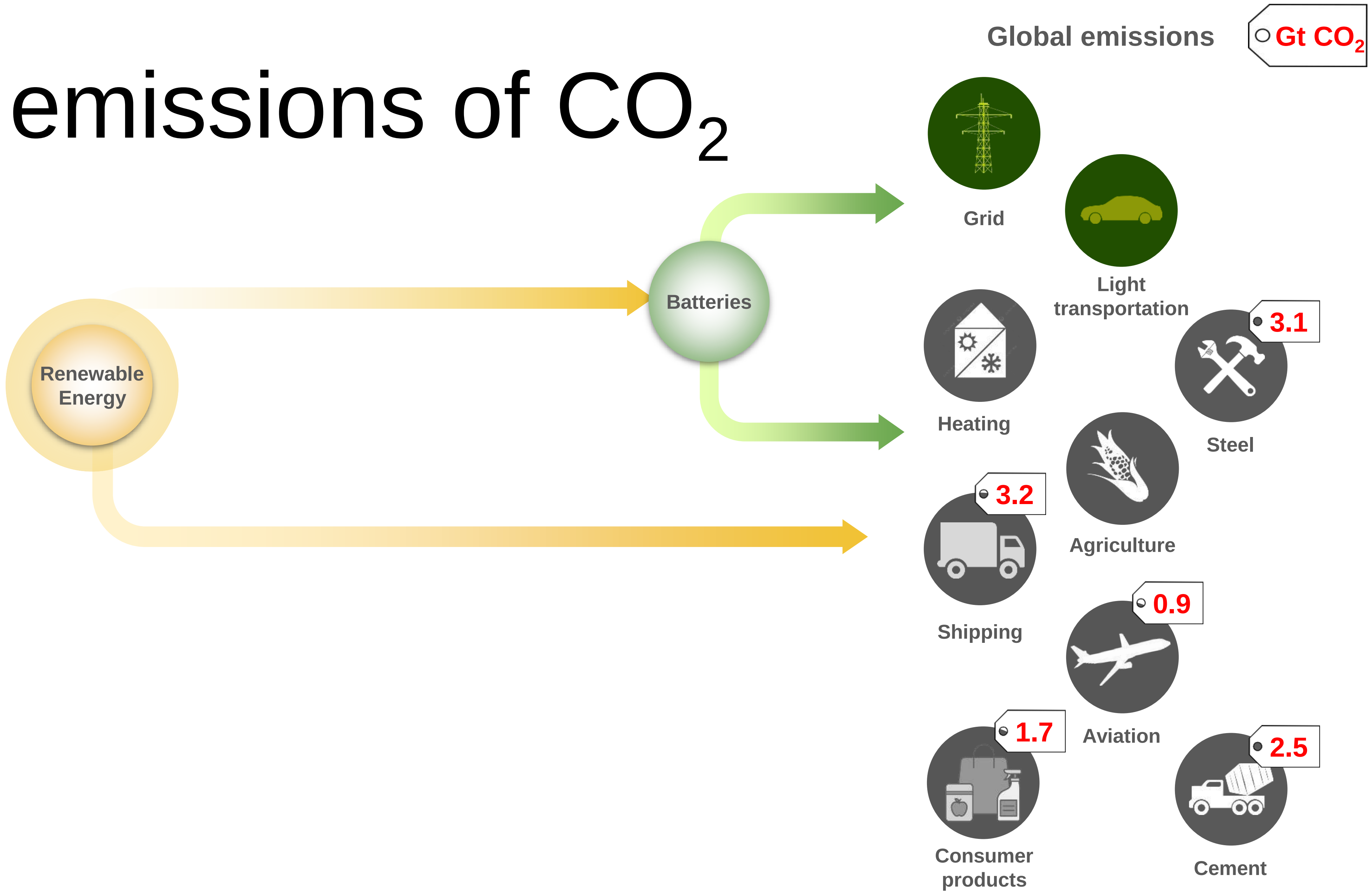
# Electrifying our energy needs



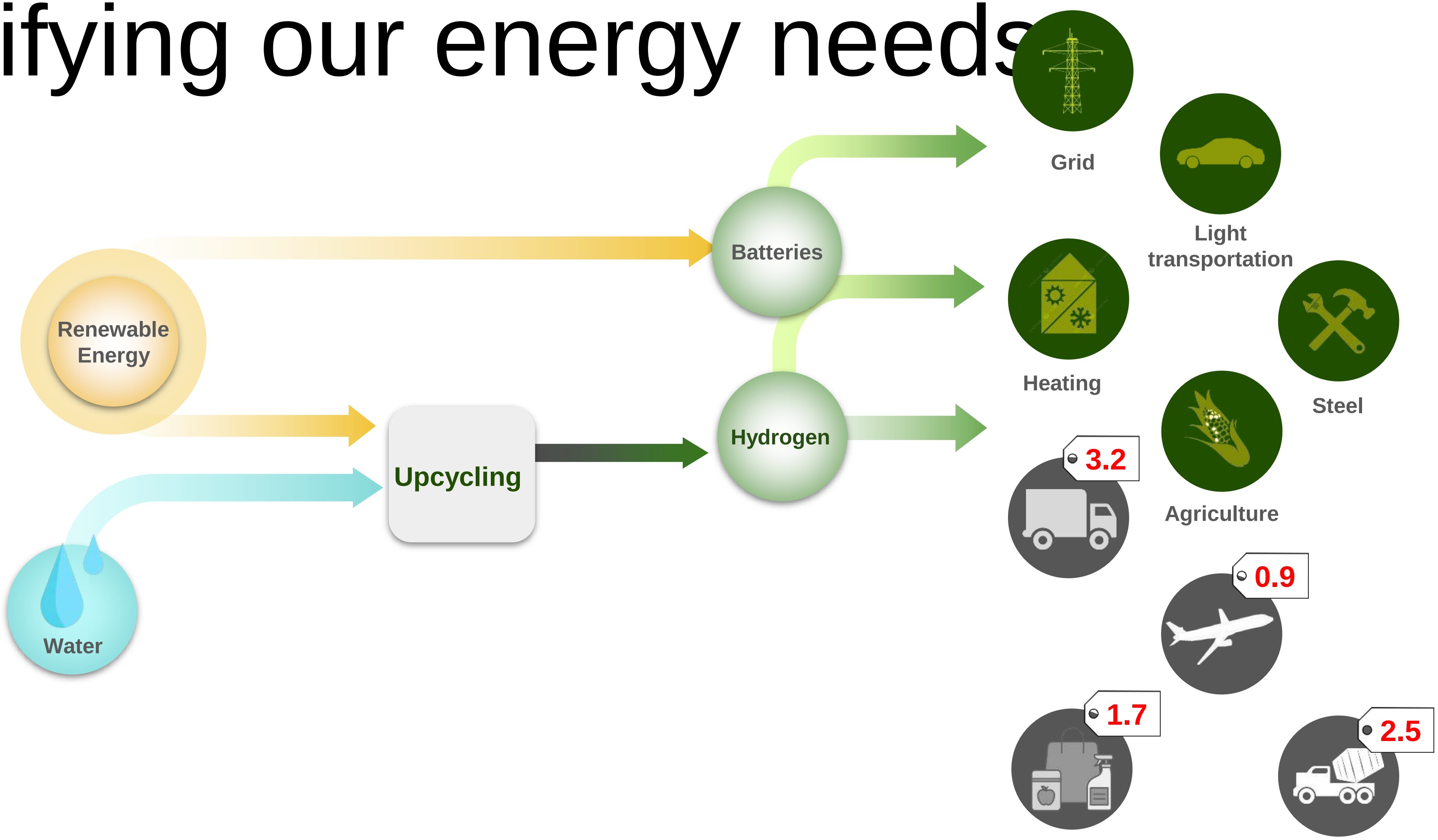
# Electrifying our energy needs



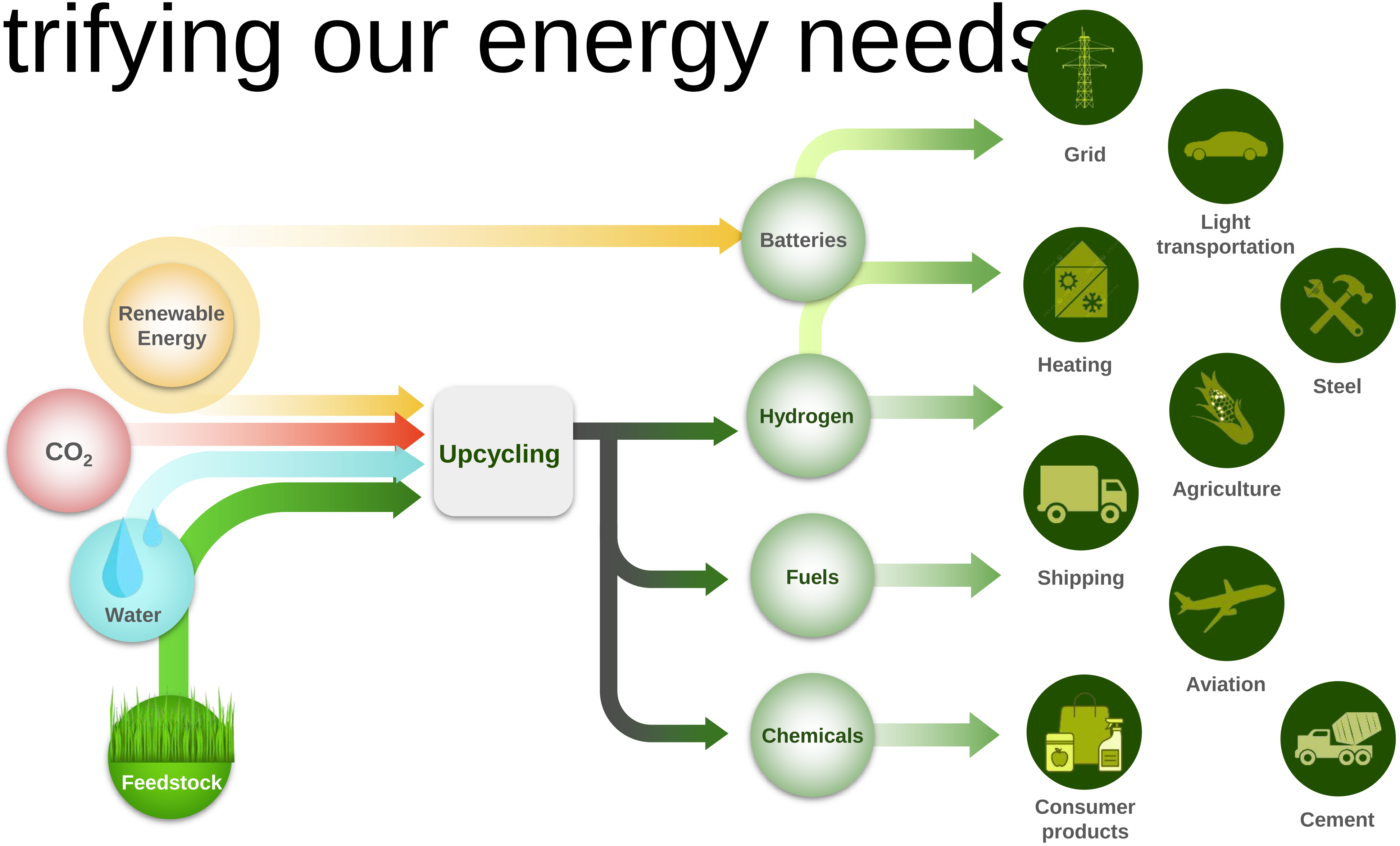
# Large emissions of $CO_2$



# Electrifying our energy needs



# Electrifying our energy needs

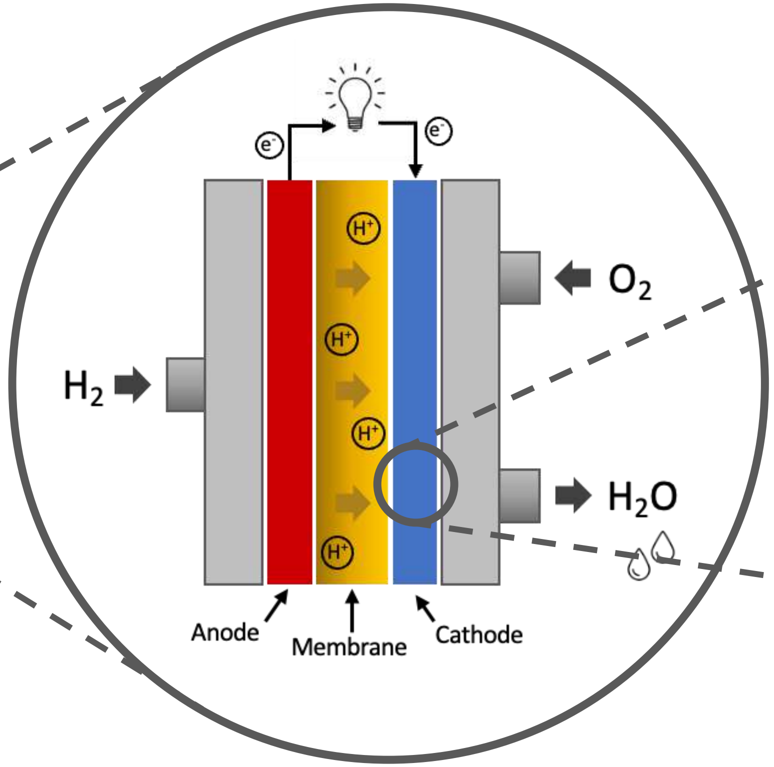


# Catalyst *noun*

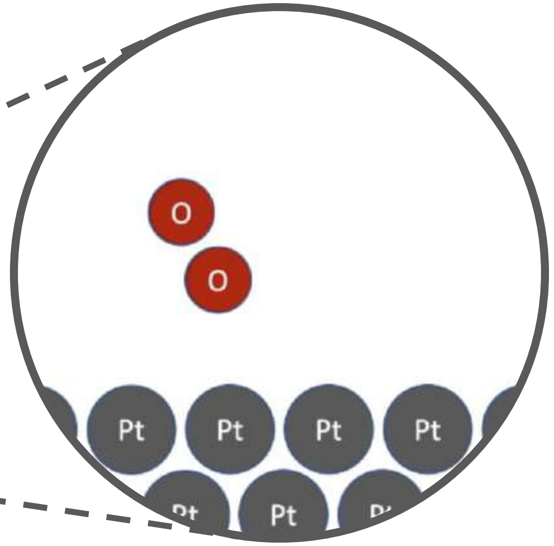
Material used to increase the rate of a chemical reaction without being consumed in the process.

$H_2 + O_2 \rightarrow$ Electricity + $H_2O$

Toyota Mirai



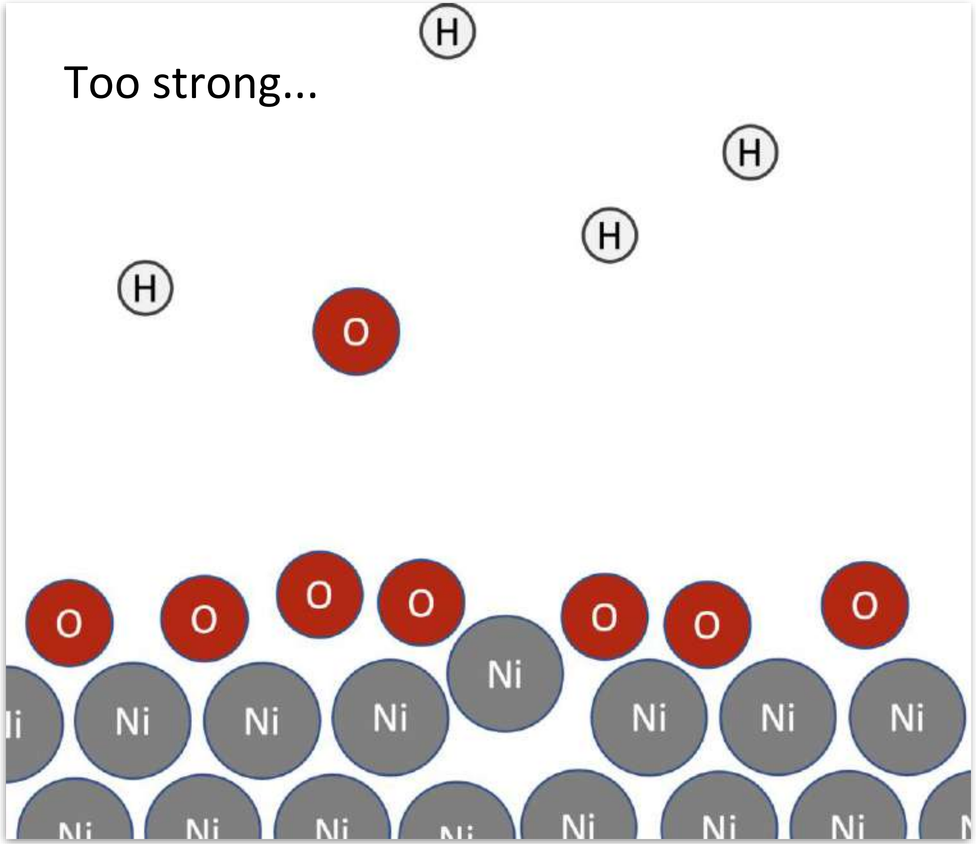

Fuel Cell

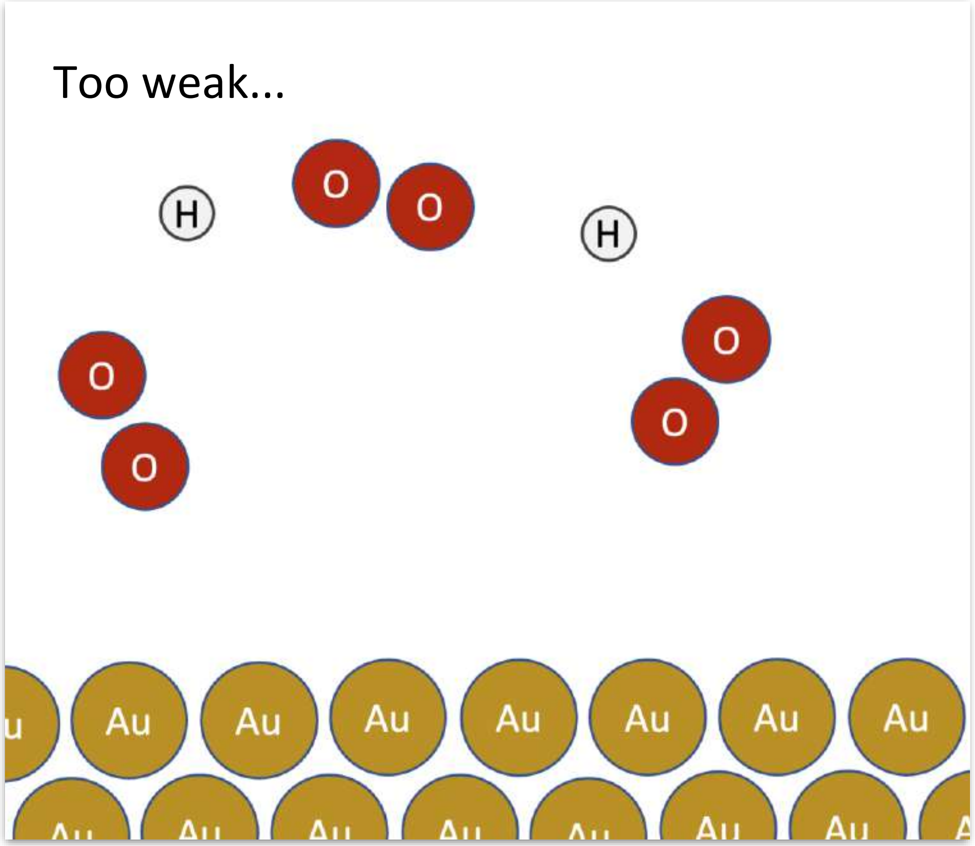



Catalyst

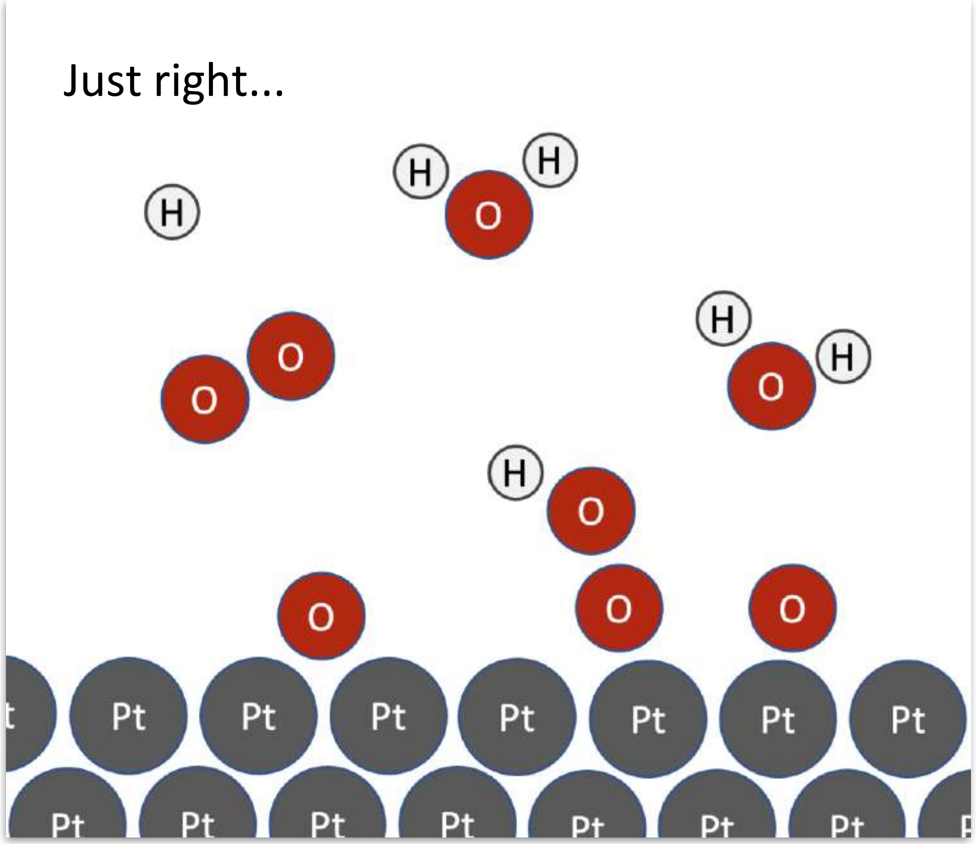
$$O_2 + 4H^+ \longrightarrow 2H_2O$$

# Goldilocks...


Too strong...
H
H
H
H
O
O
O
O
O
O
O
O
Ni
Ni
Ni
Ni
Ni
Ni
Ni
Ni


Too weak...
H
O
O
H
O
O
O
O
Au
Au
Au
Au
Au
Au
Au

# Goldilocks...


Just right...
H
H
H
O
O
O
H
O
H
H
O
O
O
O
Pt
Pt
Pt
Pt
Pt
Pt
Pt
Pt
Pt
Pt
Pt
Pt
Pt
Pt
Pt

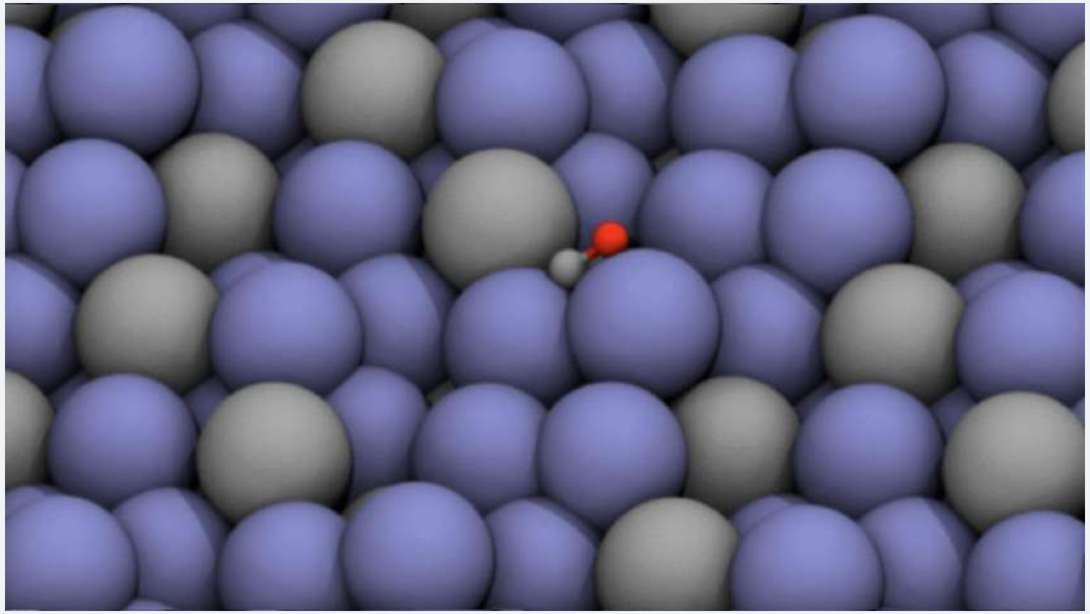
$$$

# How are catalysts screened?

1. Place adsorbate near the catalyst

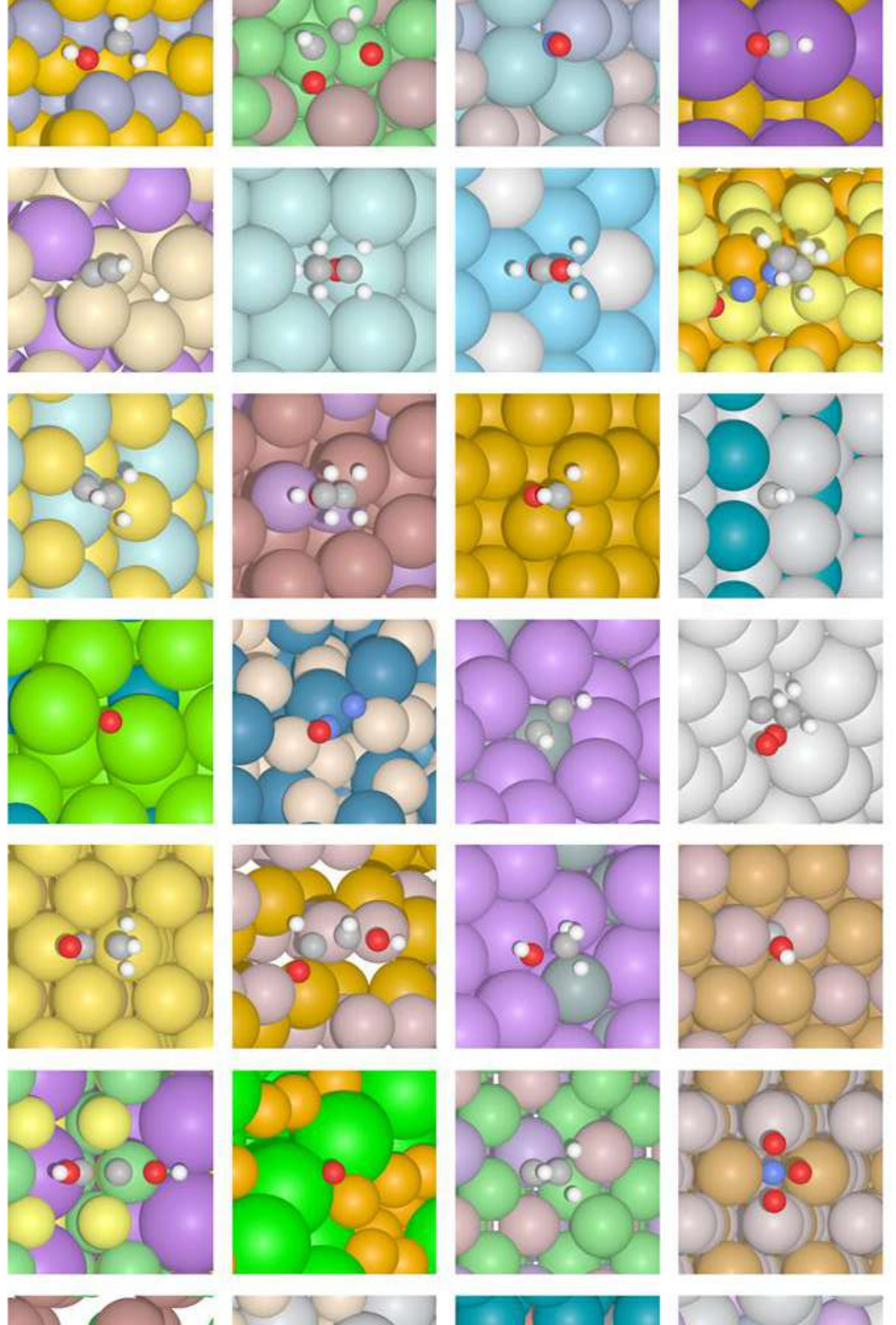
2. Relax atom positions
    a. Compute forces
    b. Update atom positions
    c. Repeat

3. Use relaxed energy to estimate reaction rate trends



A single relaxation using DFT*
takes ~1 day

...billions of possibilities :(



*Density Functional Theory

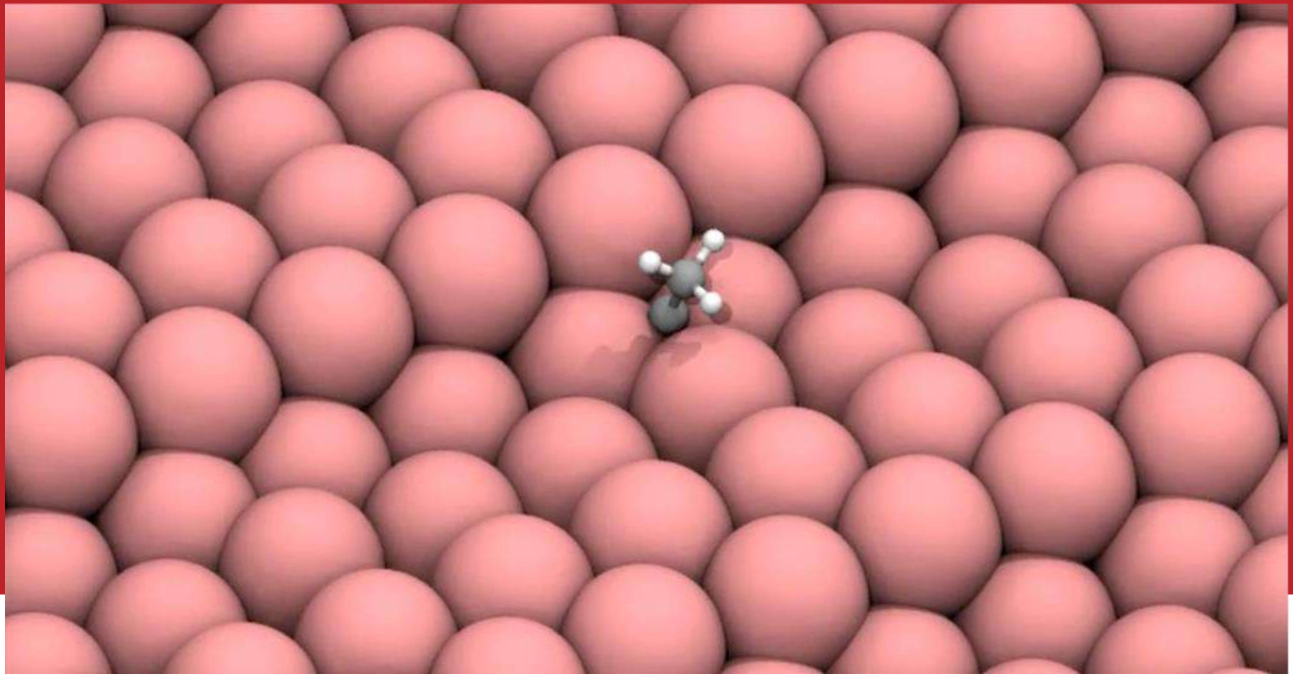
# Reducing computation from 1 day to 1 second?

AI* to the rescue!

*and also chemistry :)

# Open Catalyst Project

Using AI to model and discover new catalysts to address the energy challenges posed by climate change.



Meta

Carnegie Mellon University

UNIVERSITY OF TORONTO

OpenCatalystProject.org

# Training data

## OC20 and OC22 datasets

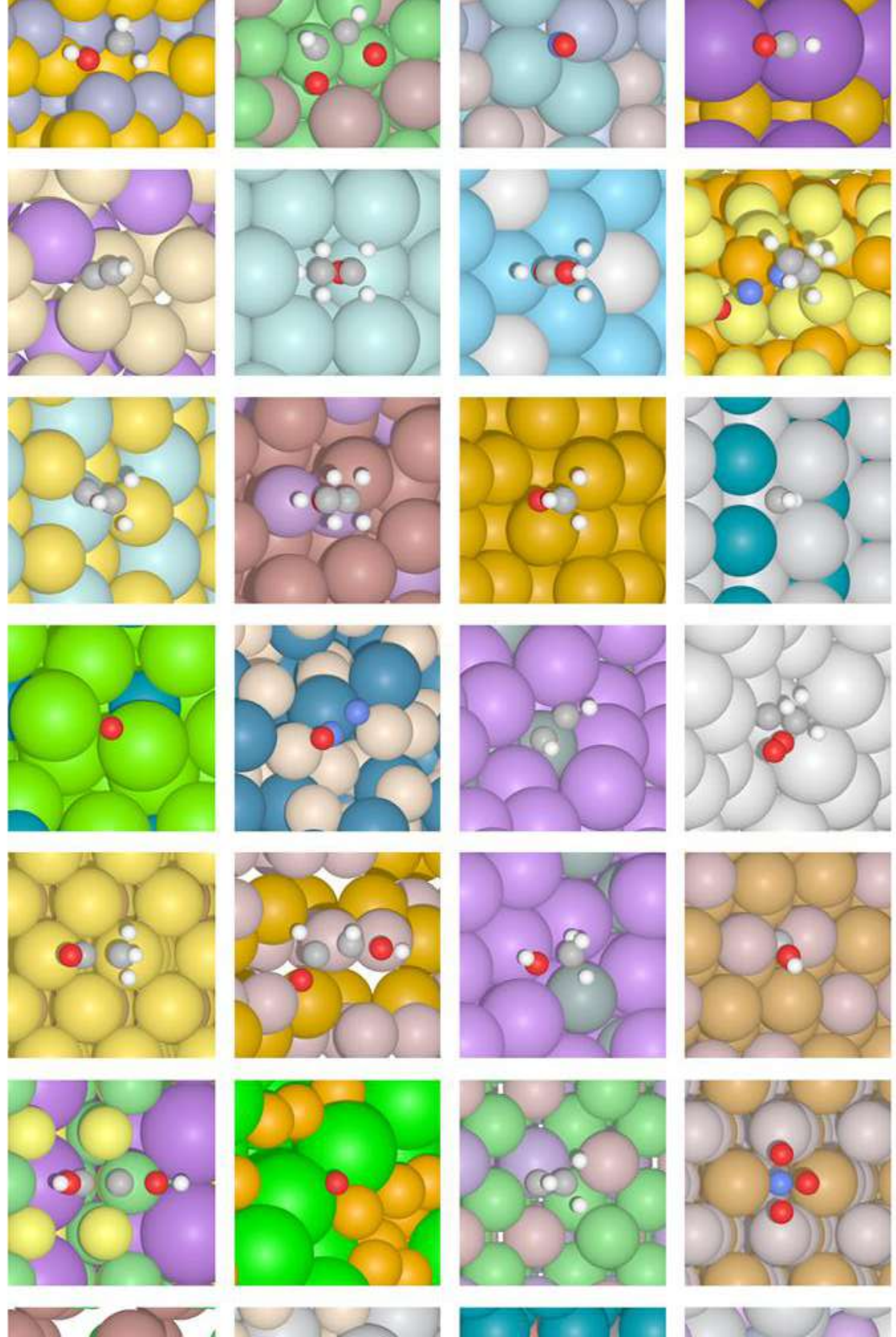
> 140M training examples

> 500M hours of compute!

Open sourced

Creative Commons Attribution 4.0 License

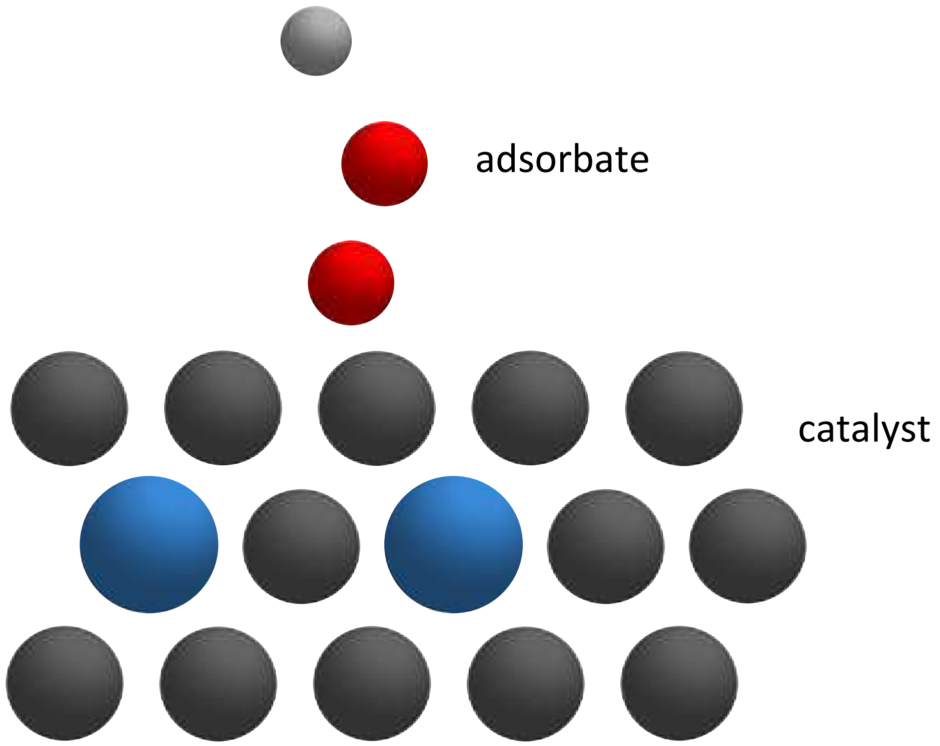
*The Open Catalyst 2020 (OC20) Dataset and Community Challenges,*
Chanussot et al., 2020



# Data

**Input:**

3D atom positions and atomic numbers



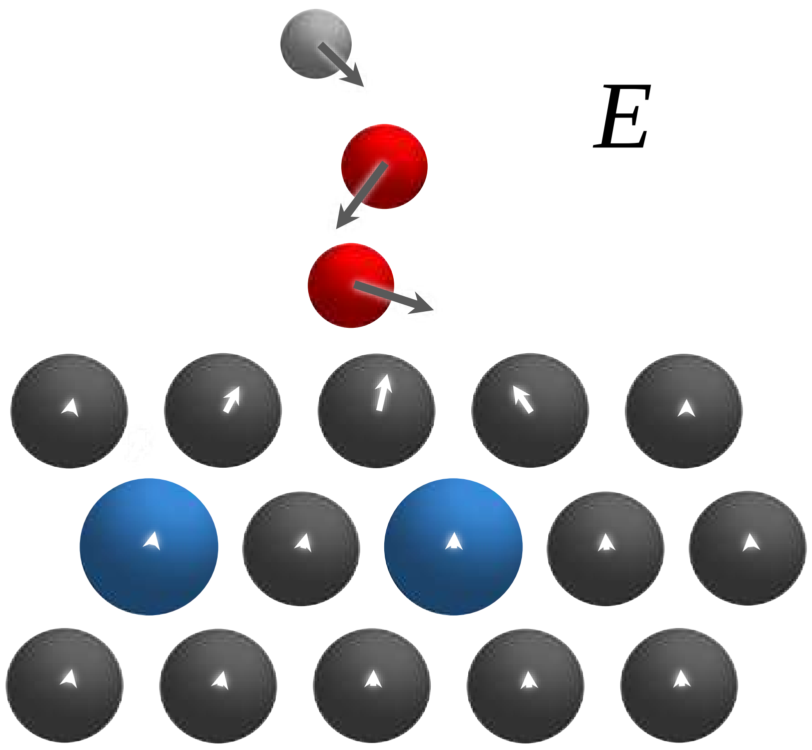
# Data

**Input:**

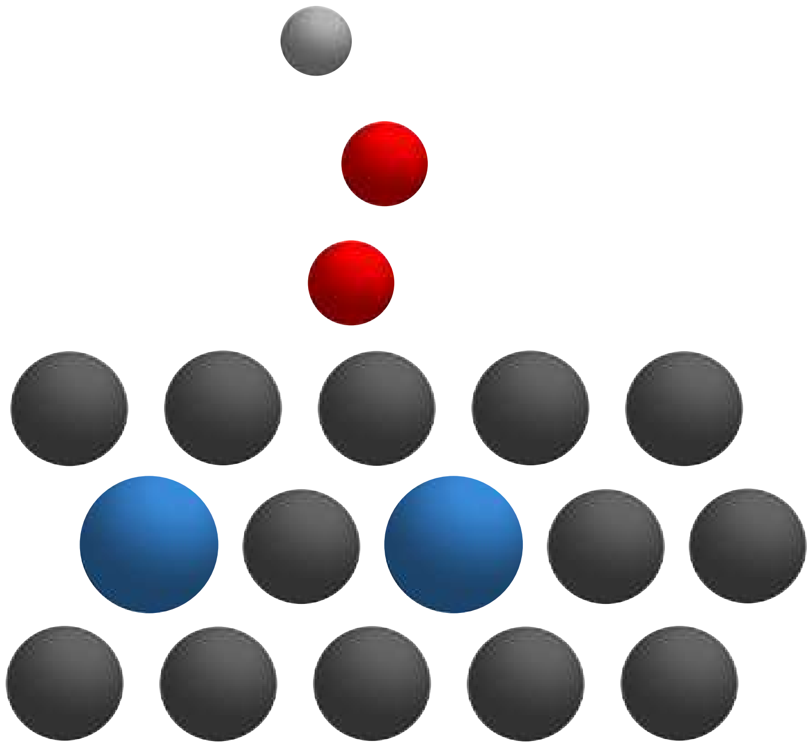
3D atom positions and atomic numbers

**Output:**

Energy and 3D atom forces

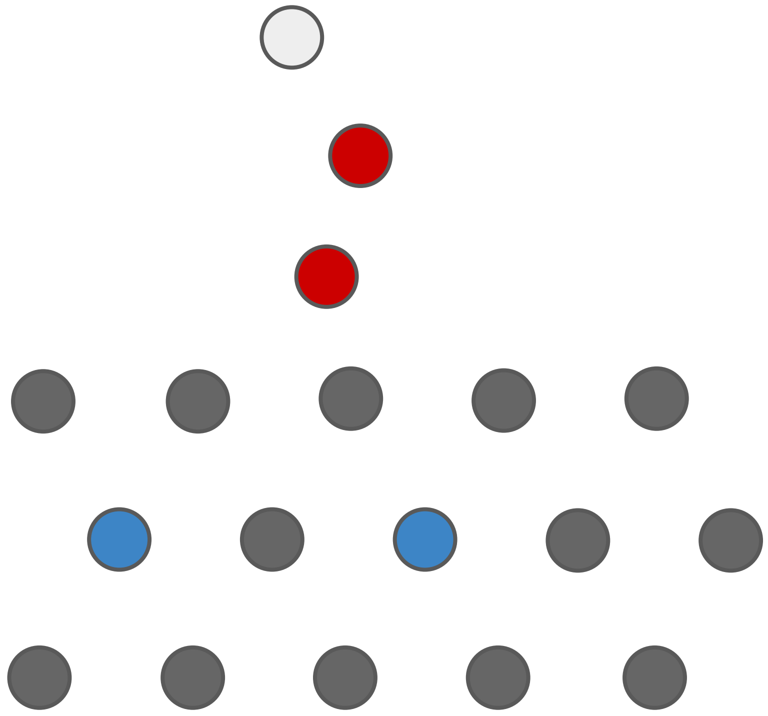


# Graph Neural Network



# Graph Neural Network

Node = Atom

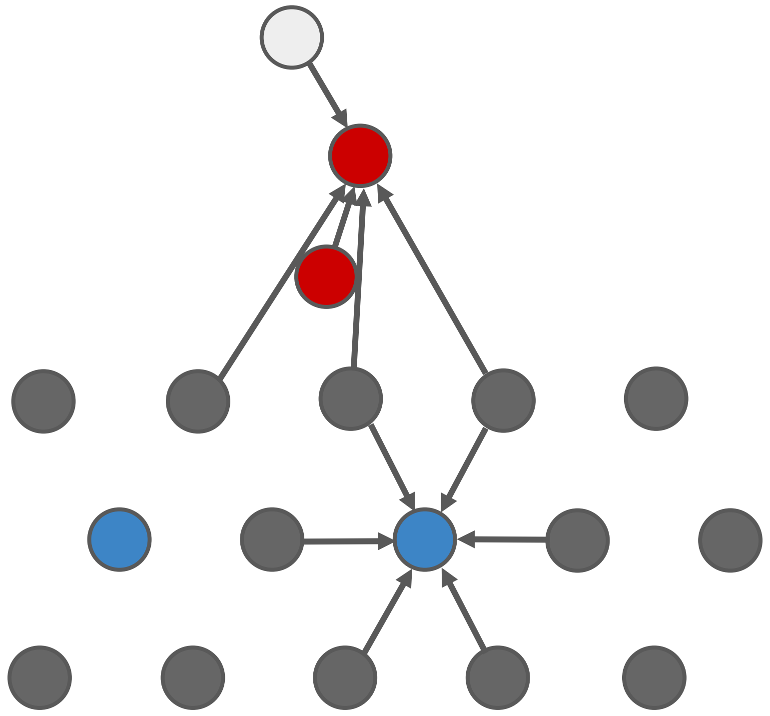


Nodes

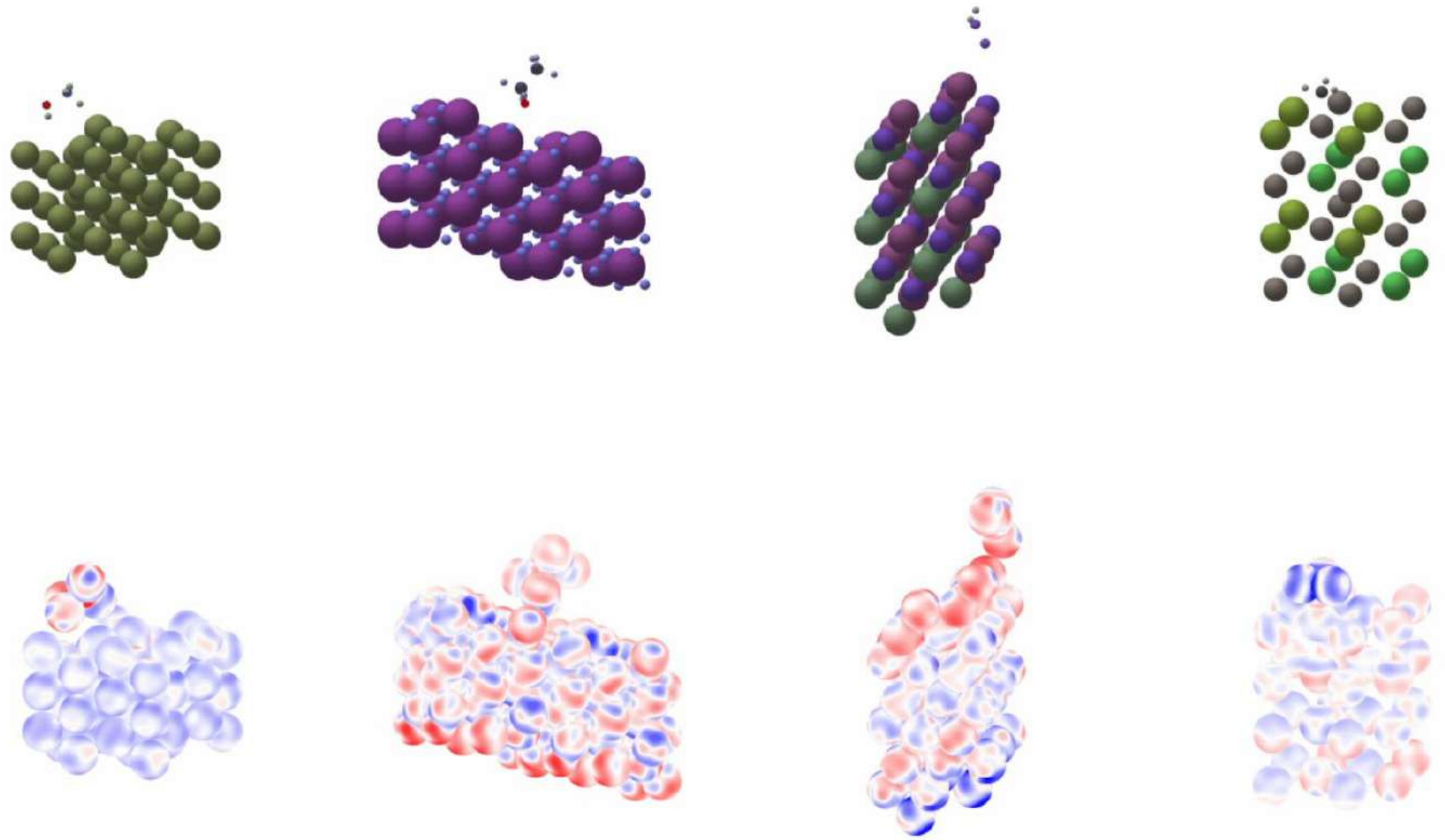
# Graph Neural Network

Node = Atom

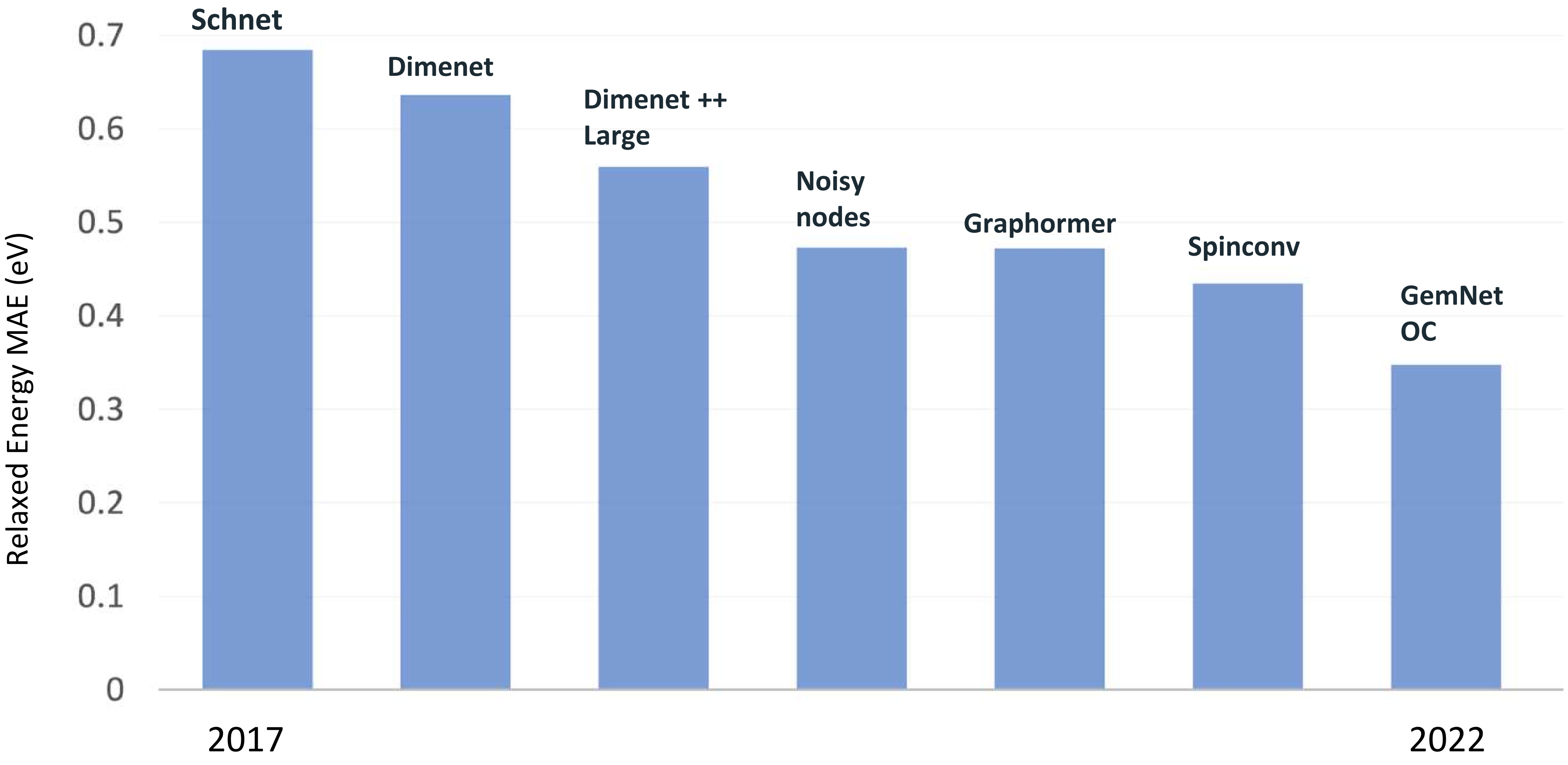
Edge = Neighbor



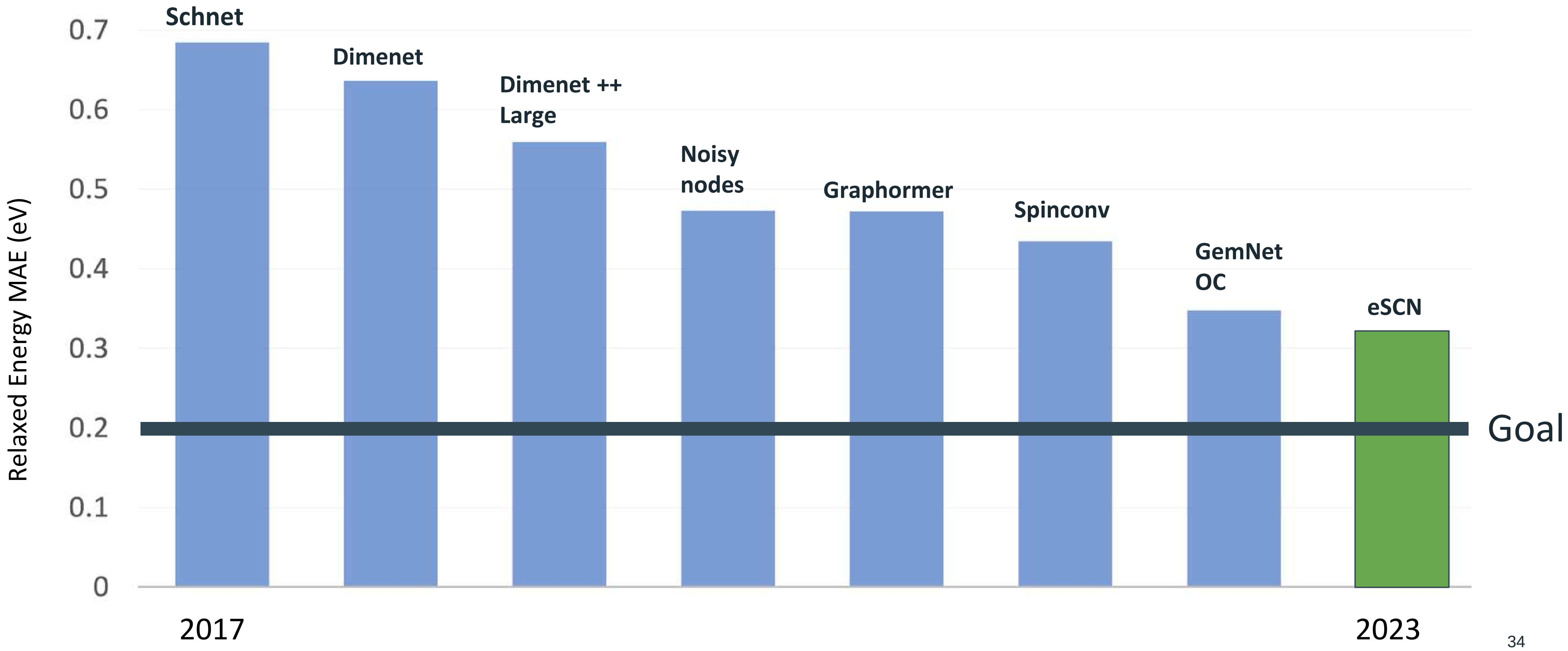
# Spherical channels



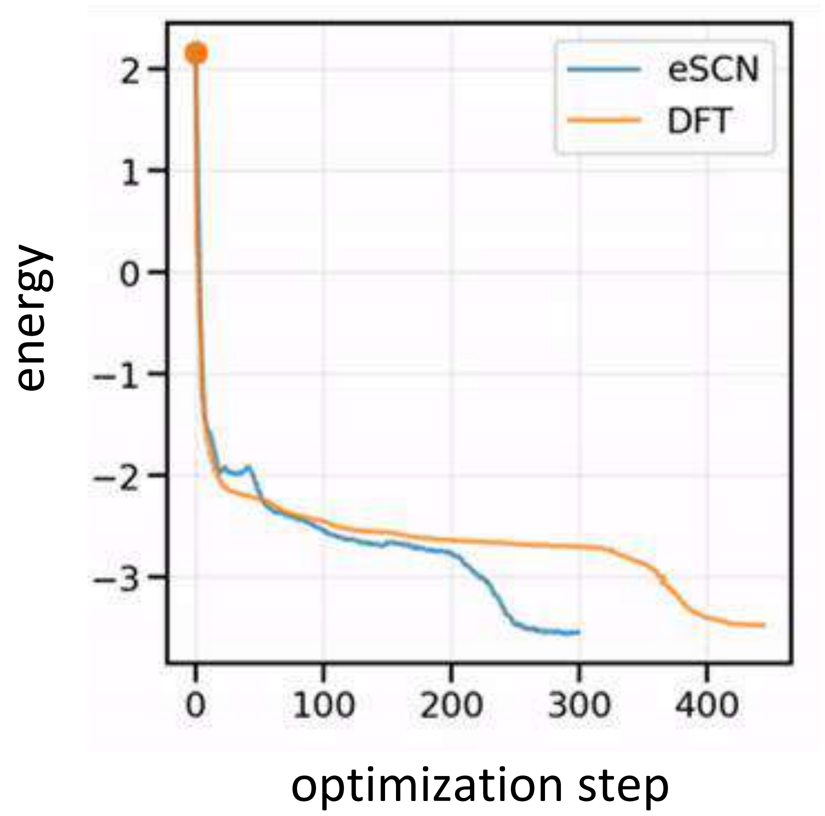
# Results: Relaxed energy

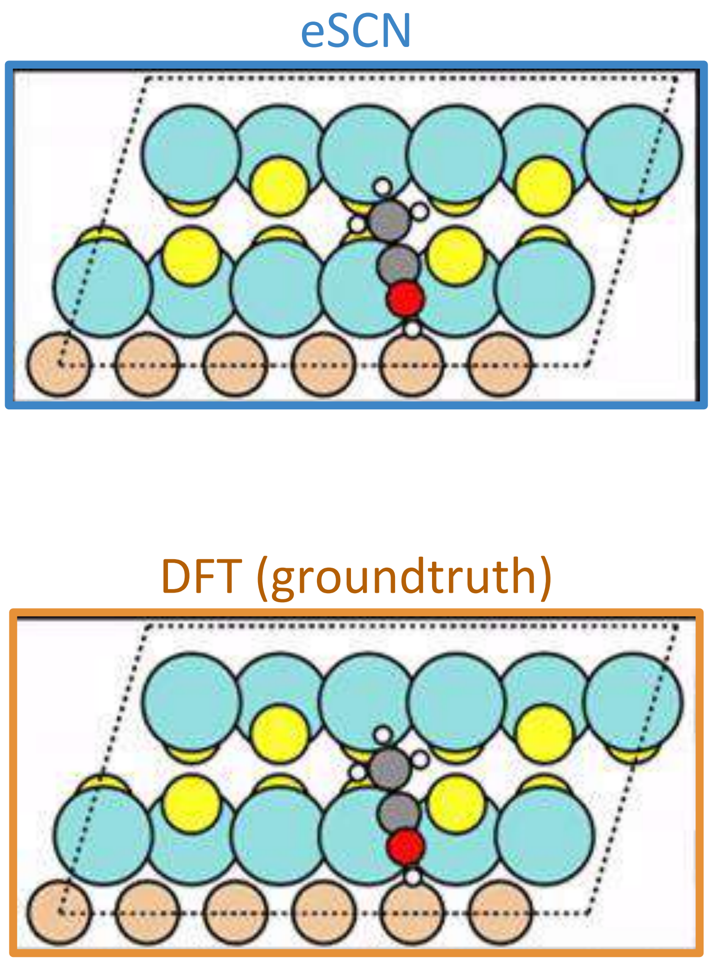


# Results: Relaxed energy



# Relaxations



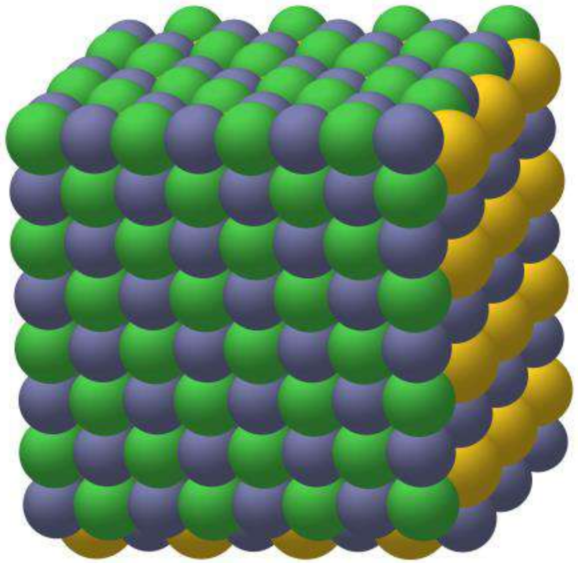


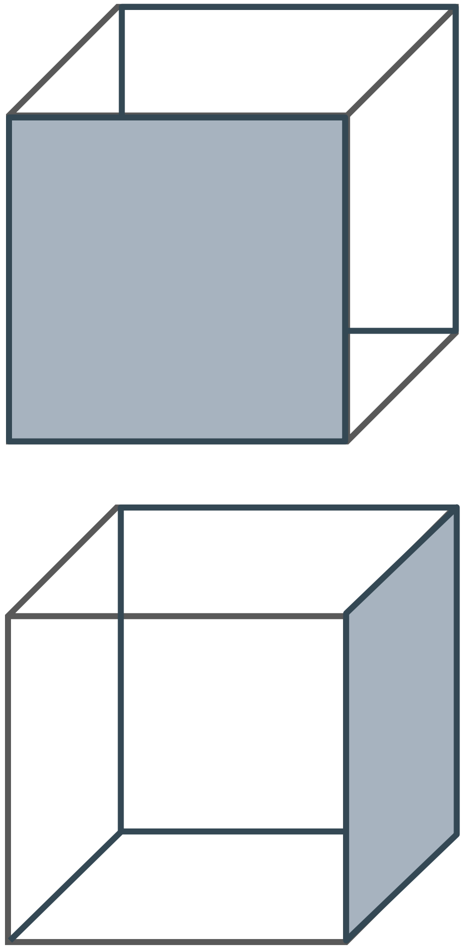

*Reducing SO(3) Convolutions to SO(2) for Efficient Equivariant GNNs*, Passaro and Zitnick, 2023

# Screening a new material…

# Bulk materials

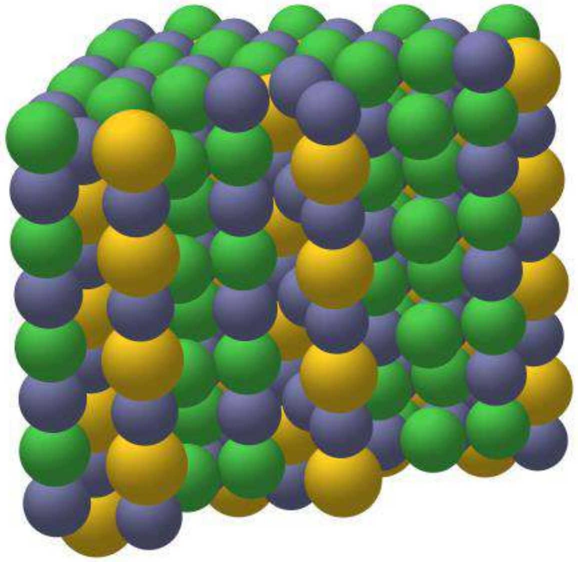
How do you slice the material?

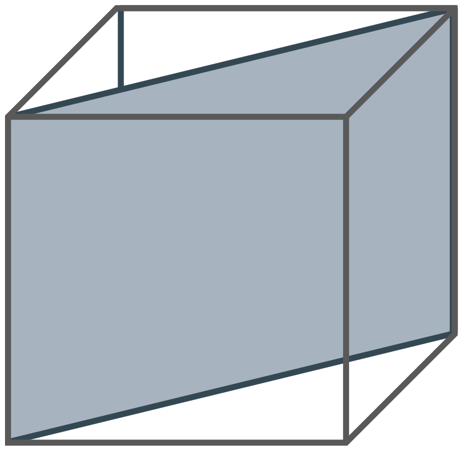




# Bulk materials

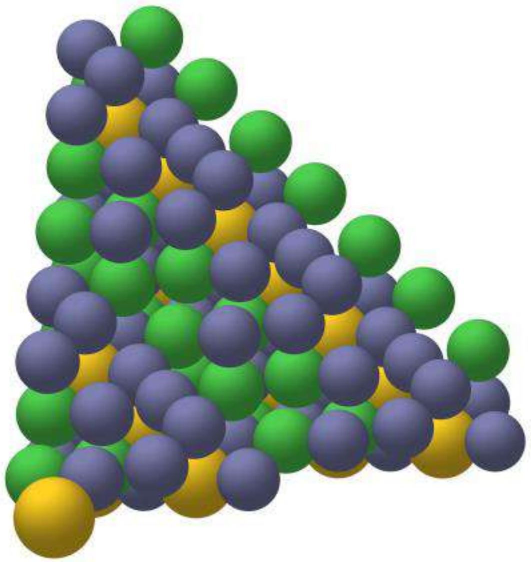
How do you slice the material?

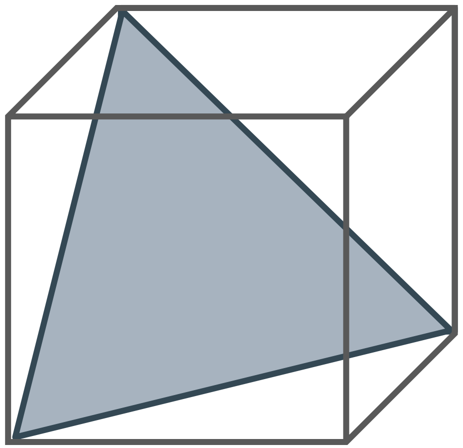




# Bulk materials

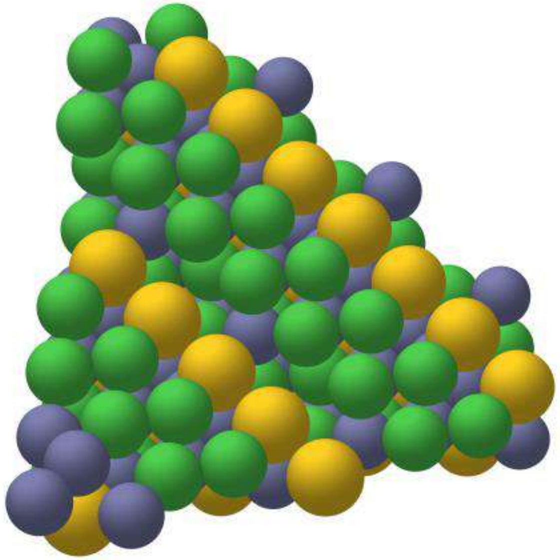
How do you slice the material?

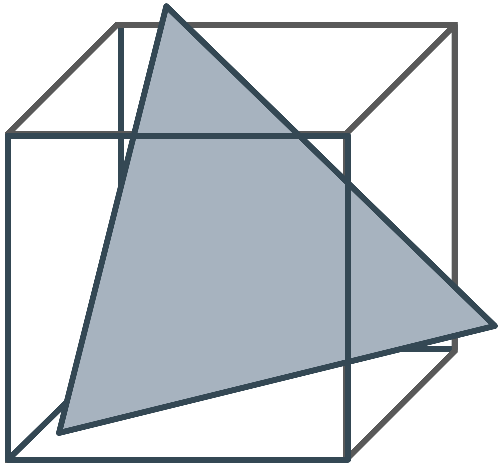




# Bulk materials

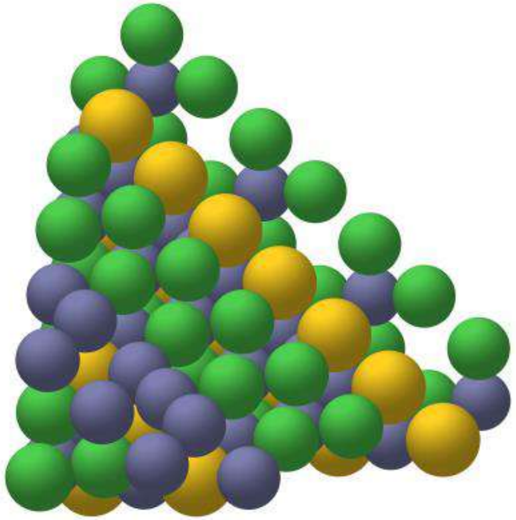
How do you slice the material?

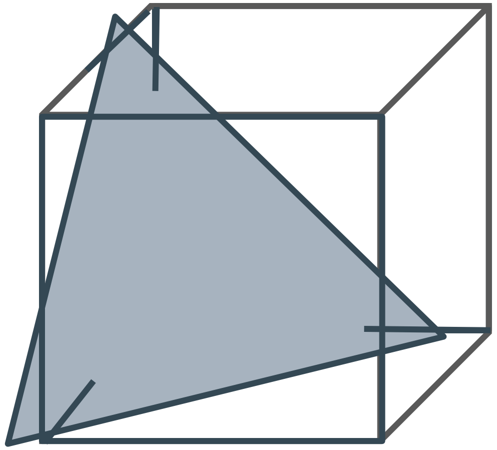




# Bulk materials

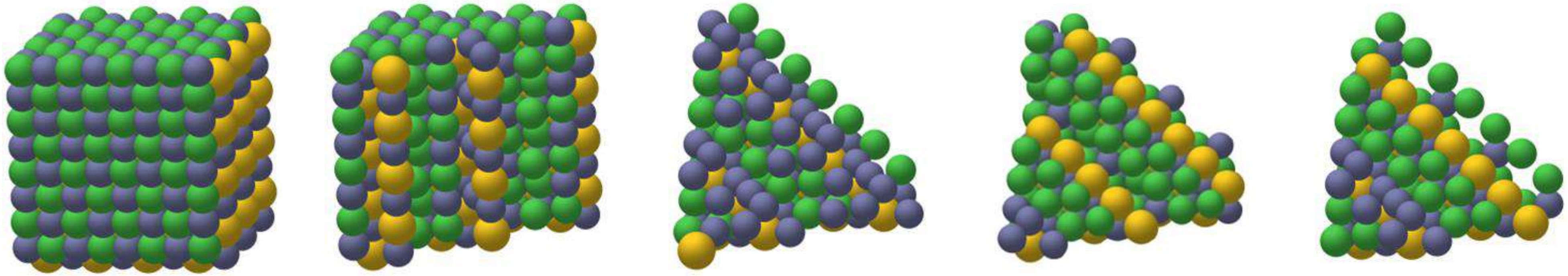
How do you slice the material?





# Bulk materials

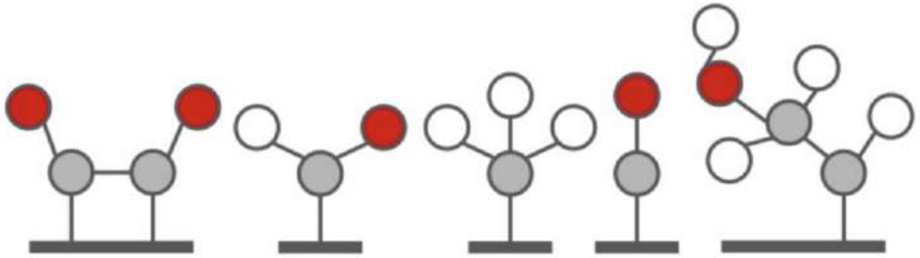
~90 possible slices!

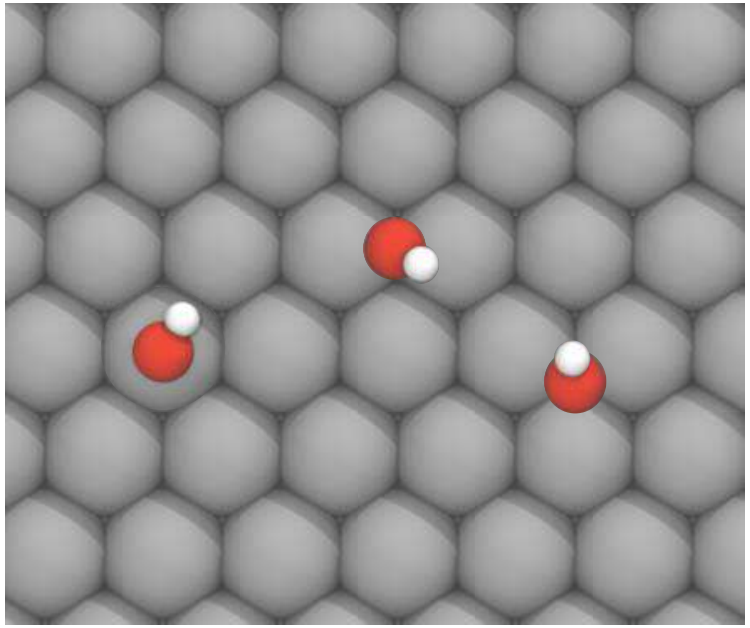


# Adsorbates

~100 different initial placements for each adsorbate.

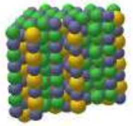
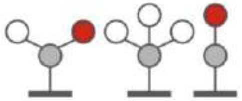
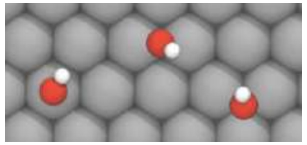
~5 adsorbates of interest





# How many relaxations do we need?

90 slices x 5 adsorbates x 100 placements = 45,000 relaxations!

DFT = 120 CPU* years!

ML + DFT = 2.5 GPU days + 70 CPU* days

*AdsorbML: Accelerating Adsorption Energy Calculations with Machine Learning*, Lan et al., 2022

* 12 cores

# How many known materials are there?

Materials Project

155k

Stable in reaction conditions

6k

https://materialsproject.org/

# Generative AI!

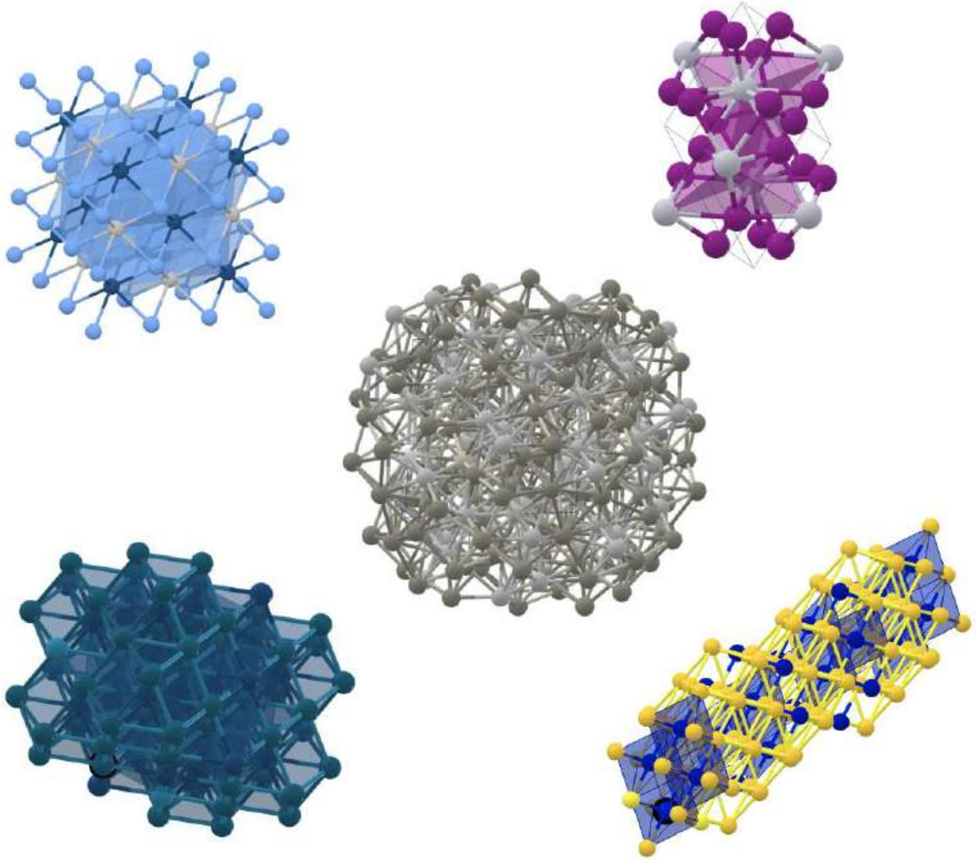
**Make-A-Video**

Sailboat sailing on a sunny day in a mountain lake, highly detailed

A confused grizzly bear in calculus class

A ballerina performs a beautiful and difficult dance on the roof of a very tall skyscraper; the city is lit up and glowing behind her

https://makeavideo.studio/



https://materialsproject.org/

BEST WAY TO SIFT CONFECTIONERS' SUGAR

# Easy Chocolate Cake

**WHY THIS RECIPE WORKS**

This easy wartime cake made with just a few ingredients (flour, sugar, cocoa powder, baking soda, vanilla, and mayonnaise, a stand-in for butter and eggs) had a lot of good things going for it, but chocolate flavor wasn't one of them. We changed that.

**DEEPEN THE CHOCOLATE FLAVOR** More than a half-cup of cocoa would turn the cake dry and chalky so we supplement the cocoa powder with a little melted chocolate. "Blooming" the cocoa powder in hot water intensifies its flavor, and using hot coffee instead of water enriches the flavor even more. Chopping the dark chocolate fine means we can melt it in the hot coffee as well—no need for an extra pan.

**ACCENT THE CHOCOLATE WITH** ...FFEE A full cup of coffee adds moisture ...ightens the chocolate flavor in this ...a also serves to give the chocolate

...H THE MAYO As for the mayonnaise—we won- ... the cake richer by ...utter or eggs and ...st and velvety ...We learned ... emul- ... in

**EASY CHOCOLATE CAKE**

SERVES 8

Choose a high-quality chocolate for this cake. Instead of confectioners' sugar, the cake can be served with Whipped Cream (page 348).

- 1½ cups (7½ ounces) all-purpose flour
- 1 cup (7 ounces) sugar
- ½ teaspoon baking soda
- ¼ teaspoon salt
- ½ cup (1½ ounces) Dutch-processed cocoa powder
- 2 ounces bittersweet chocolate, chopped fine
- 1 cup brewed coffee, hot
- ⅔ cup mayonnaise
- 1 large egg, room temperature
- 2 teaspoons vanilla extract
- Confectioners' sugar (optional)

1. Adjust oven rack to middle position and heat oven to 350 degrees. Grease 8-inch square baking pan, line with parchment paper, grease parchment, and flour pan.

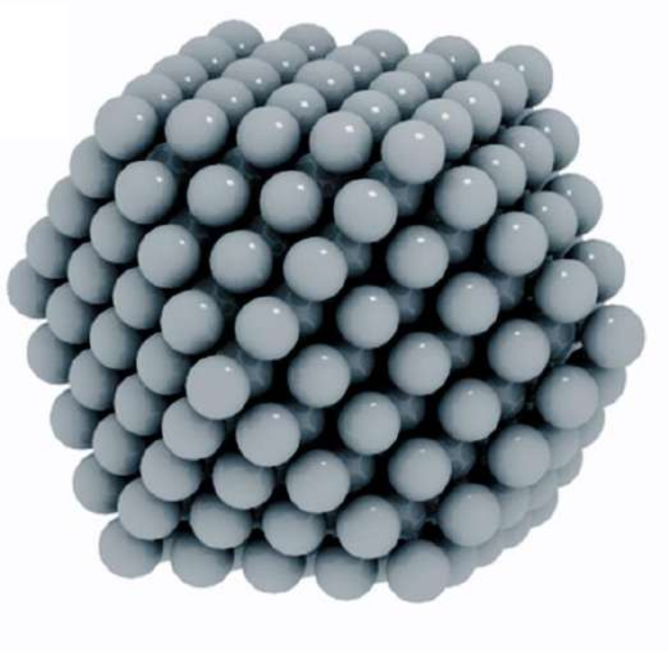
2. Whisk flour, sugar, baking soda, and salt together in large bowl. In separate bowl, combine cocoa and chocolate. Pour hot co... fee over cocoa mixture and let sit, covere... 5 minutes. Gently whisk mixture until ... let cool slightly, then whisk in ... g, and vanilla. Stir mayonna... mixture until combi... ape batter ... with

You pour in 20% platinum and 80% copper what do you get?

Which crystal structure?

Which facets?

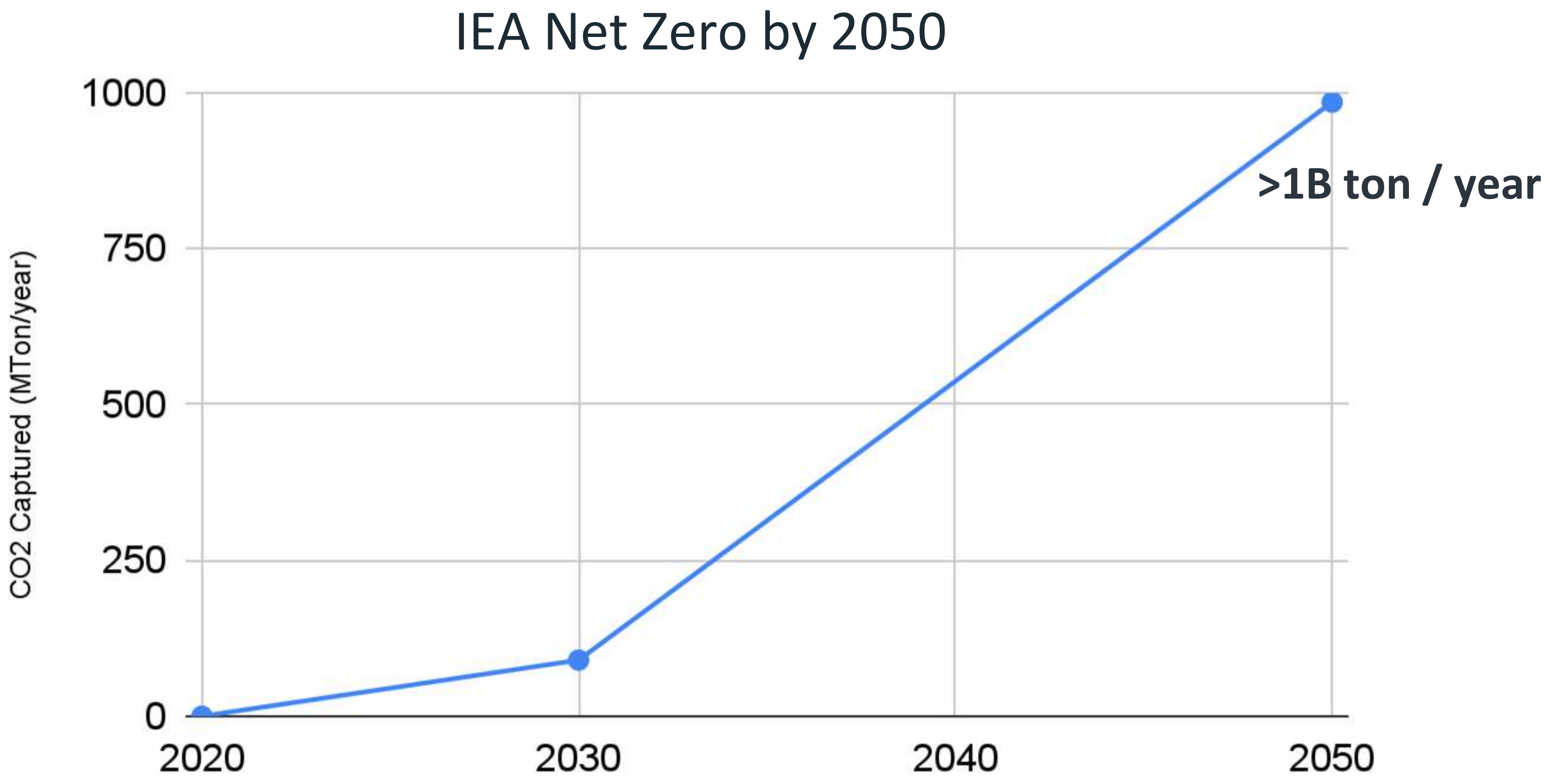
Does it create a uniform material?



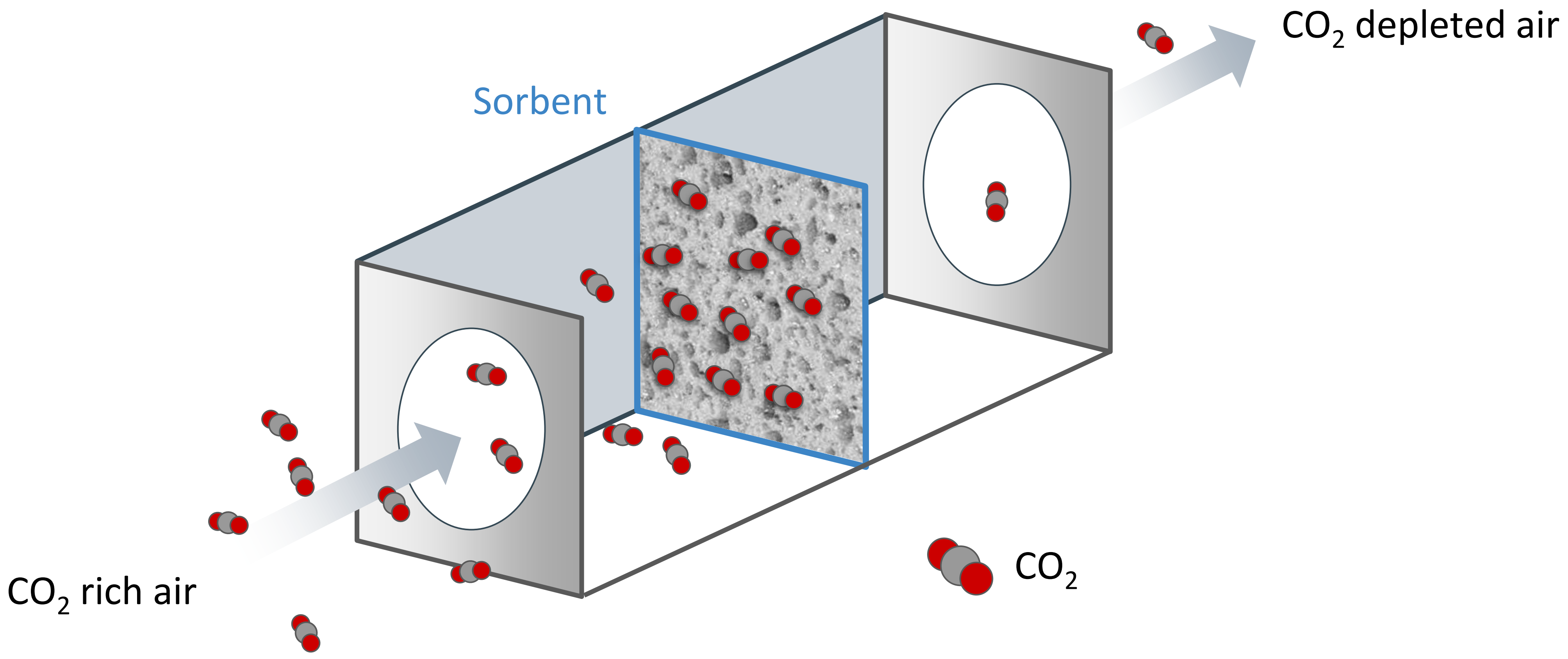
UNIVERSITY OF TORONTO

# Direct Air Capture

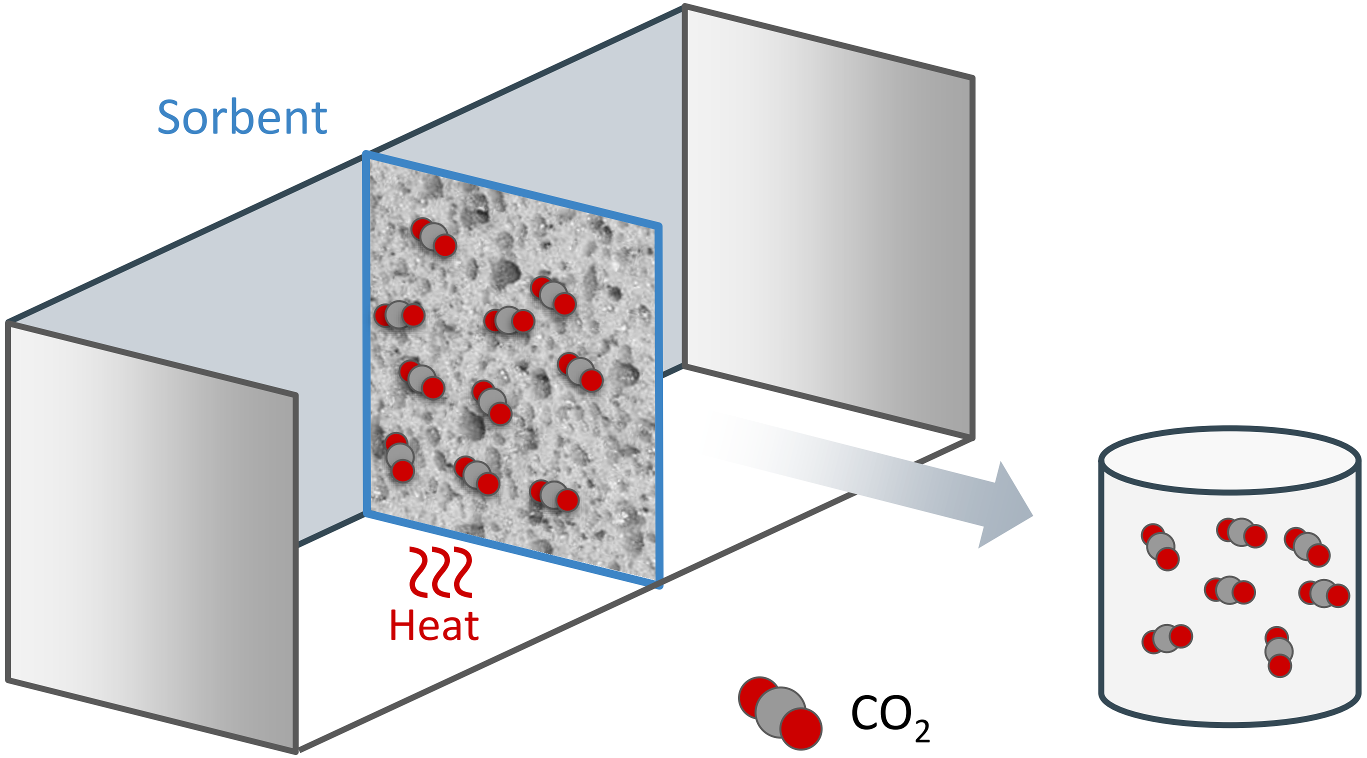
# Direct Air Capture



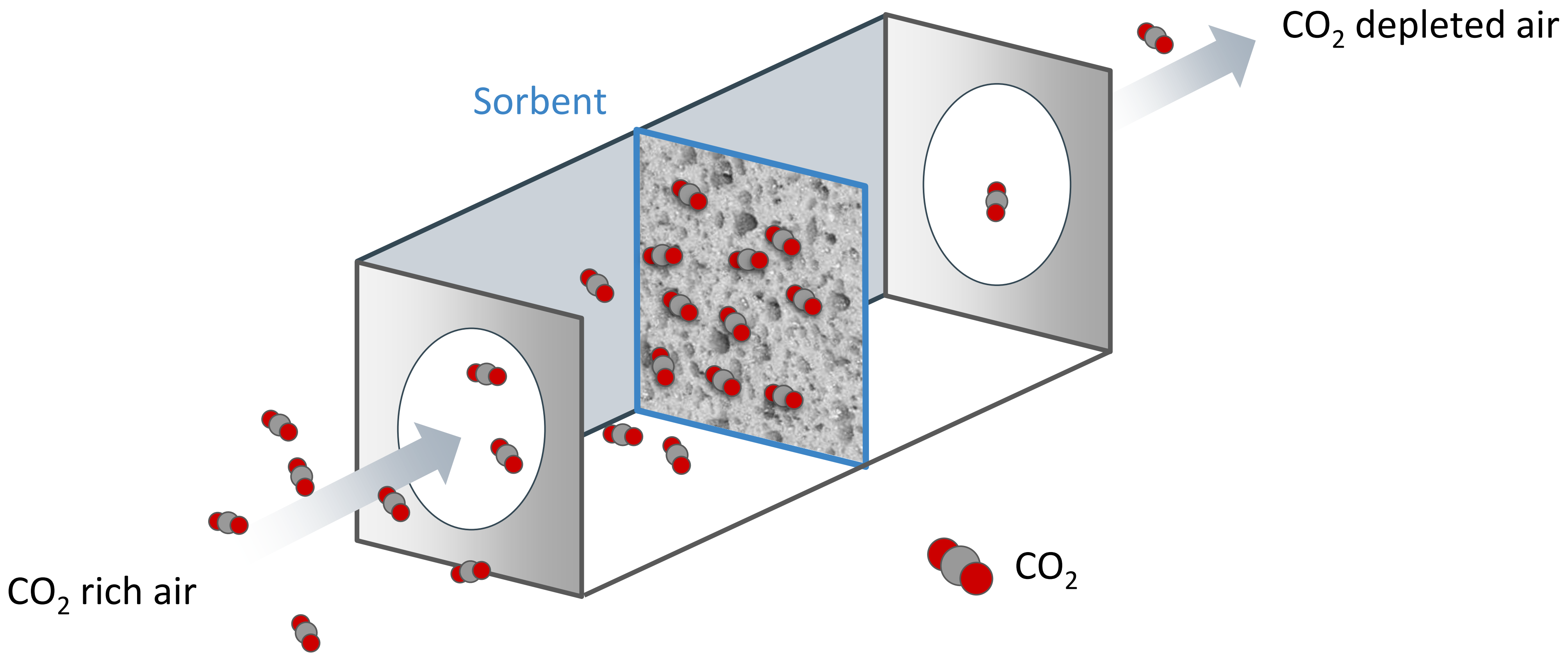
# OpenDAC



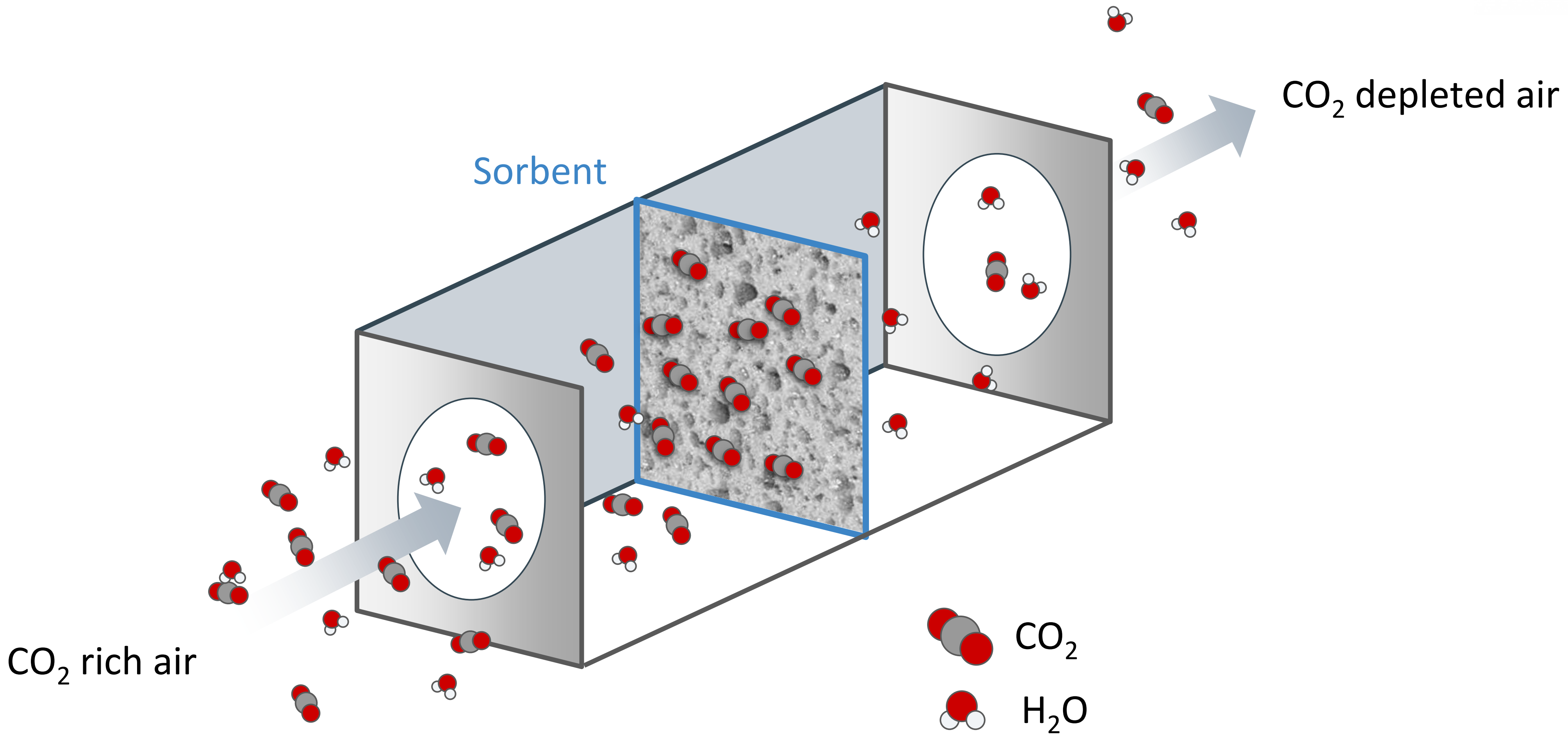
# OpenDAC



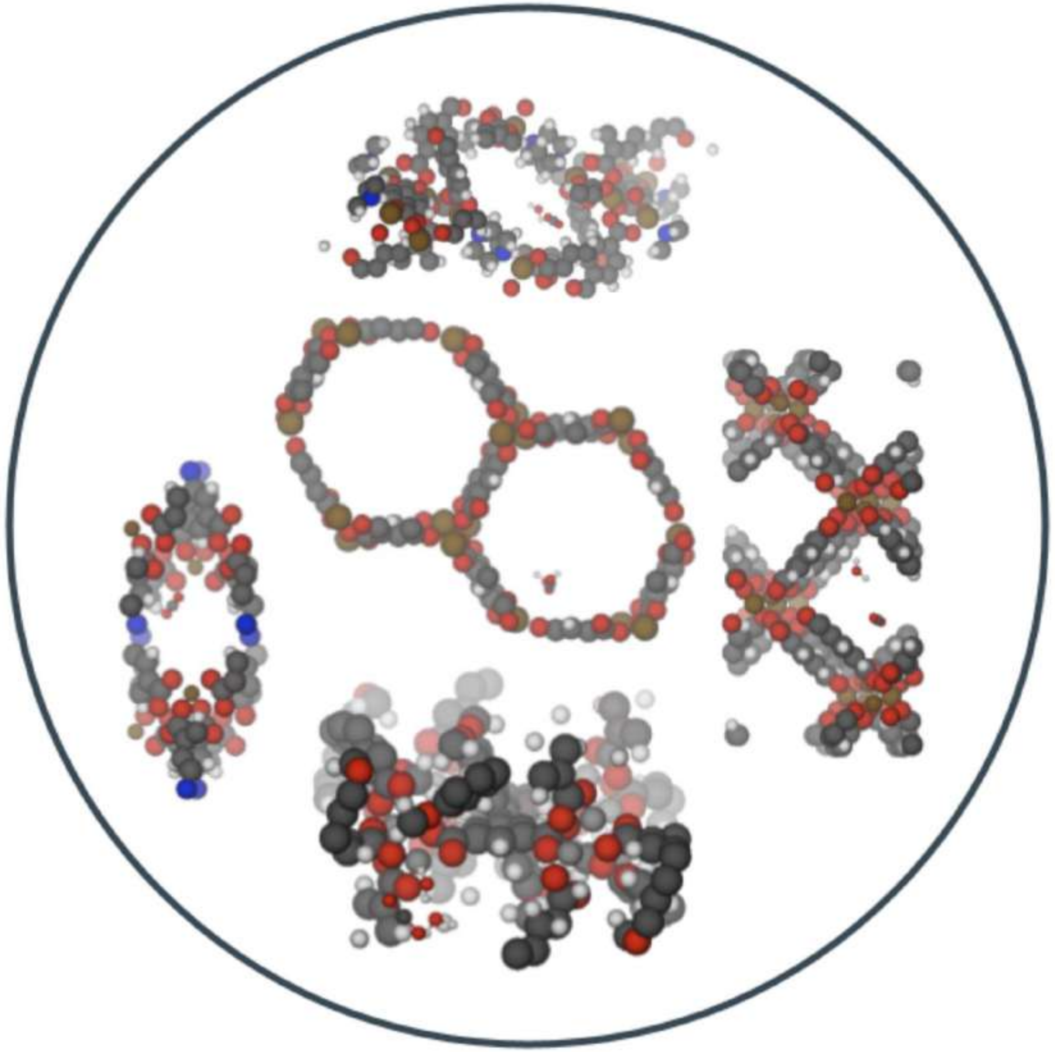
# OpenDAC



# OpenDAC

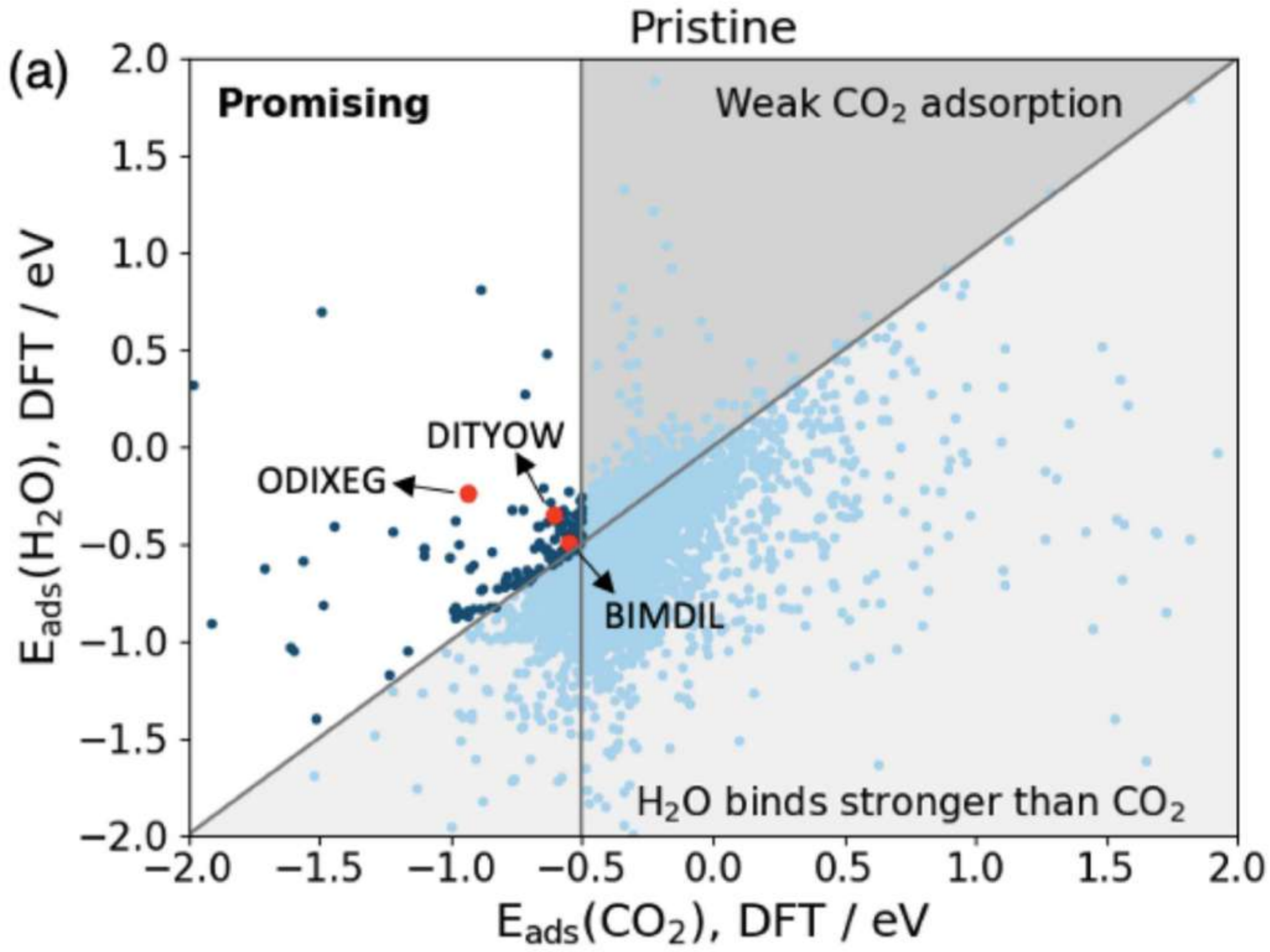


# OpenDAC23



*The Open DAC 2023 Dataset and Challenges for Sorbent Discovery in Direct Air Capture*, Sriram et al., 2023

# OpenDAC23




*The Open DAC 2023 Dataset and Challenges for Sorbent Discovery in Direct Air Capture*, Sriram et al., 2023

# AI Datacenters

# What if we interacted with AIs for 1 billion hours per day?

Let's assume it takes one A100 to power an AI.

An A100 requires 400W plus a PUE of 1.1…

…results in 160 TWh of power required per year.

A100

# 160 TWh (scenario 1)

0.5% of the world's electricity

Roughly doubles the power required by datacenters worldwide.

@ $0.08 per kWh = $12.8 Billion

---

0.86 pounds of $CO_2$ are emitted per kWh in the US

70 million metric tons of $CO_2$ per year

@ $200 per ton = $14 Billion

# 160 TWh (scenario 2)*

@ $0.02 per kWh for solar = $3.2 Billion

---

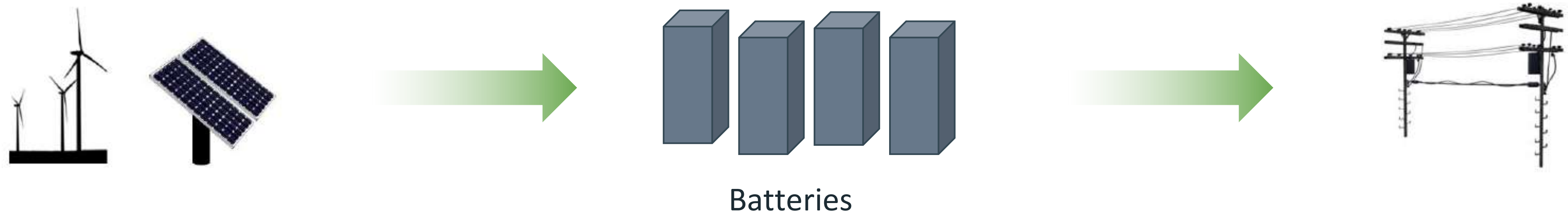
0 pounds of $CO_2$ are emitted per kWh of solar power in the US

## $26.8 Billion vs. $3.2 Billion

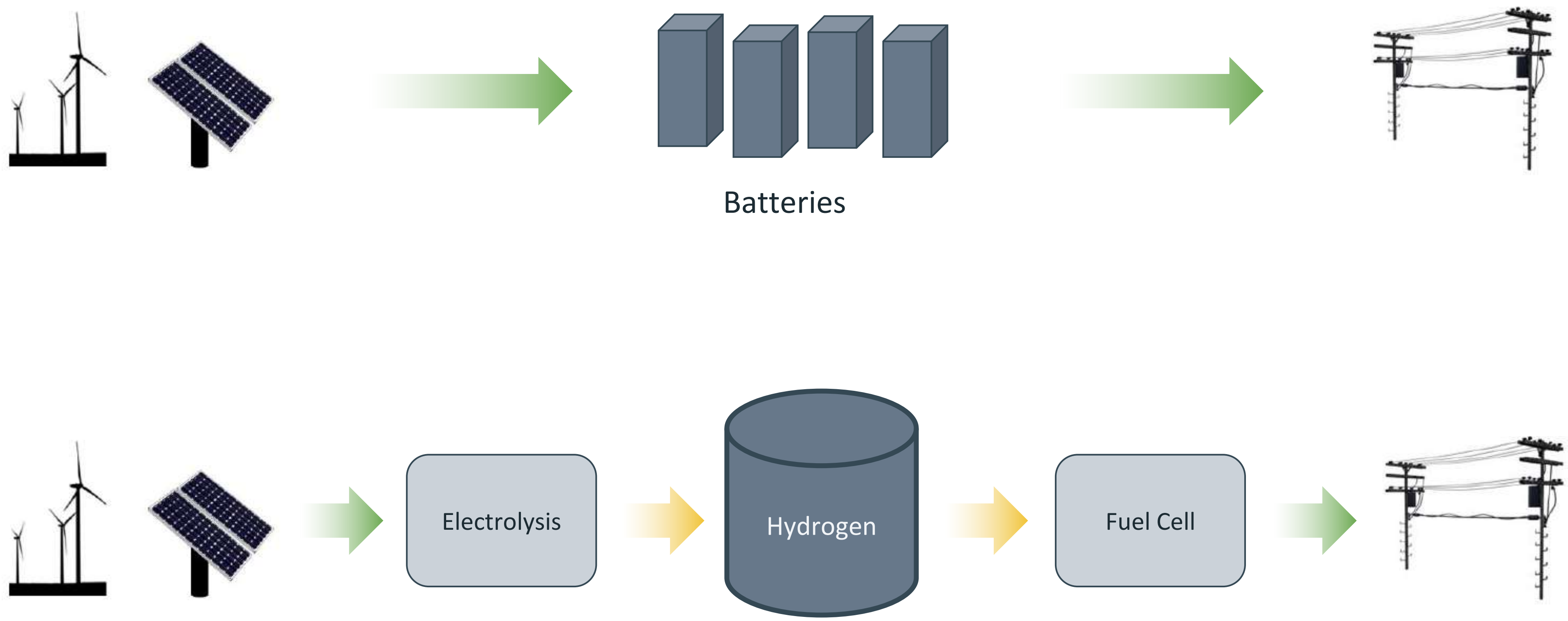
(scenario 1) (scenario 2)

*only runs for ~8 hours a day

# Renewable energy storage

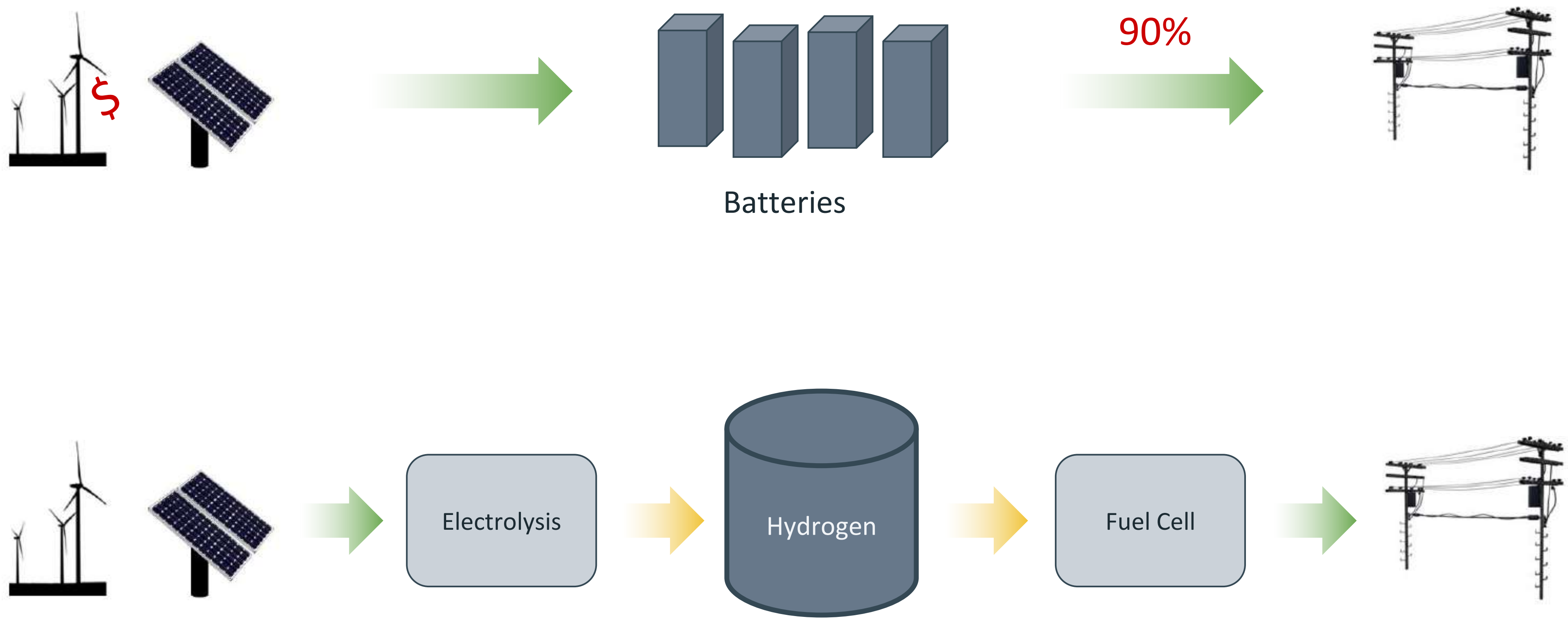


# Renewable energy storage

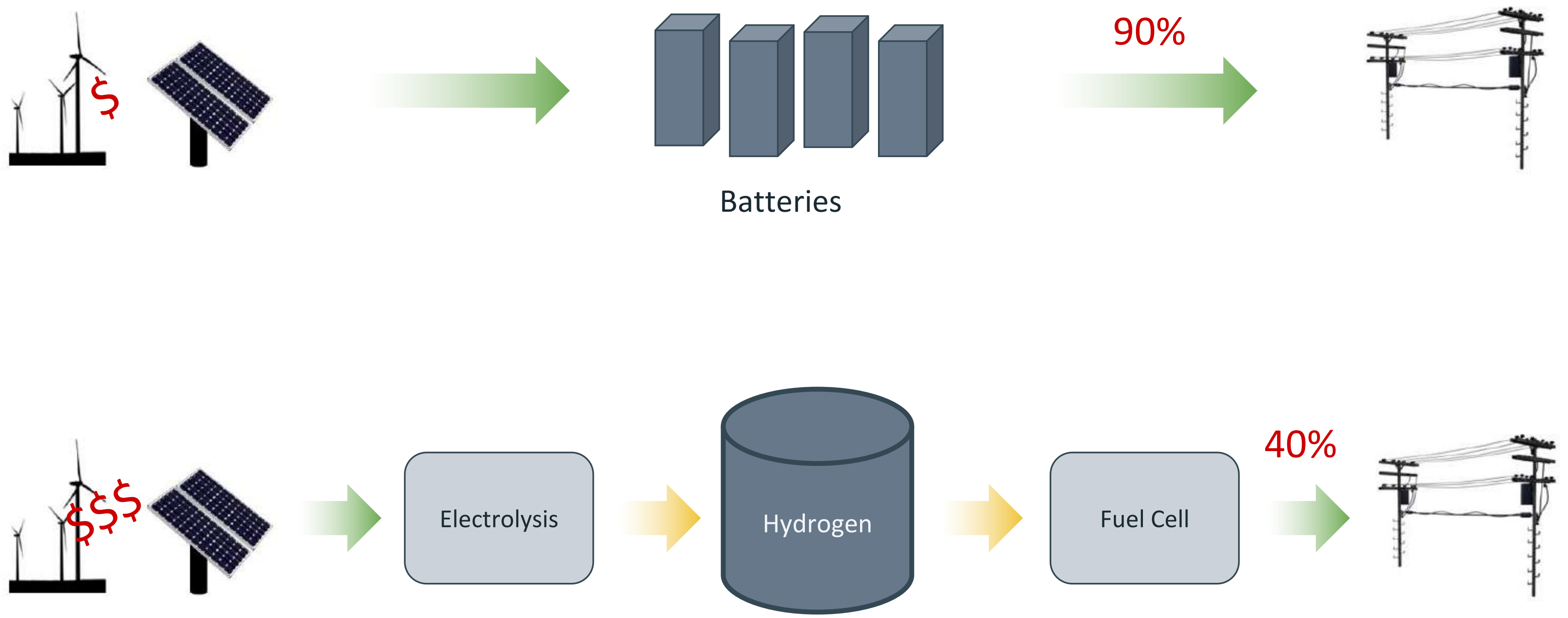


# Scenario A (high electricity costs)

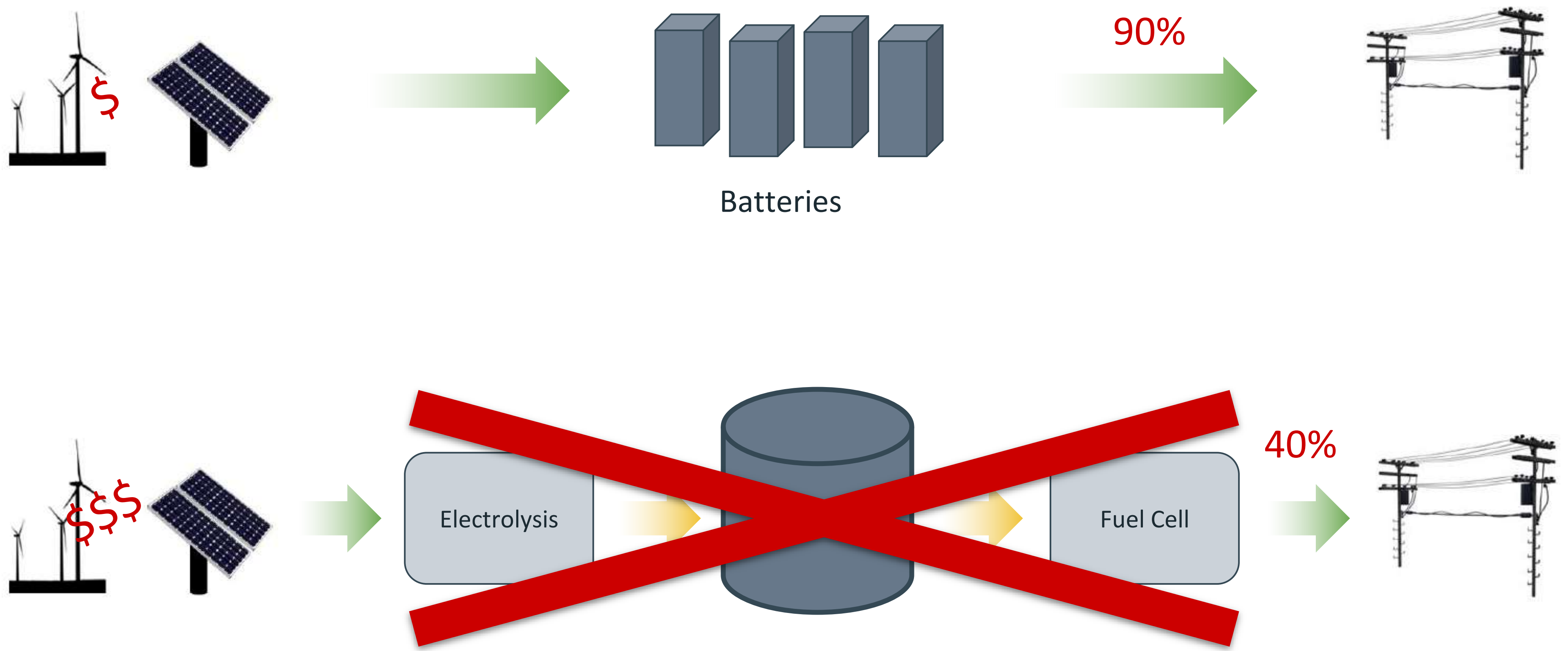
# Scenario A (high electricity costs)



# Scenario A (high electricity costs)

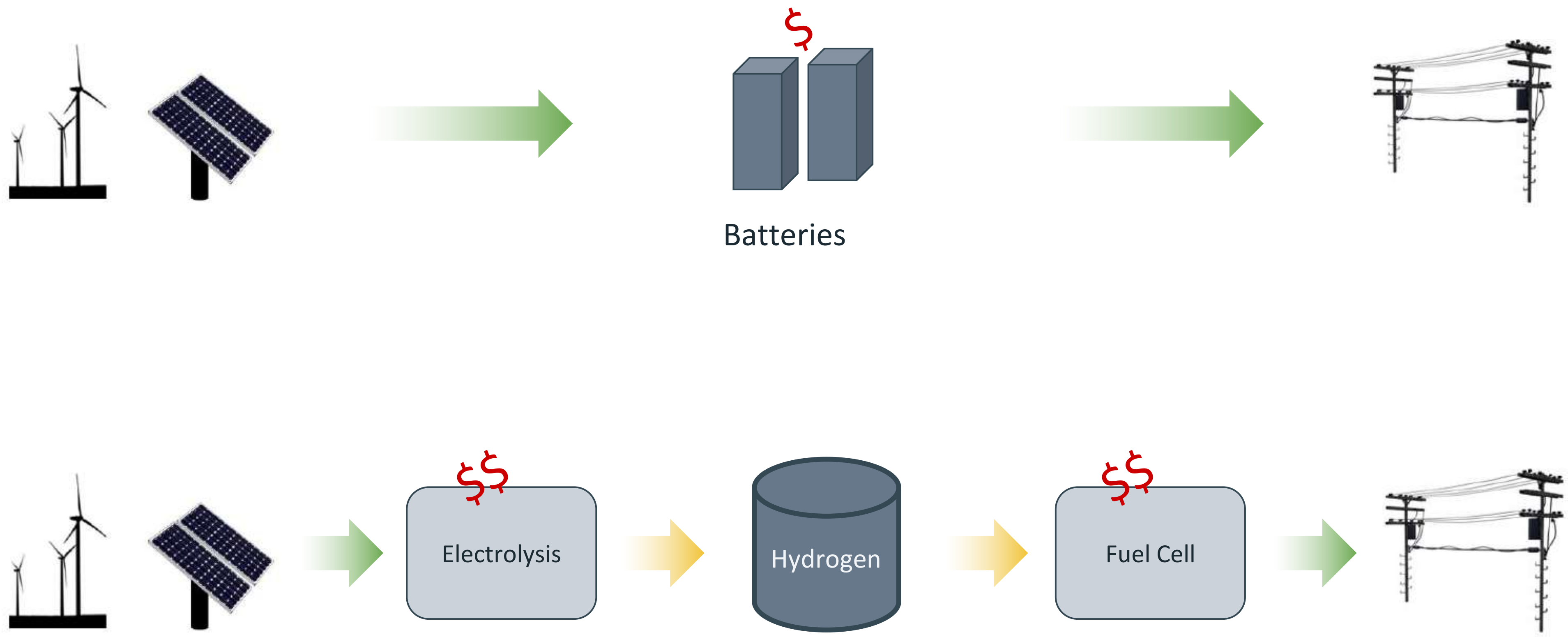


# Scenario A (high electricity costs)

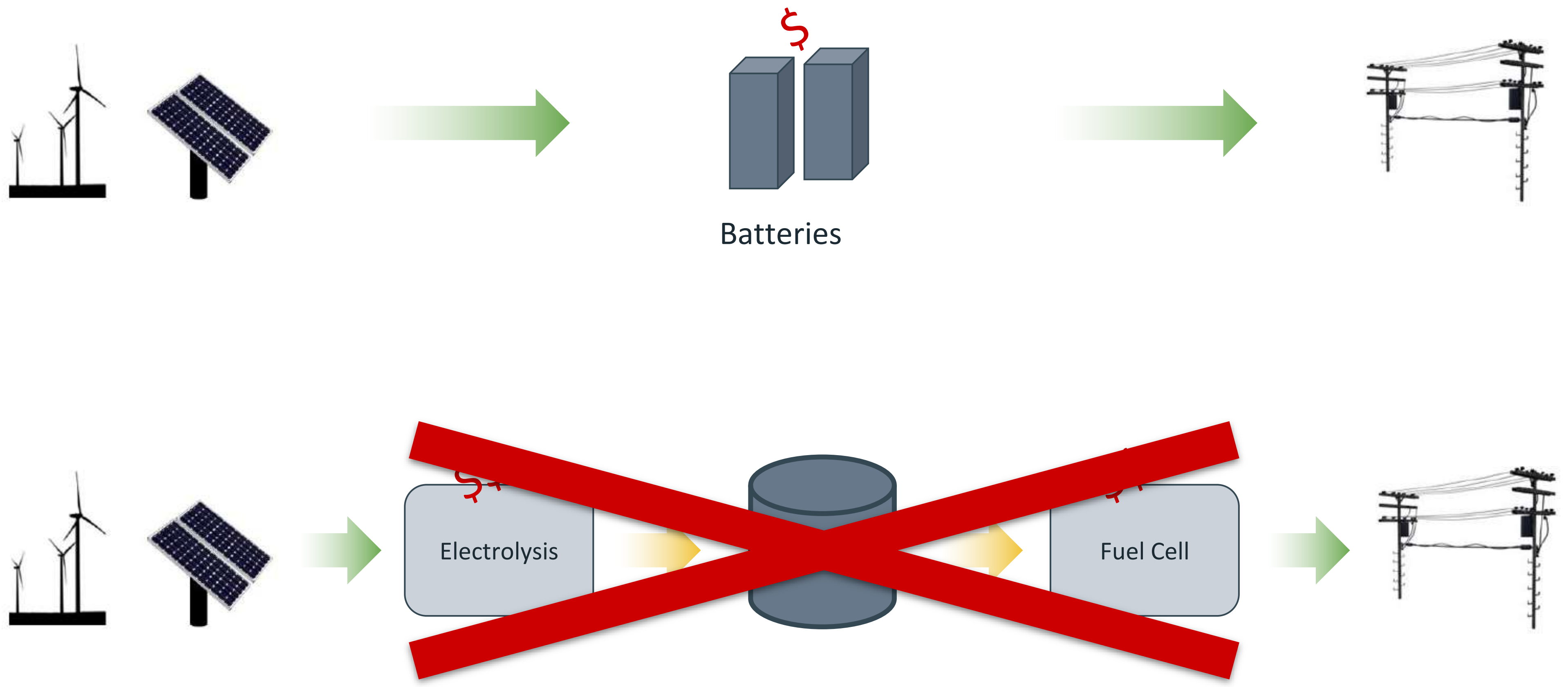


# Scenario B (low electricity costs, short-term storage)

# Scenario B (low electricity costs, short-term storage)

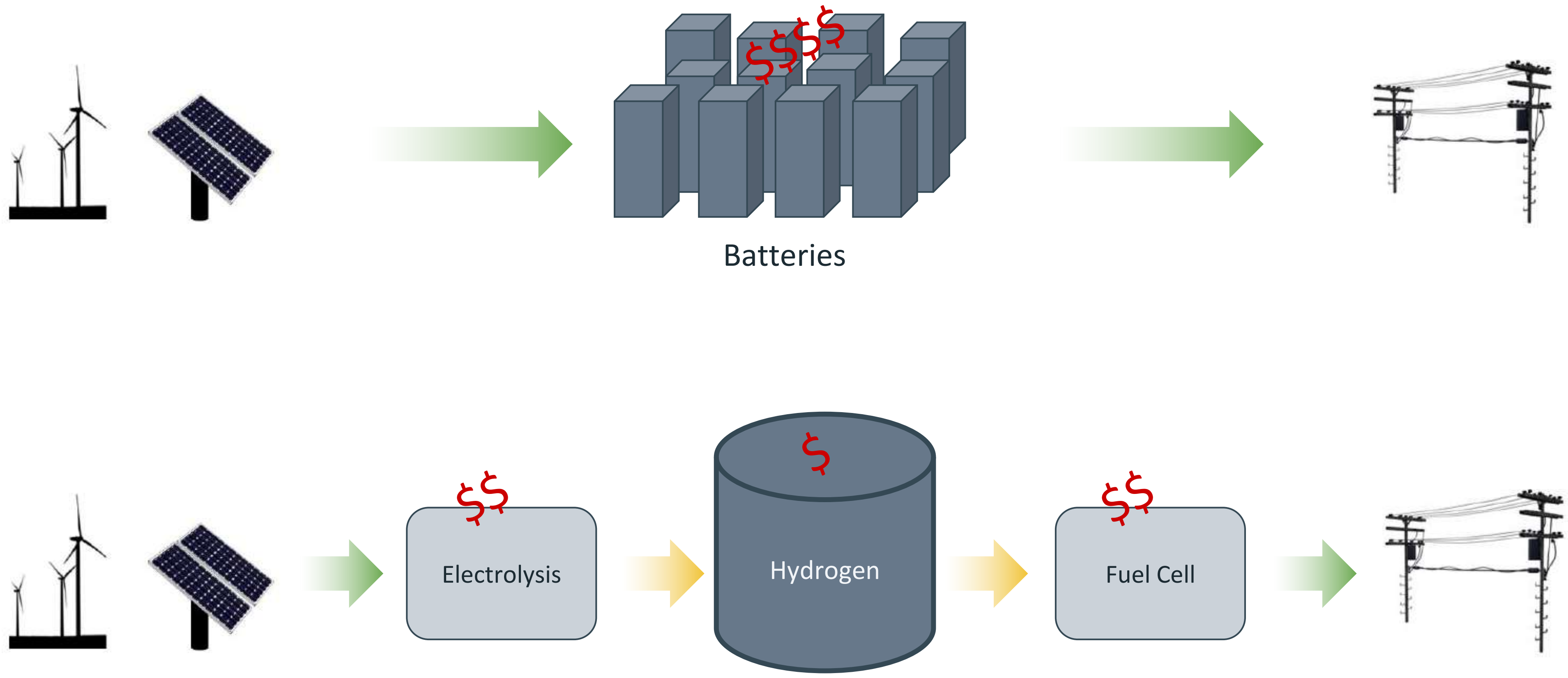


# Scenario B (low electricity costs, short-term storage)



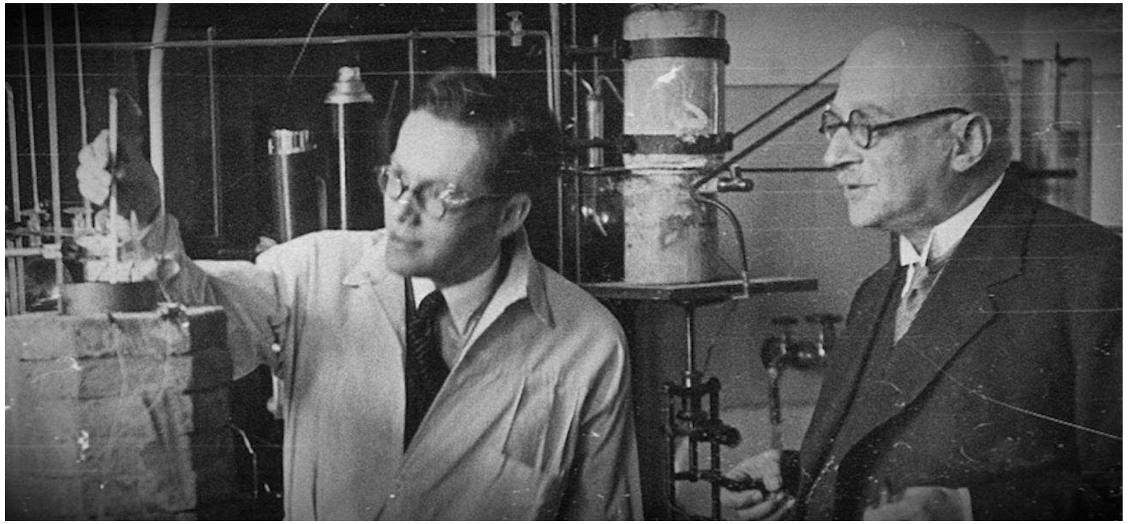
# Scenario C (low electricity costs, long-term storage)

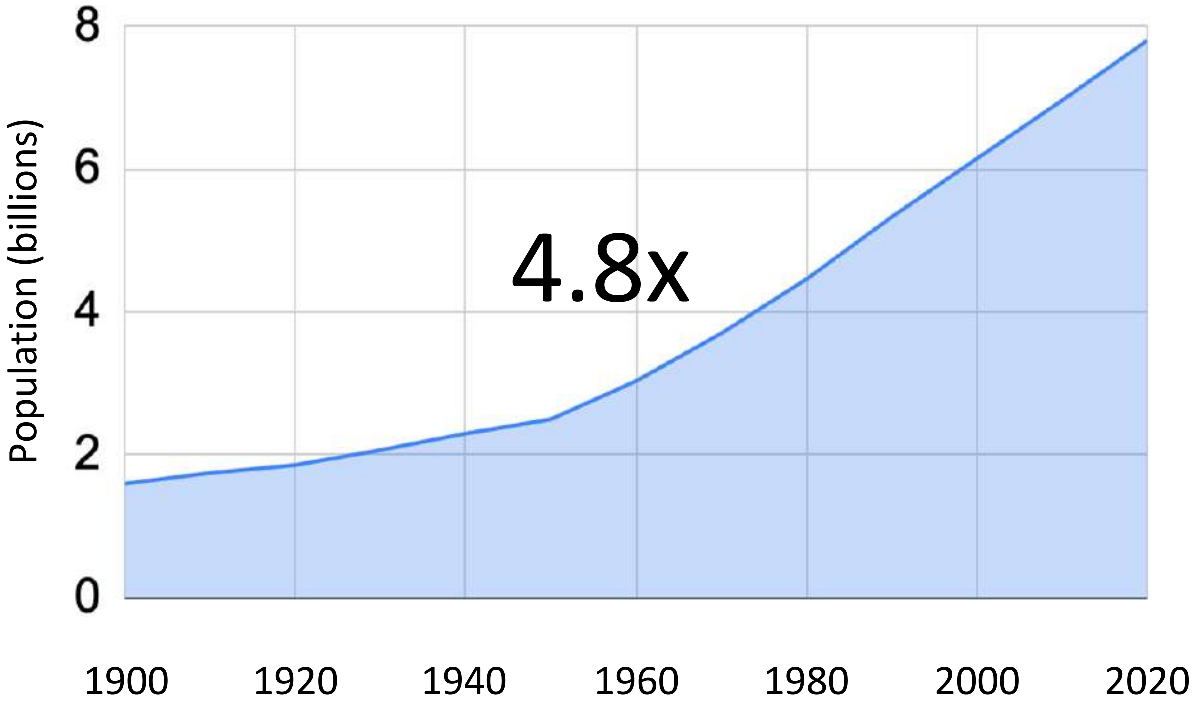
# Scenario C (low electricity costs, long-term storage)



# More areas…

1. Batteries
2. Proteins
3. Drug discovery
4. Hazardous waste cleanup
5. …

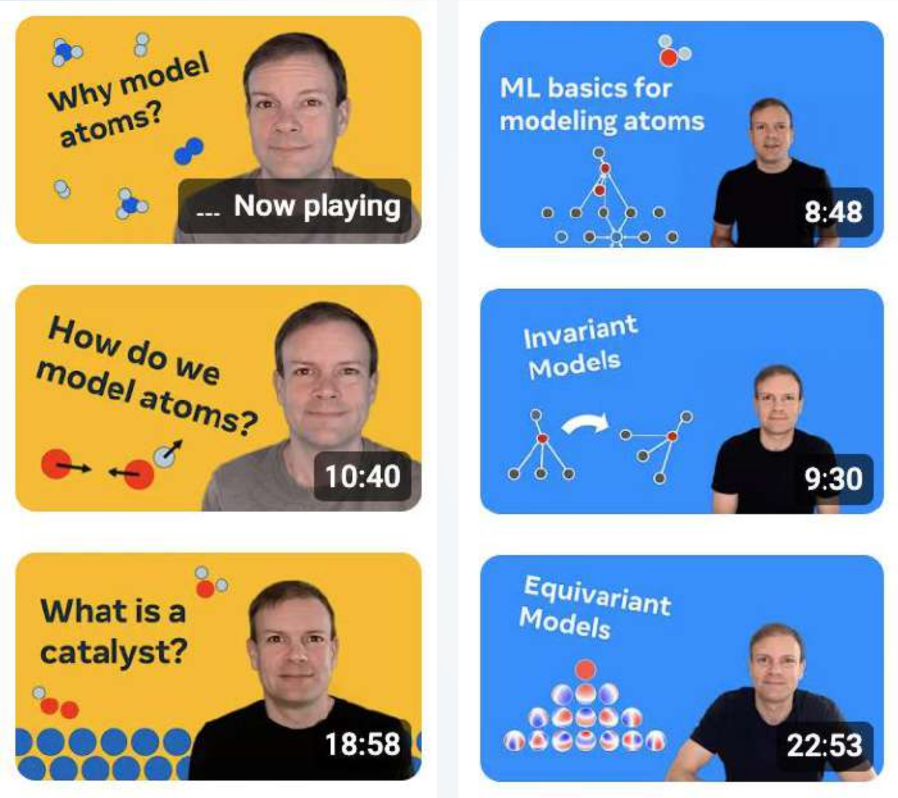





Helped keep Germany supplied with munitions during World War I.

The overuse of ammonia fertilizers has led to ocean dead zones.

# Thanks!




Open Catalyst YouTube

OpenCatalystProject.org

# Accelerating the Transition to Liquid Cooling Through Standardization

## Iceotope Technologies

Nathan Blom, Co-CEO & CCO
Neil Edmunds, VP of Product Strategy

September 23, 2024

ICEOTOPE®

PRECISION LIQUID COOLING
www.iceotope.com

# About Us

## Our Vision

To be the Global Leader in Advanced Cooling Solutions, Enabling Next-Generation Computing Infrastructure.

## Our Mission

To Innovate & Deliver Cutting-Edge Cooling Technologies that Enhance Performance, Efficiency & Reduce Environmental Impact.

## Our Company

Extensive IP Portfolio with 52 Granted Patents & 90 Pending Applications.

Recognized for Market Leadership, Built on Strong Relationships with Industry Experts, Influencers, & Key Stakeholders.

Global Presence & Team Established in Key Markets: UK (Sheffield), US (Raleigh) & Singapore.

# Our Technology


Transform the Design of Next Generation IT to **Maximize Compute performance and Efficiency.**

Maintain **Familiar Rack Based Form Factor.**

Enhance Energy, Water and Space Efficiency by Capturing **almost 100% of IT thermal load** to fluid system.

Support Flexible, Hybrid Environments with Standardized Form Factors, **Ensuring Scalability & Adaptability.**

ICEOTOPE®

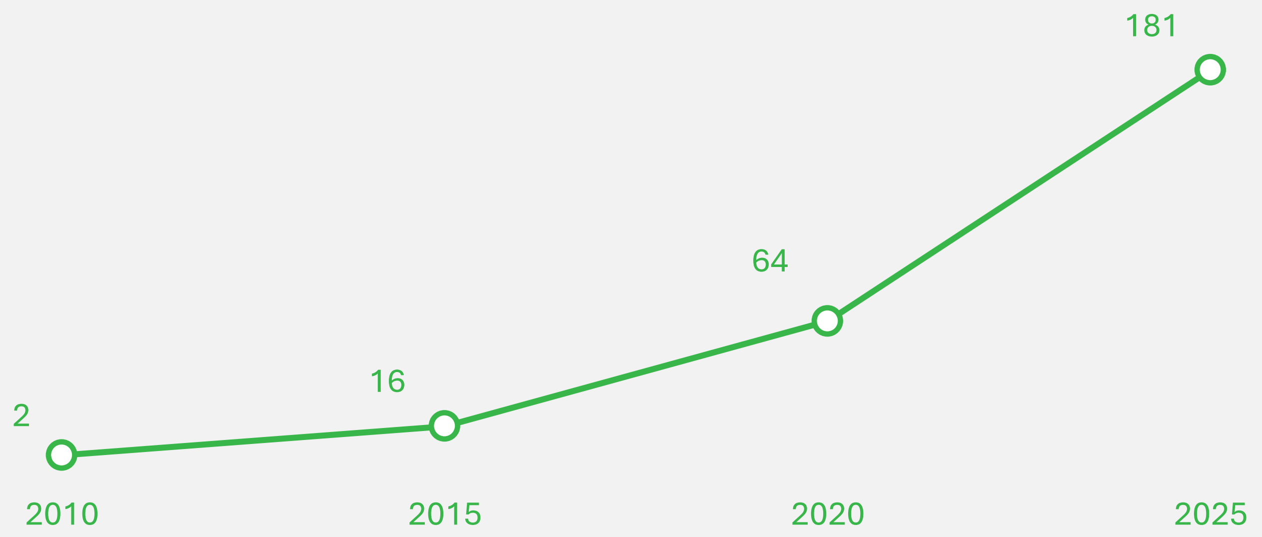
ICEOTOPE

# Evolving Challenges in IT Infrastructure

# We are in the midst of a global data explosion

Data is Growing Exponentially

Global Data Generated Annually
(In Zettabytes = 1 Trillion GB)[1]




$200 billion

Global investment in AI in 2025

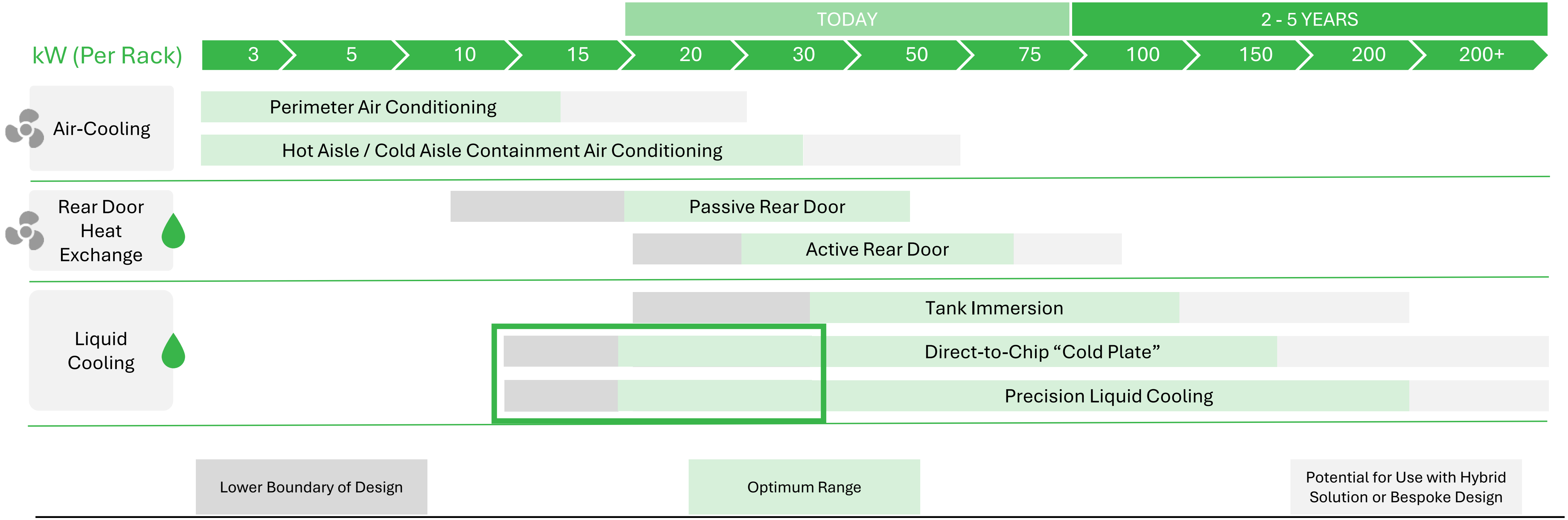
Up from $90 Billion in 2022[2]

Source:
1. Statista, Bernard Marr & Co
2. Goldman Sachs Economics Research, Aug 2023

ICEOTOPE®

# Air-Cooling Technology is in Diminishing Returns

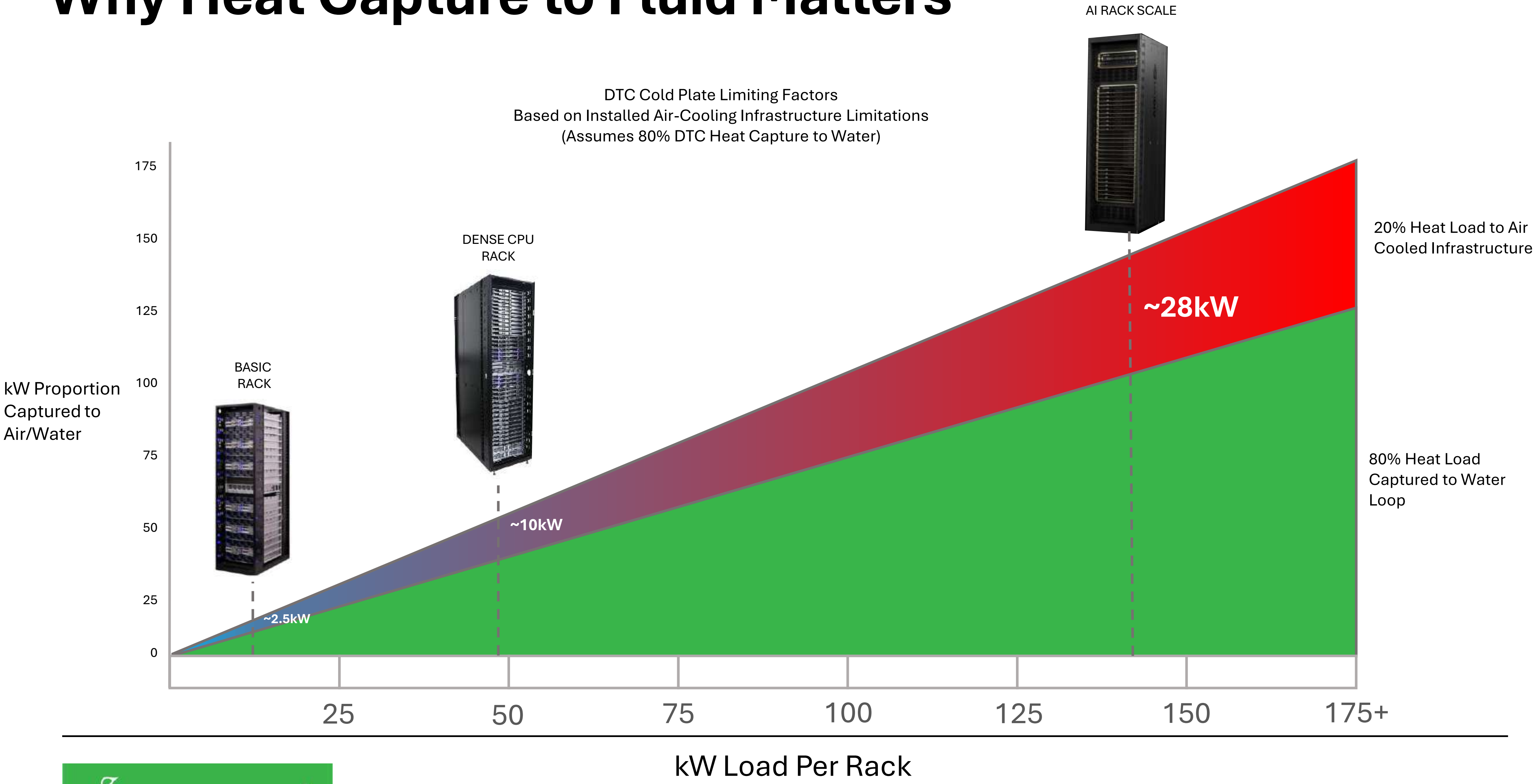
Air is Up to
**4,000x**
Less Efficient at Transferring Heat than Liquid[1]




ICEOTOPE

Source: Vertiv White Paper: Understanding Data Center Liquid Cooling Options and Infrastructure Requirements

# Why Heat Capture to Fluid Matters




ICEOTOPE®

# Encouraging Industry Alignment & Standardization

# The Future of Liquid Cooling in a Hybrid Environment

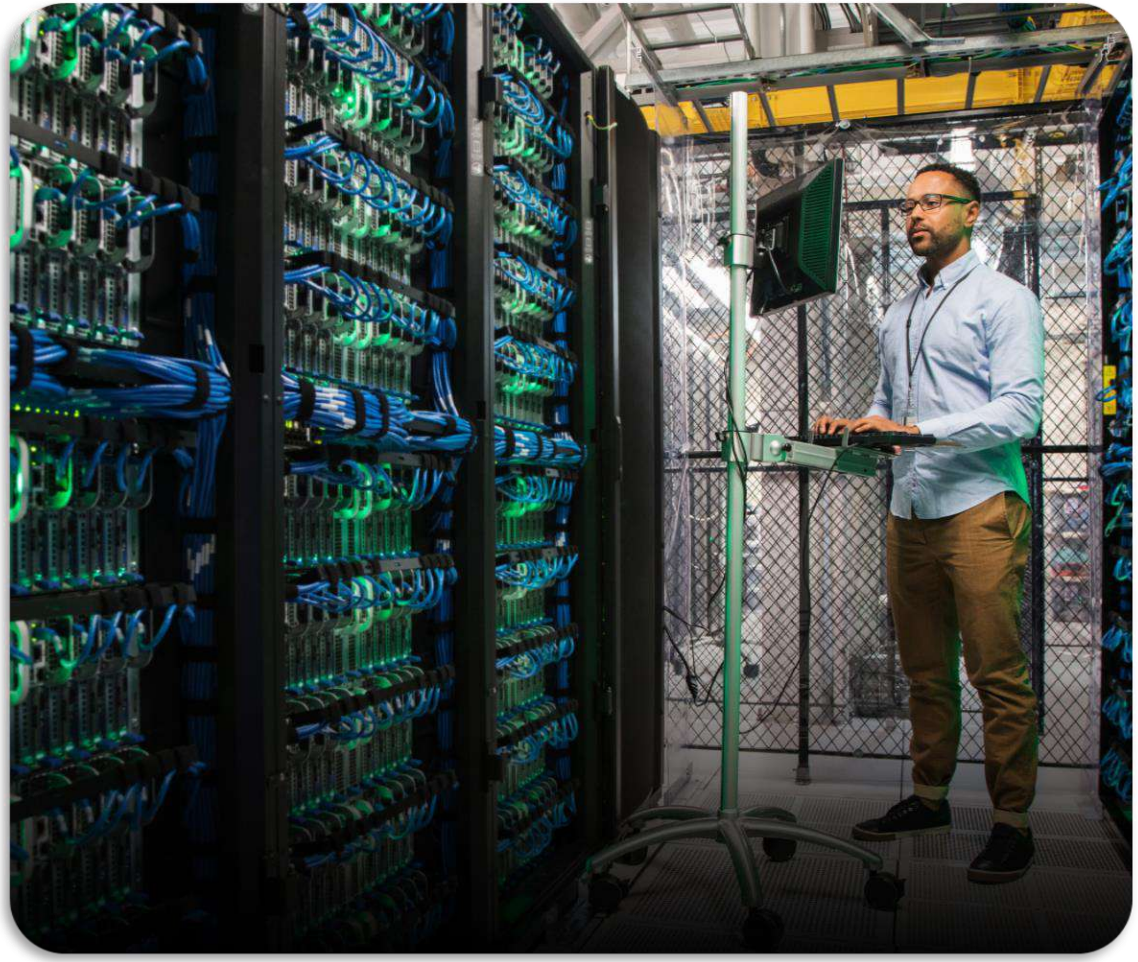
**Standardization** across Systems allowing multiple technologies to co-exist in-rack.

Leverage **Enhanced Cooling Technology** for Greater Performance and Efficiency & Maximize impact.

Maintain a **Rack-Based** Infrastructure for Seamless Integration and minimized operational disruption

Optimize **Heat Capture** for Improved Performance.

Expand Focus **Beyond CPUs & GPUs** to Enhance Cooling Efficiency Across all Components.



ICEOTOPE

# Accelerating Adoption of Liquid Cooling

Adoption of Liquid Cooling Technology is Happening Now.

↓

Universal Standards could Accelerate Availability & Diversity of Solutions.

↓

Allow a Hybrid Air-Cooled, DTC & PLC Operating Model in Rack.

↓

What Elements would be Standardized?


ICEOTOPE

# Examples of Standardization

**Sensible Starting Point is Standardization of Liquid Cooling Enabled Racks.**

- ORv3 was originally designed to support ~18-36kW of power. With AI driving increasing power requirements, a new iteration called HPR (High Power Rack) is being designed at Meta in conjunction with rack, power, and cable partners

| | ORv3 | ORv3 HPR |
|---|---|---|
| Rack Depth | 42" | 48" |
| Busbar Capacity | 18kW+ | 92kW+ |
| PSU Shelf | 18kW (6*3kW PSUs) | 33kW (6*5.5kW PSUs) |
| BBU Shelf | 18kW (6*3kW BBUs, 90sec) | 33kW (6*5.5kW BBUs, 90 sec) |
| Grounding Path | ORv3 Standard | Improved to avoid overcurrent |
| PSU/BBU Shelves/Rack | 2/Rack | 3/Rack + |
| AC WHIPs / PSU Shelf | NA: 2x 20A, 12AWG Wire, L22-20P<br>EU: 1x 32A, 4mm^2 Wire, IEC309 | NA: 2x 30A, 8AWG Wire, L22-30P<br>EU: 2x 32A, 4mm^2 Wire, IEC309 |
| Blind Mate Manifold | Compatible | Compatible w/ room for expansion |

OCP REGIONAL SUMMIT | 24-25 APRIL 2024 LISBON, PORTUGAL

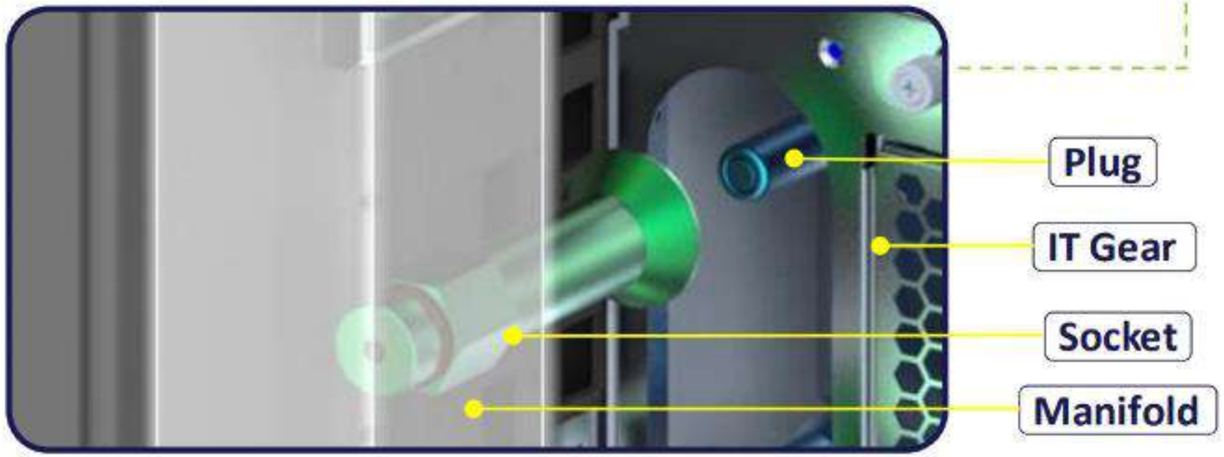
Scaling Innovation Through Collaboration

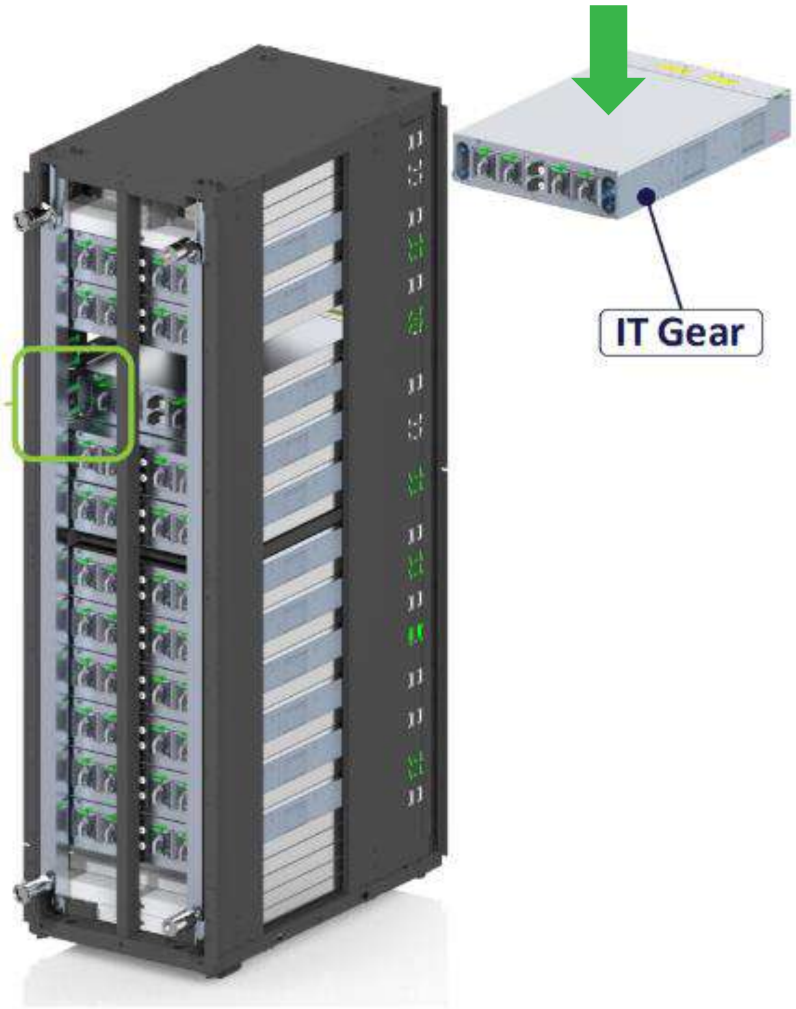
# Examples of OCP Standardization

## Orv3 Blind Mate Rack Assy

- Frame with add on liquid cooling kit with interfaces for manifolds
- Hot and cold manifolds split at each rear corner
- IT gear contain the plug valves
- Manifolds contain the socket valves
- All connections at the rear of the rack
- Valves self-align during mating between chassis and manifolds

OPEN Compute Project



# Hybrid Deployment at Row Level

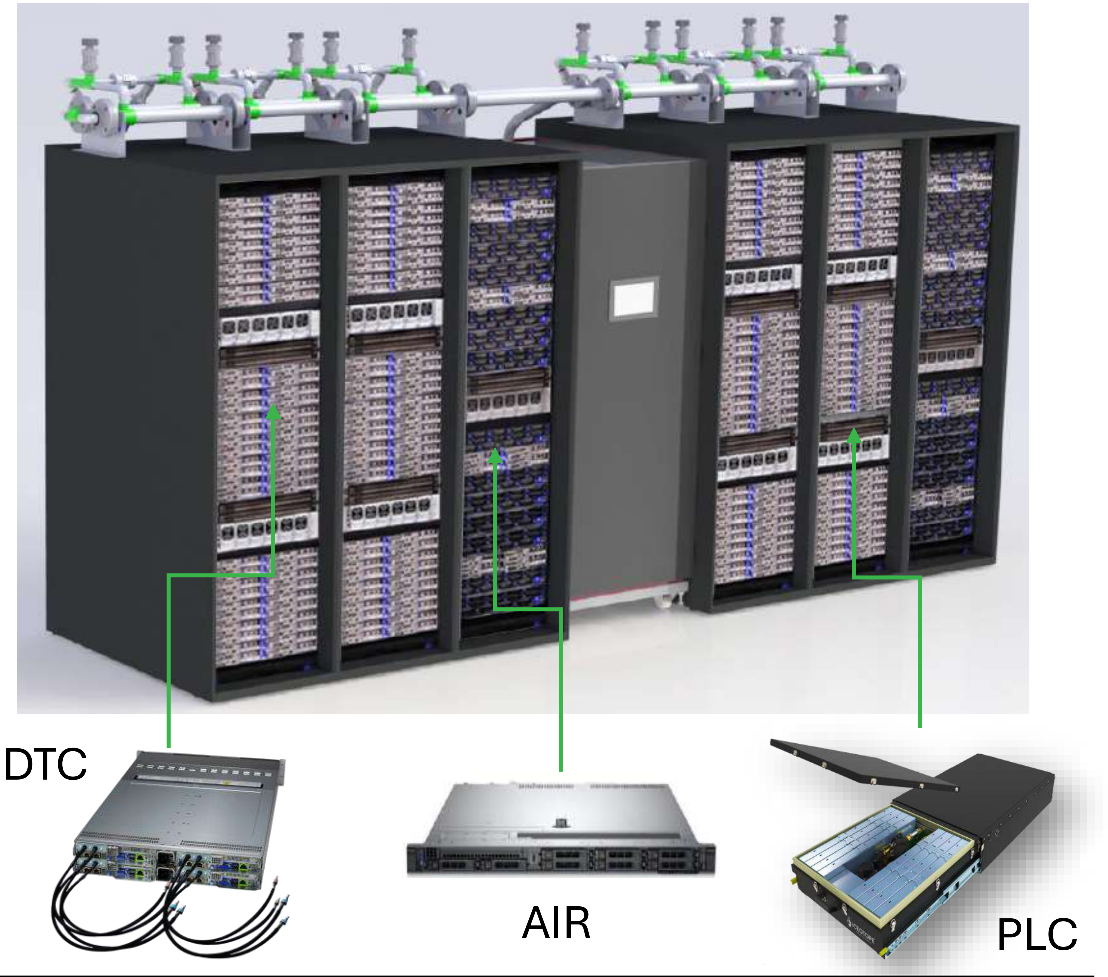
**Standardize Rack & Row Configurations** with Hybrid Air, DTC & PLC Technologies working in harmony.

Aim to **Increase Liquid Cooled %** Over Time.

Increase **Simplicity & Flexibility** for Data Center Infrastructure.

Consider longer term power and cooling requirements and provision **Spare Capacity in CDUs and Fluid Network.**

Aim To **Replicate Separated Model of IT & Infrastructure** (Treat Rack as a 'Black Box') as Air-Cooled Approach Today.




ICEOTOPE

# Collaboration with Global Suppliers & Partners

## Silicon

- NVIDIA
- intel
- AMD

## IT Infrastructure

- GIGABYTE
- Hewlett Packard Enterprise
- SUPERMICRO
- DELL
- Inventec
- MiTAC
- Quanta
- Lenovo
- wistron
- FOXCONN

## Data Center Infrastructure

- CUNDALL
- Schneider Electric
- motivair COOLING SOLUTIONS
- nVent
- VERTIV
- EIT efficiencyit

## Integration & Support

- AVNET Reach Further
- SANMINA
- ARROW ELECTRONICS, INC.
- AVASO
- TD SYNNEX

## Fluid Providers

- PETRONAS
- Shell
- EF
- ENGINEERED FLUIDS
- Valvoline
- Castrol ON

ICEOTOPE

# Iceotope: Driving Innovation with Precision Liquid Cooling

# Liquid Cooling Architectures

Rack Based Form Factor → ← Maximized Heat Load Capture

**Liquid Cooling**

| Direct-to-Chip (Cold Plate) | **Precision Liquid** | Liquid Immersion |
|---|---|---|
| Single Phase | Single Phase | Single Phase |
| Two Phase | | Two Phase |

ICEOTOPE®

# The Value of Precision Liquid Cooling

## Sustainable

Nearly **100%** Heat Capture in
a Single Technology

Reduce Electricity use up to **40%**

Reduce Water Consumption up to **90%**

**Accelerate Sustainability Initiatives**

## Scalable

Highly Configurable for Rapid Deployment
**One Server to Many Racks**
Any Location From the
Data Center to the Edge

**Easily Scale Distributed Workloads**

## Serviceable

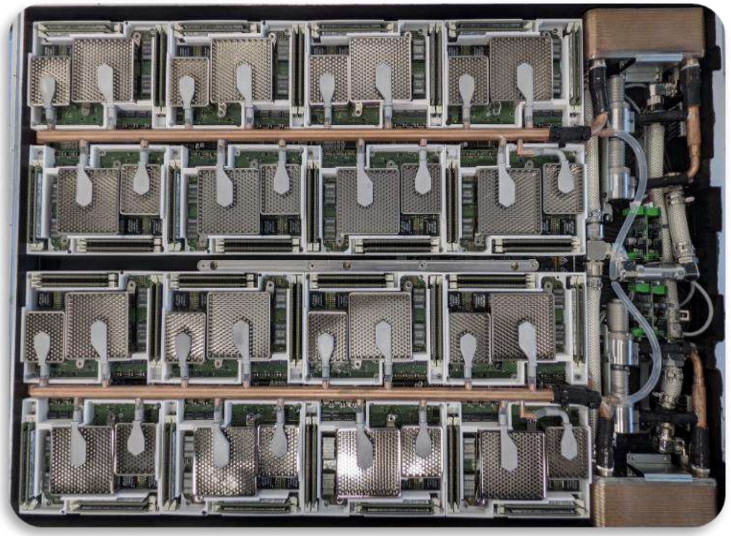
**Significantly Lower** Failure Rate
Extend Server Lifecycle
Field Replaceable Systems
to Simplify Service Calls

**Significantly Reduce Maintenance Costs**

# Flexibility Redefined

Fit to Existing Racks

Enhanced Power Density & Efficiency



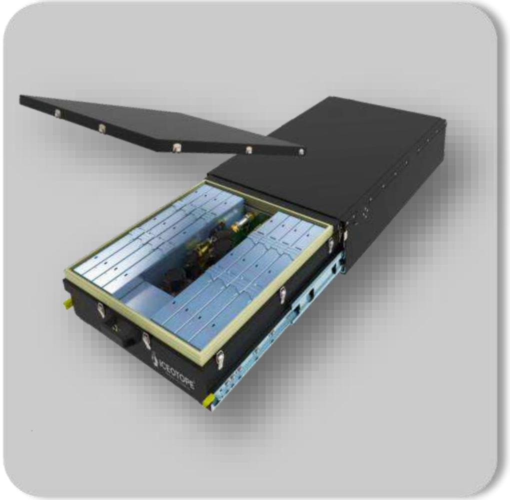
Redefine Hardware Design

Single-Phase Immersion Cooling Study of a High-Density Storage System | Iceotope

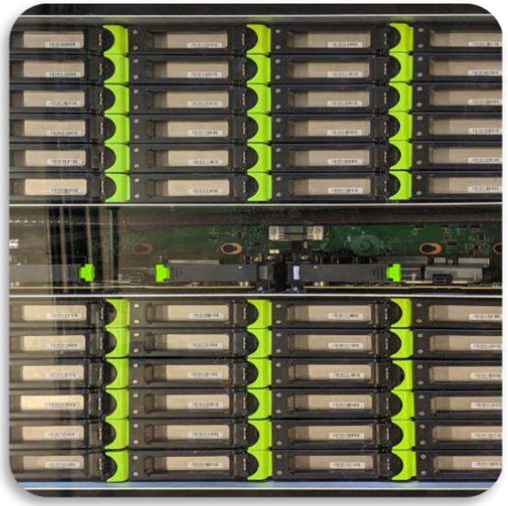
# Versatility Across the Whole Stack


AI GPU

Blade Server



PSU



Storage

Single-Phase Immersion Cooling Study of a High-Density Storage System | Iceotope

# Compliance & Quality Standards


Data Sheets
Operator Manuals
Installation Support

## Best Practices from Industry Leaders

OPEN Compute Project
ASHRAE
uptime INSTITUTE

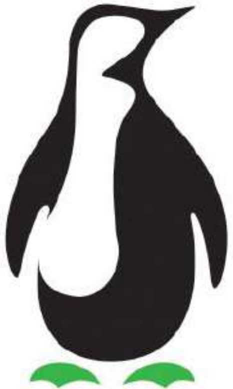
## Certification & Regulatory Compliance

IEC CE CB
UL ROHS WEEE compliant

ICEOTOPE

# Iceotope Partnership:

# The Engagement Model for Precision Liquid Cooling



# Your Control, Our Expertise

- **You Own the Product Specification**: Complete Control Over Product Design & Customization.
- **Minimize Disruption**: Maximize Impact with Minimal Change to Operating Model.
- **Same Manufacturing & Integration**: Our Technology Fits into Your Existing Processes with Minimal Disruption.

Commercial & Technical Scoping

Deployment & Operations Analysis


Supply Chain & Partner Assessment

Collaborative Solution Development

## Moving Forward: The Next Steps

# Shape the Future of Data Center Cooling

- **Be First to Act**: Request your teams to explore our proposals and collaborate with Iceotope and your supply chain.
- **Accelerate Your Transformation**: Cut operational costs & elevate your environmental leadership.
- **Gradually Transition** from air-cooled systems to liquid cooling, whilst minimizing disruption to your existing operations.
- **Unlock Competitive Advantage**: Lead your market with enhanced infrastructure that's ready to handle tomorrow's AI & intense workloads.

ICEOTOPE®

# Questions & Feedback

# Thank you

Nathan Blom

nathan.blom@iceotope.com

Neil Edmunds

neil.edmunds@iceotope.com

www.Iceotope.com


ICEOTOPE®

# Engineered for Serviceability

ICEOTOPE®

# Reference sites

## STT Singapore

- 8 KUL 2 emulators
- Spring/summer time frame
- Average of **19.13kW** of chassis input power
- Installation was connected to an existing FWS via a CDU

pPUE
**1.05**

Total pump power draw (W)
**423.64**

Total node power draw (W)
**16,761.30**

Total input power draw (W)
**19,129.94**

Total PDU power draw (W)
**19,504.98**

## Hyperscaler UK

- Fall time frame
- 100kW installation – connected to a CDU, FWS & dry cooler

Power to rack PSUs
**96kW**

Total power (racks & cooling)
**99.4kW**

99.4/96
**1.036 pPUE**

POC is operating at around
**95% capacity**

TCS inlet water temperature to racks **39°C**

Outlet temperatures
**44-45°C**

ICEOTOPE

# Break

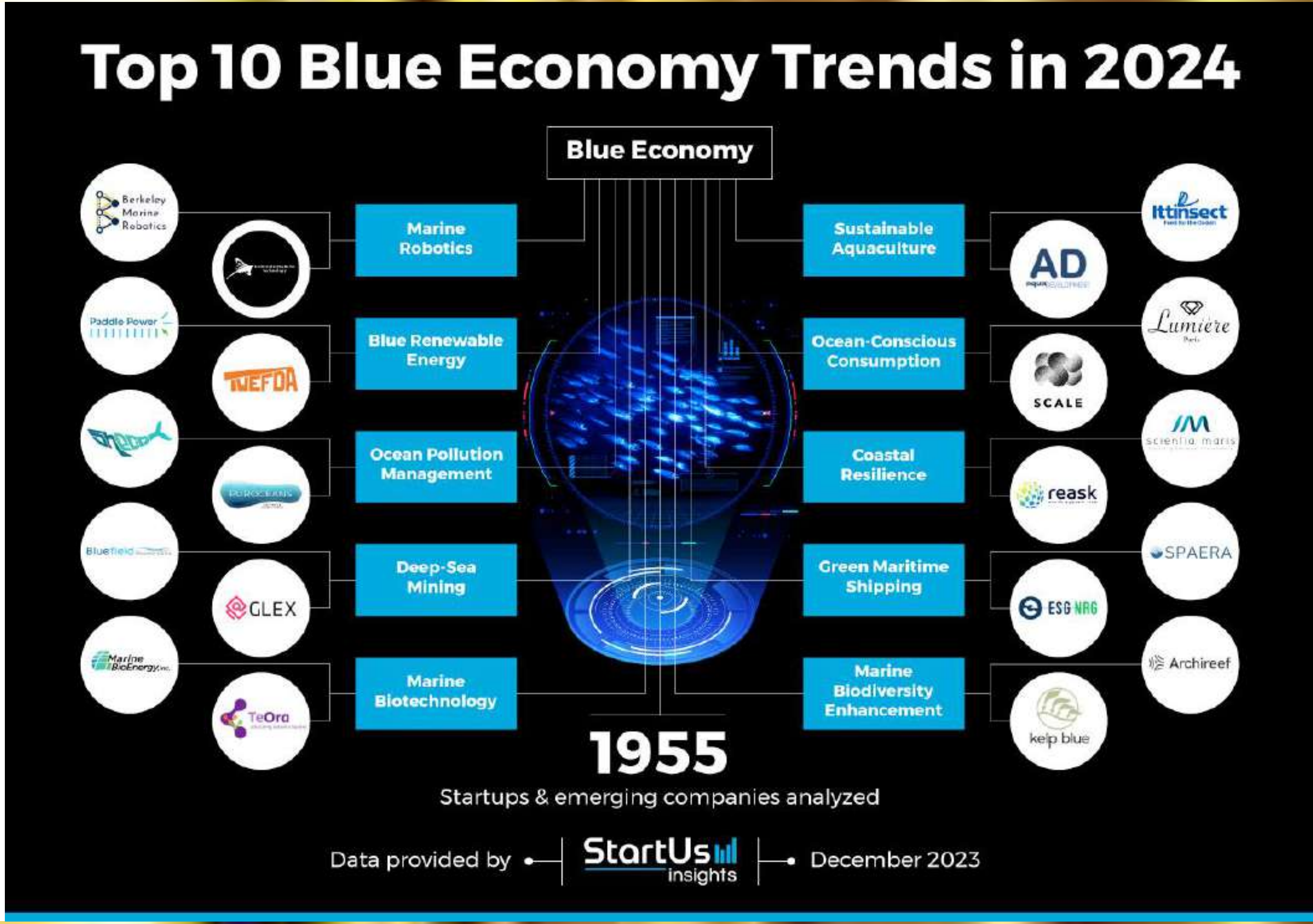
# Rosalind Rickaby

# The Awesome Ocean

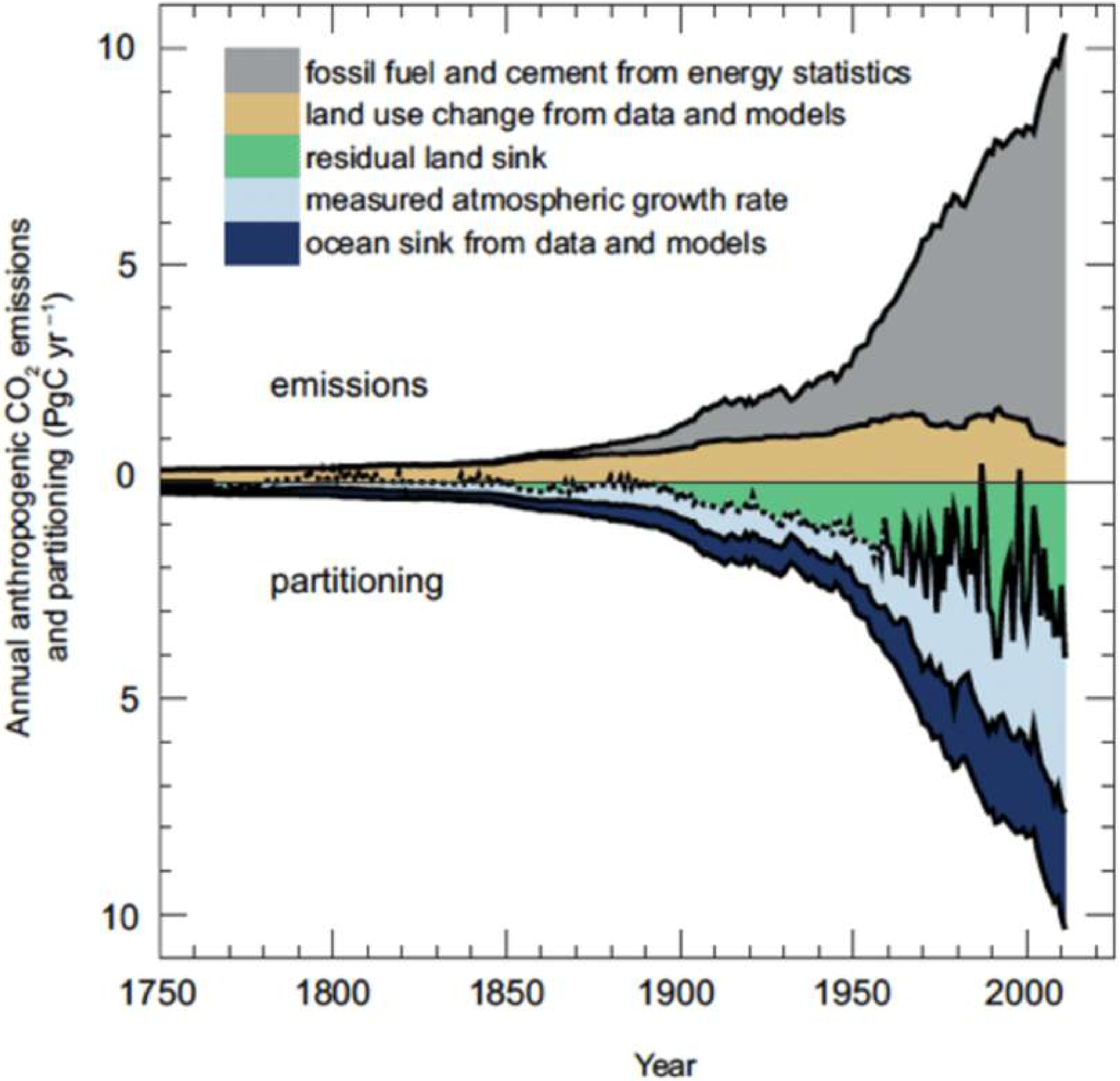
Ros Rickaby (rosr@earth.ox.ac.uk)
Department of Earth Sciences,
University of Oxford

# The Awesome Ocean- liquid gold

- The worldwide ocean economy is valued at around **$1.5 trillion per year**, equivalent to the seventh largest economy in the world.
- The worldwide ocean economy is set to double by 2030 to $3 trillion.



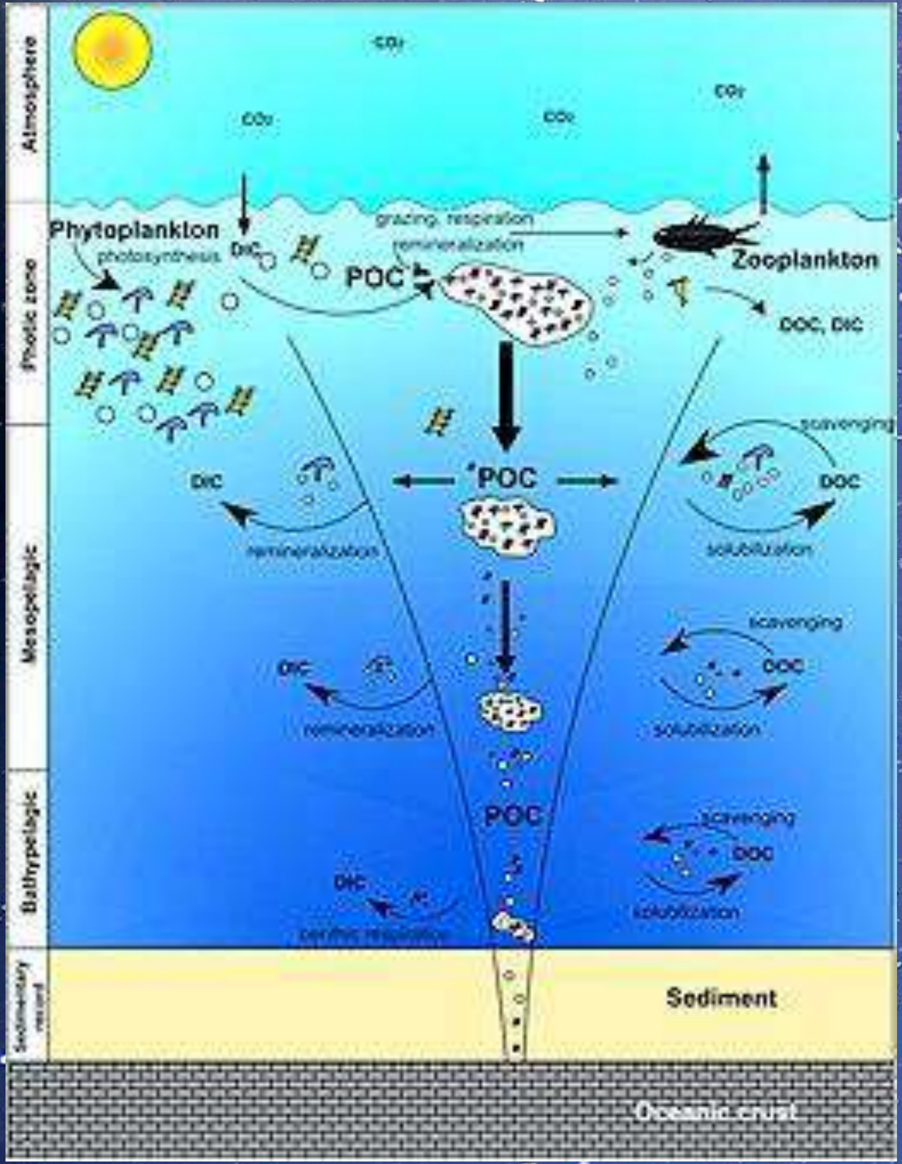
# The Oceans- Currently a huge carbon sponge

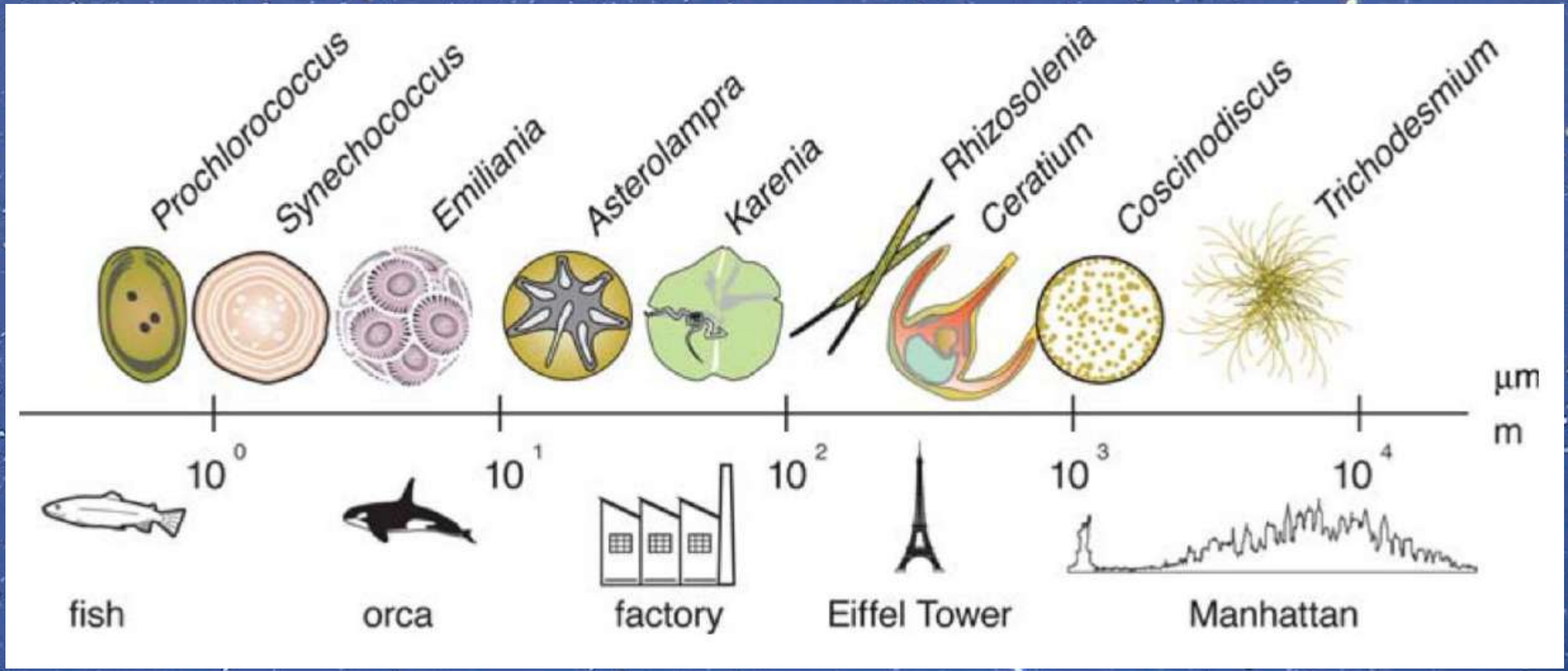



- The oceans take up emissions at a rate of about 2 GtC/yr so have absorbed 500 Gt from a total 1300 Gt emissions…**currently**
- 20kyrs ago, when mammoths roamed the planet the oceans stored an additional 900 GtC
- **All for free (in the context of C markets)**

# The Power of the Plankton

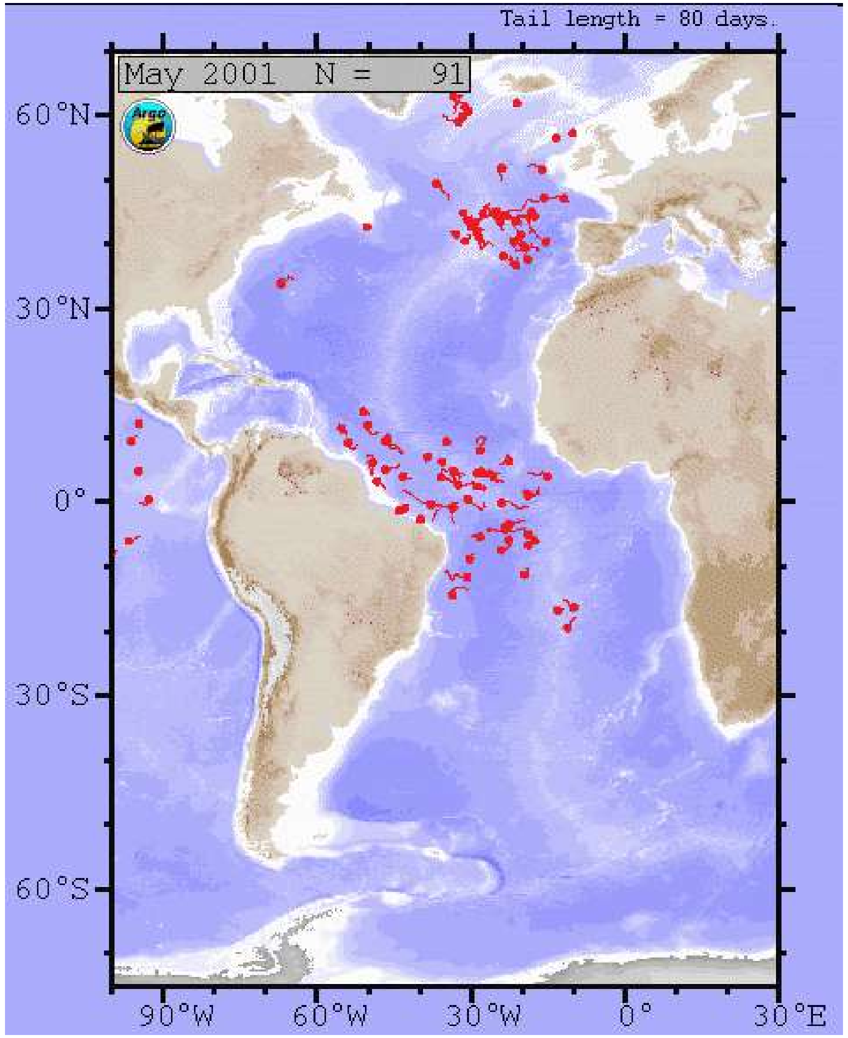
- Base of ecosystem productivity and 50-80% of global biodiversity
- Plankton are sentinels of change
- 5-12 PgC/yr

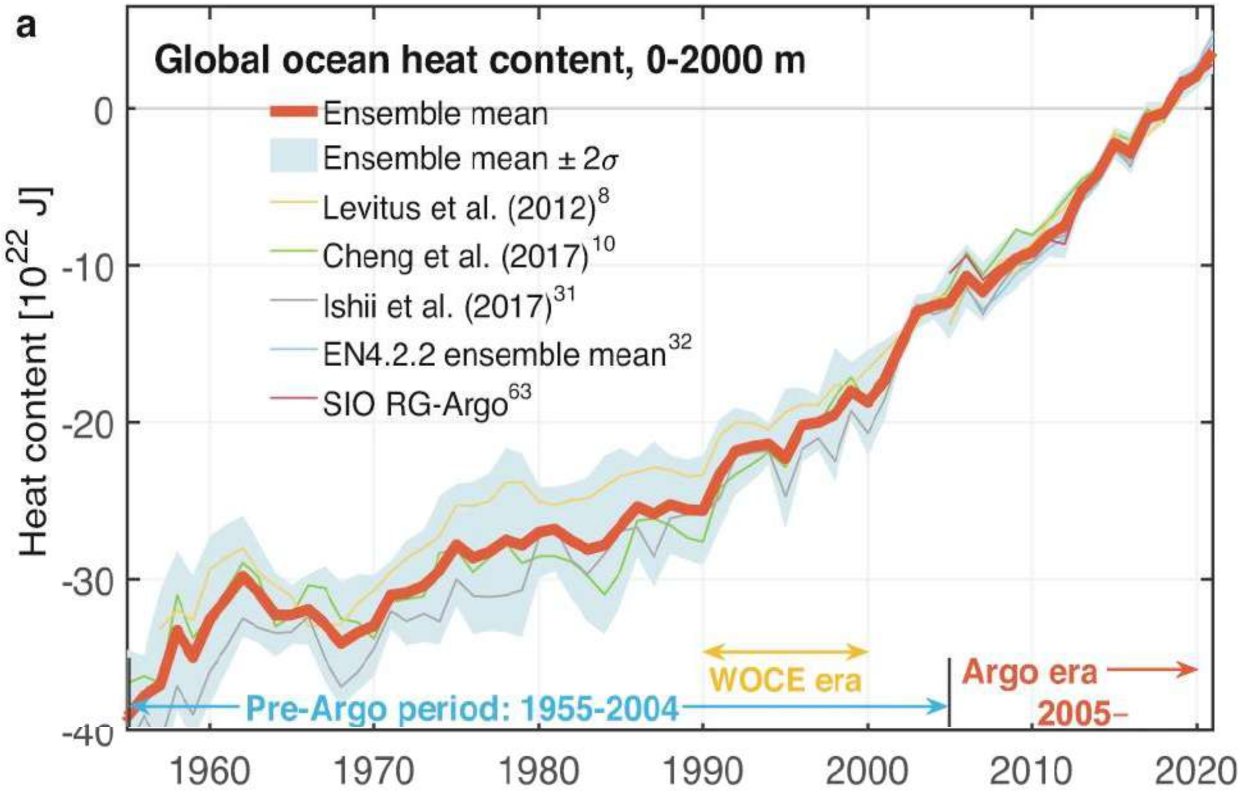


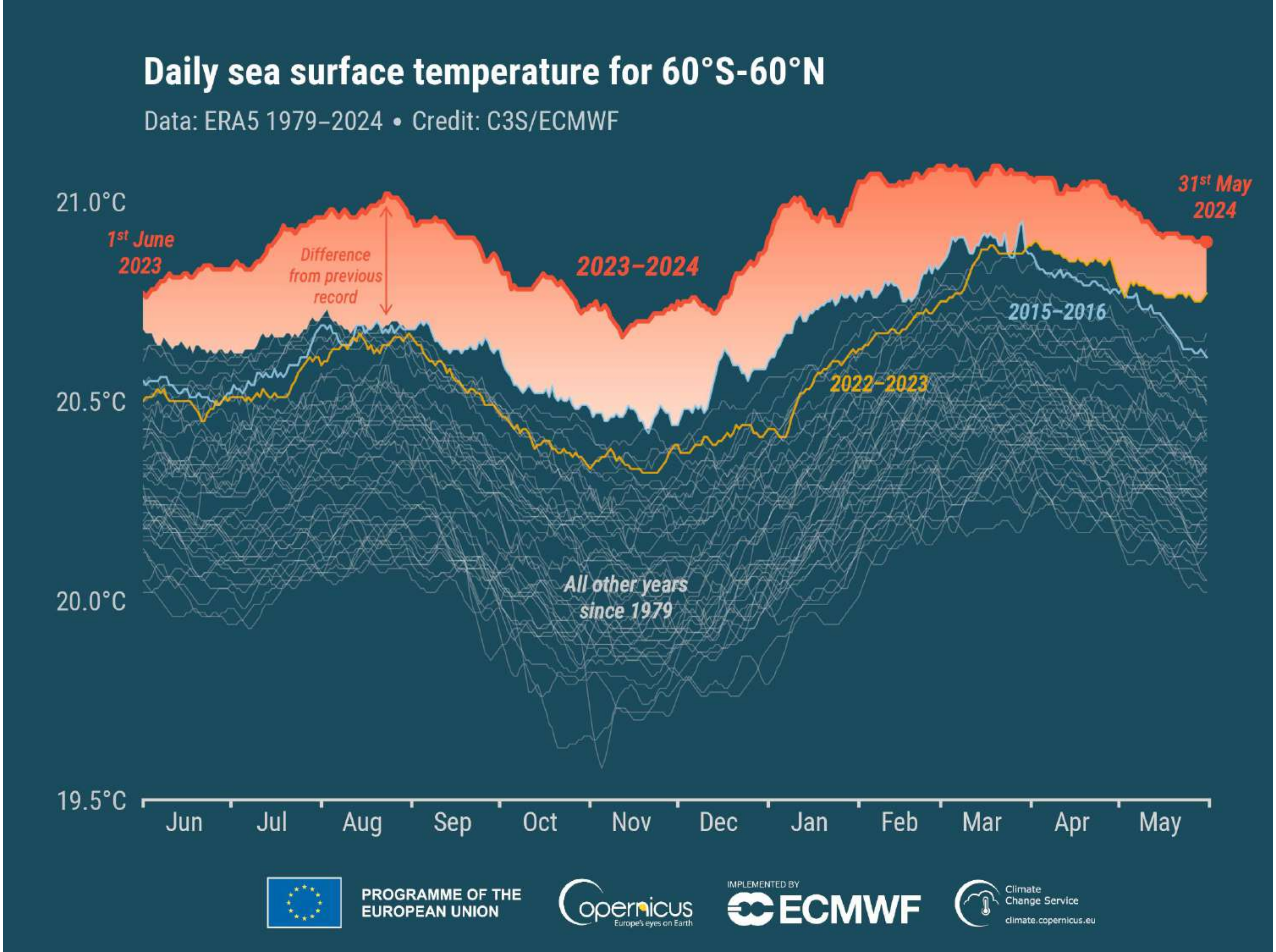

Finkel, Z.V., Beardall, J., Flynn, K.J., Quigg, A., Rees, T.A.V. and Raven, J.A., 2010. Phytoplankton in a changing world: cell size and elemental stoichiometry. *Journal of plankton research*, *32*(1), pp.119-137.

# The Oceans- a huge sponge of heat ~ 90% of our global warming



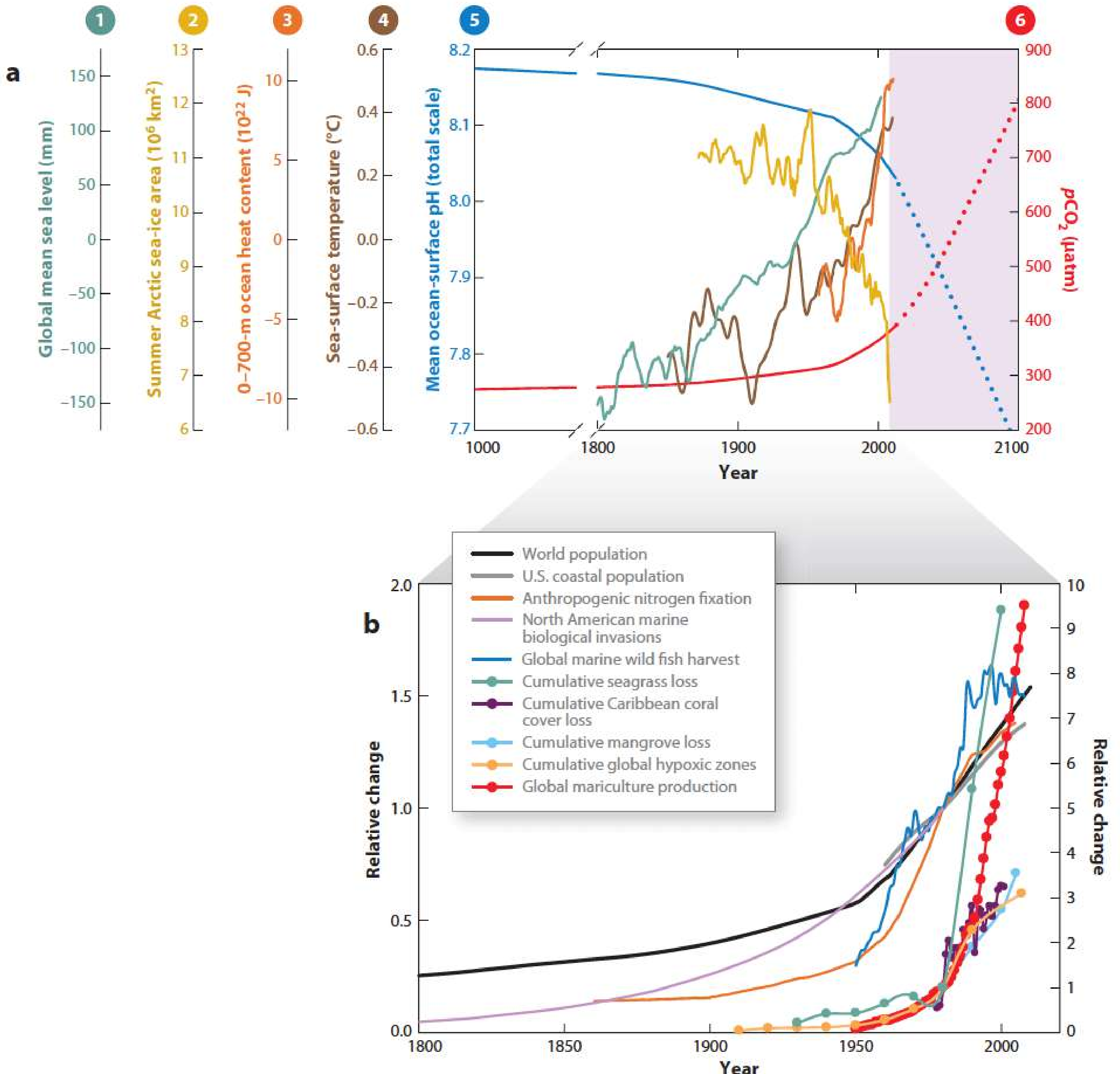



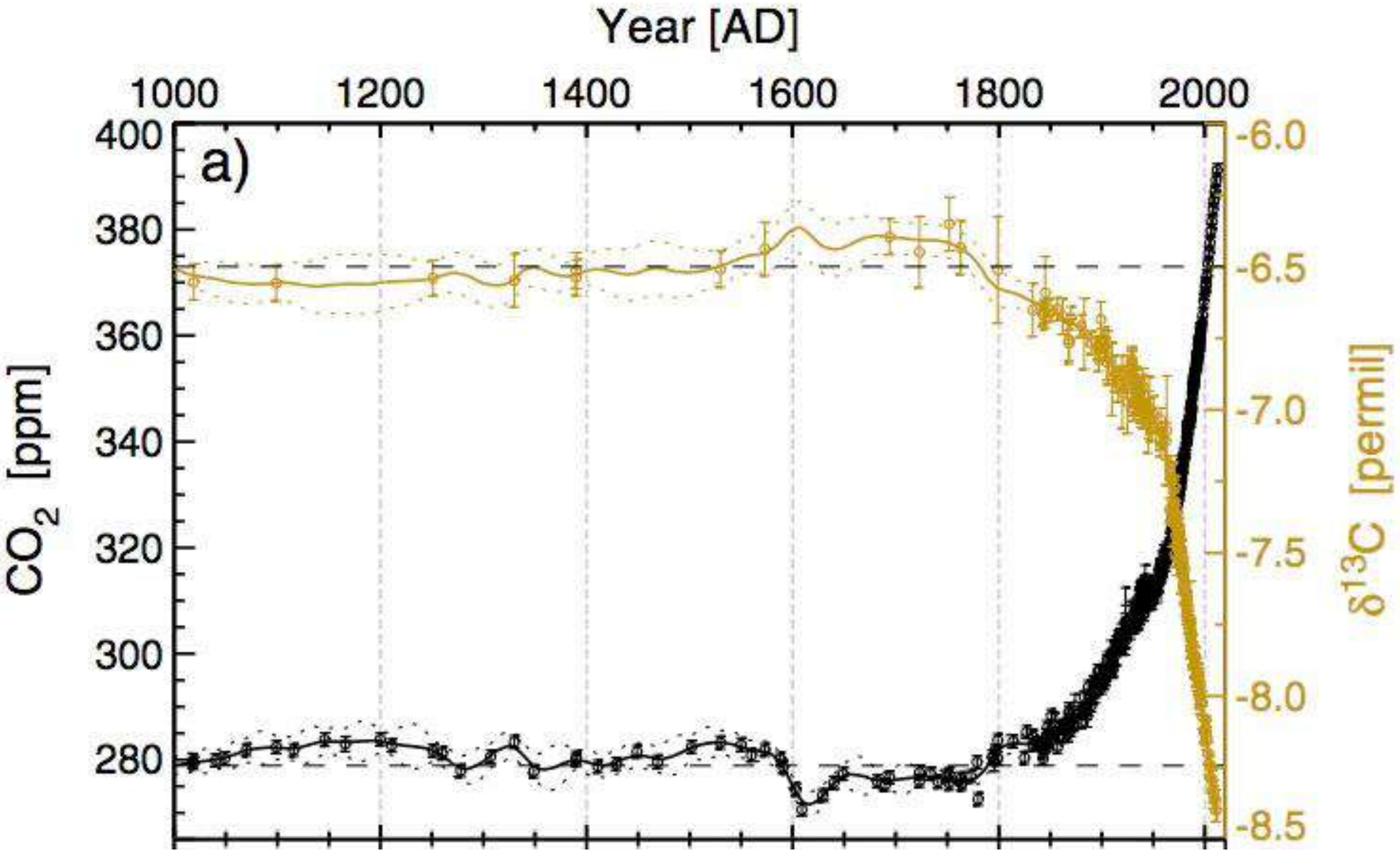

Argo Floats


Daily sea surface temperature for 60°S-60°N
Data: ERA5 1979–2024 • Credit: C3S/ECMWF
21.0°C
20.5°C
20.0°C
19.5°C
1st June 2023
31st May 2024
Difference from previous record
2023–2024
2015–2016
2022–2023
All other years since 1979
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
PROGRAMME OF THE EUROPEAN UNION
Copernicus
Europe's eyes on Earth
IMPLEMENTED BY
ECMWF
Climate Change Service
climate.copernicus.eu

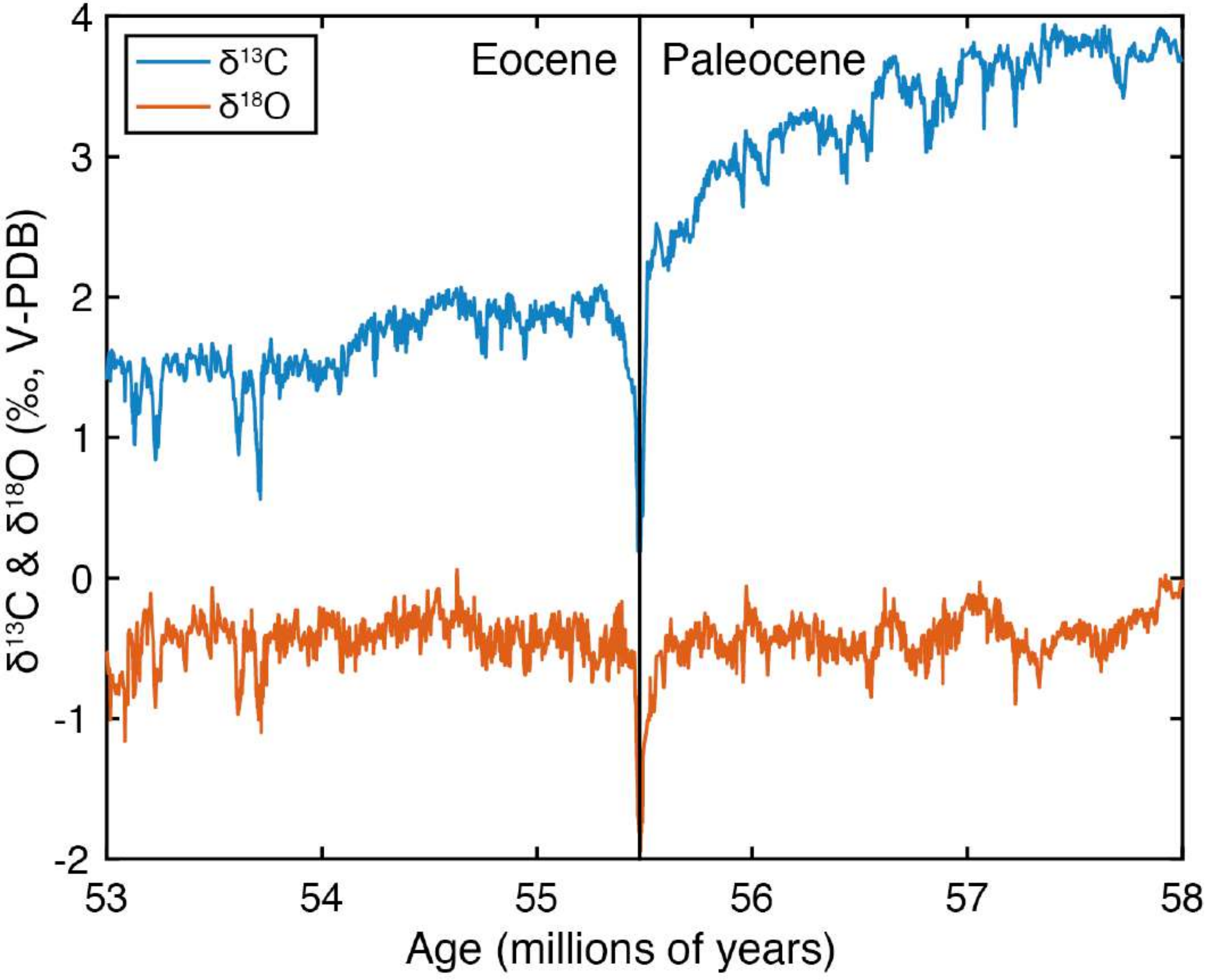
# The altered Marine Environment

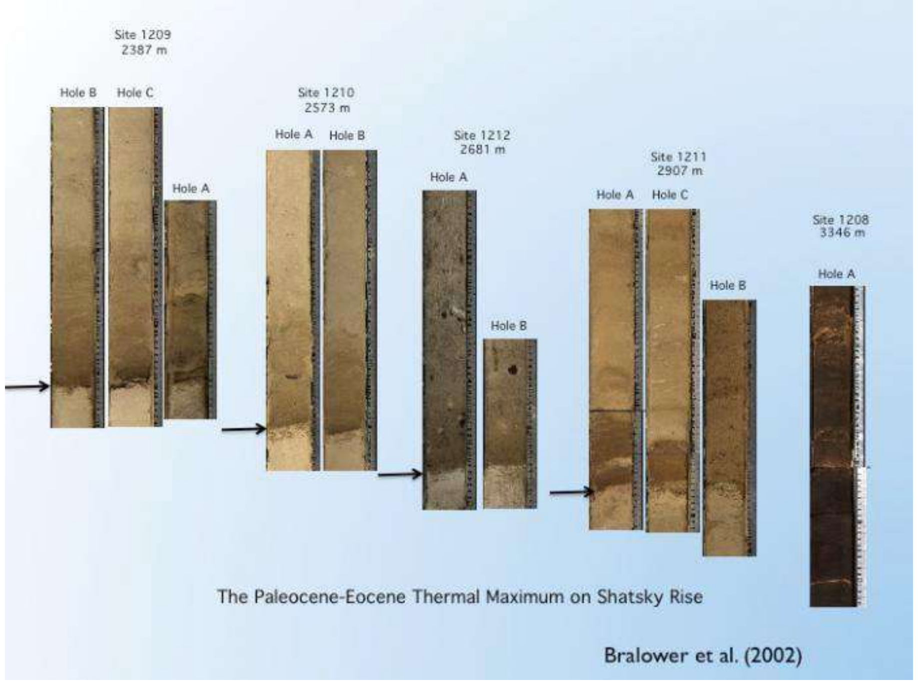
- Elevated CO2 (fertilization)
- pH- acidification
- Nutrients-stratification
- Oxygen-deoxygenation
- Temperature (P:R) (bleaching)
- Pollutants (including N2, plastics)
- Seasonal Change (mistimings: light and temperature)



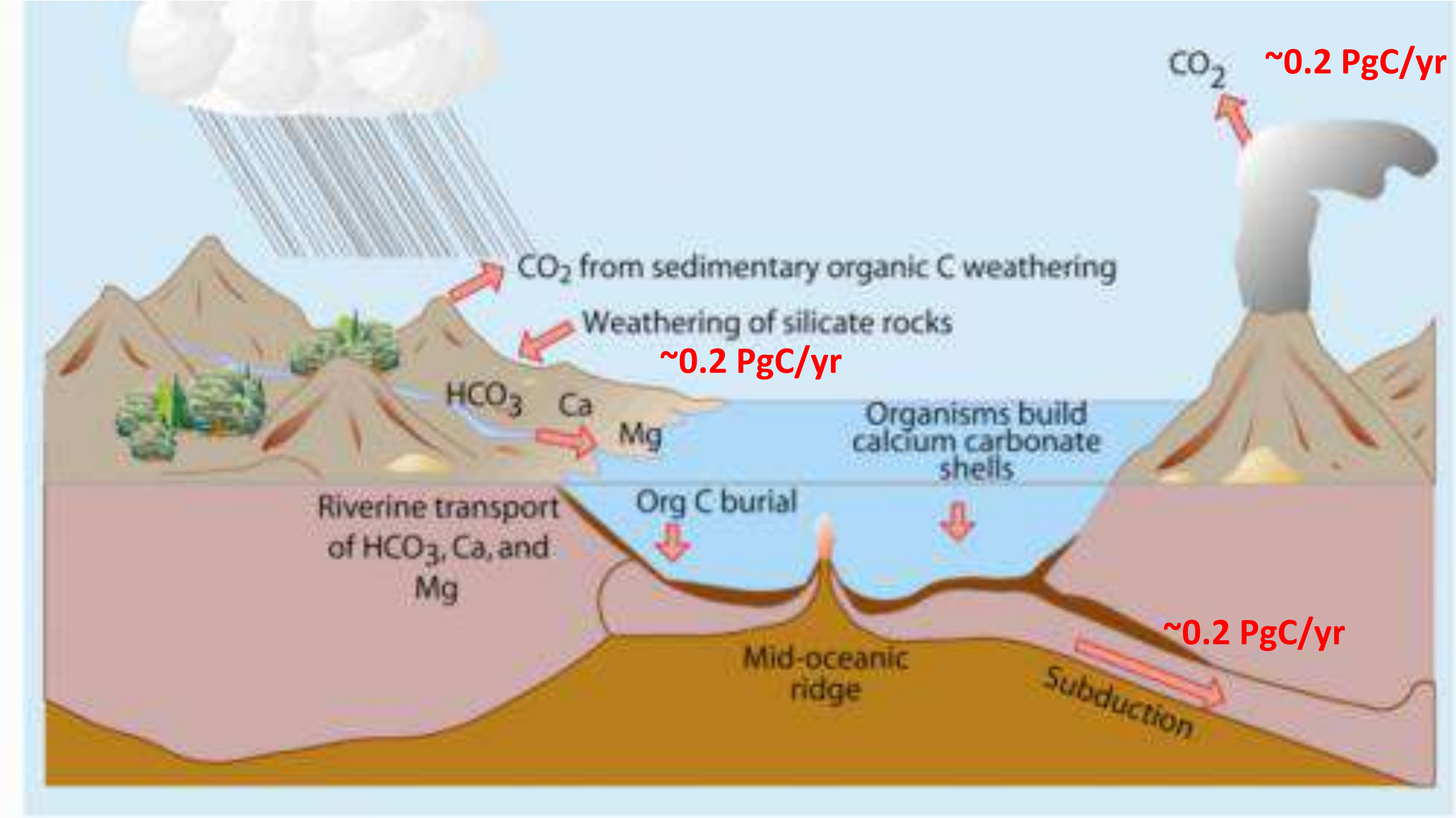

Year [AD]
1000
1200
1400
1600
1800
2000
400
380
360
340
320
300
280
a)
$CO_2$ [ppm]
-6.0
-6.5
-7.0
-7.5
-8.0
-8.5
$\delta^{13}C$ [permil]

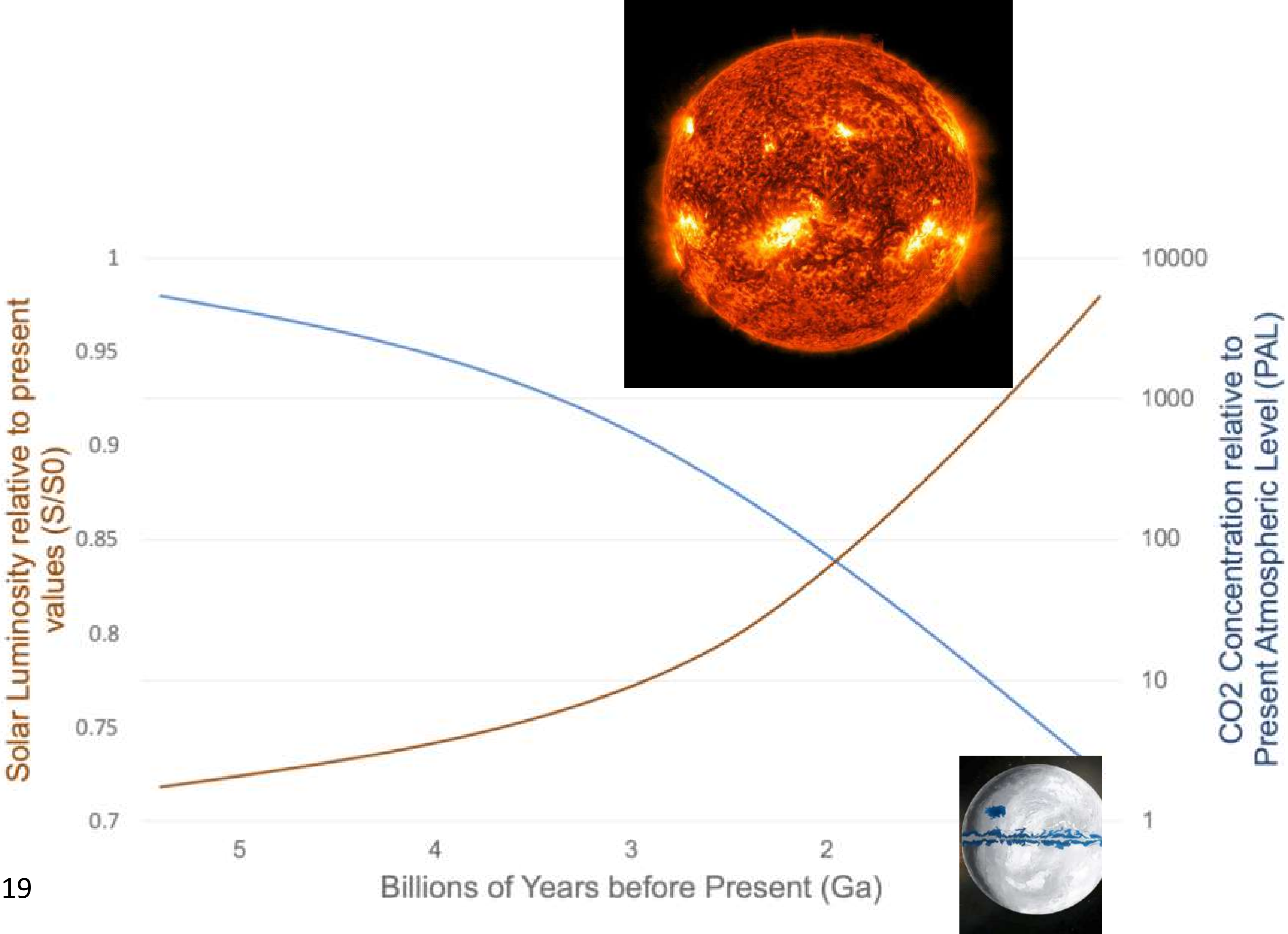
# PETM: 55800000yrs ago



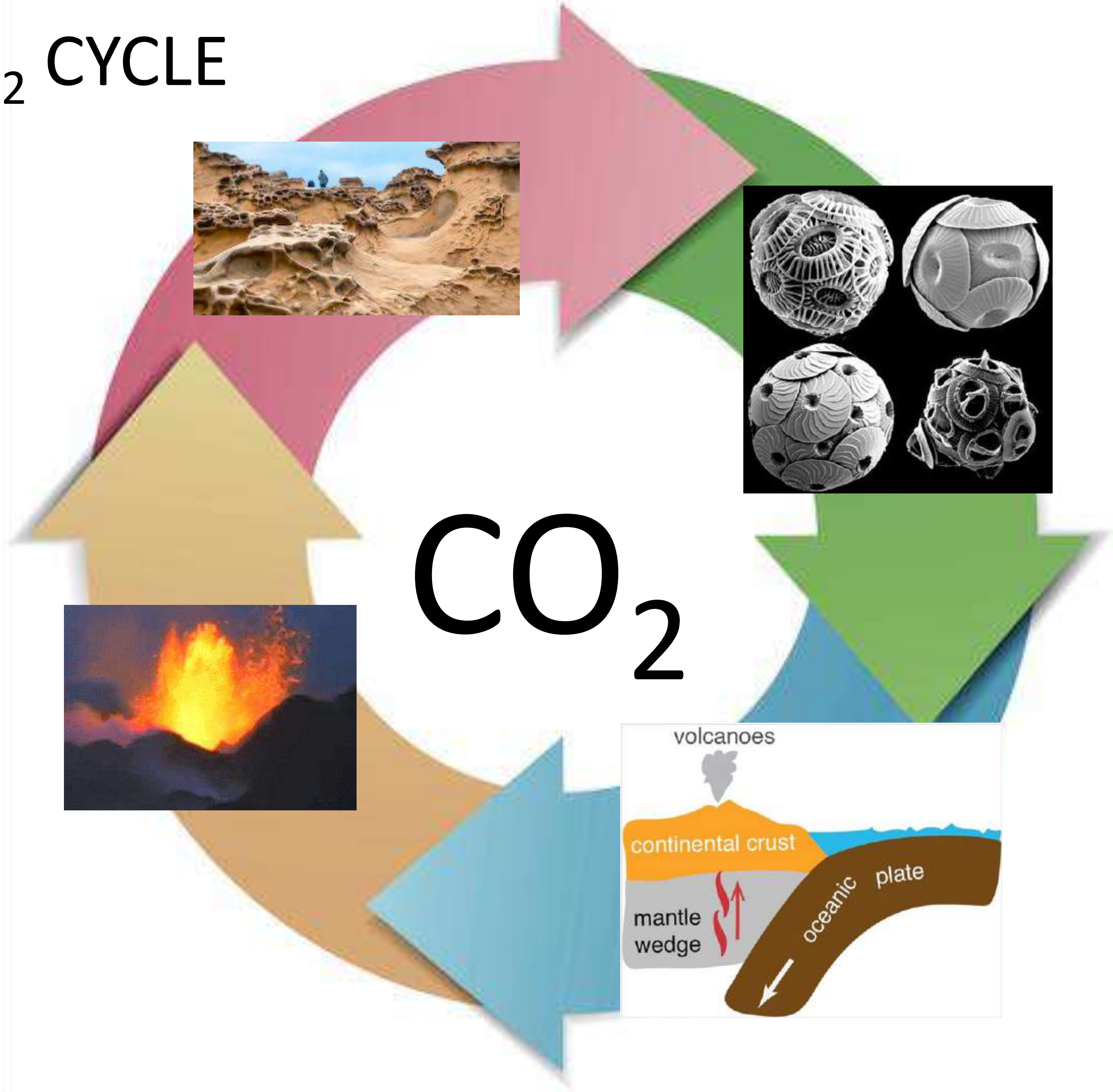

- 3000 PgC over 5000 years (0.6 PgC/yr or 2.4 $GtCO_2$/yr) emissions of $CO_2$
- 5-8 $^oC$ rise of global temperature
- Dissolved $CaCO_3$ in ocean sediments (acidification),
- Ocean Deoxygenation
- Increased weathering, increased Corg burial
- Timescale of recovery ~1-200000 years

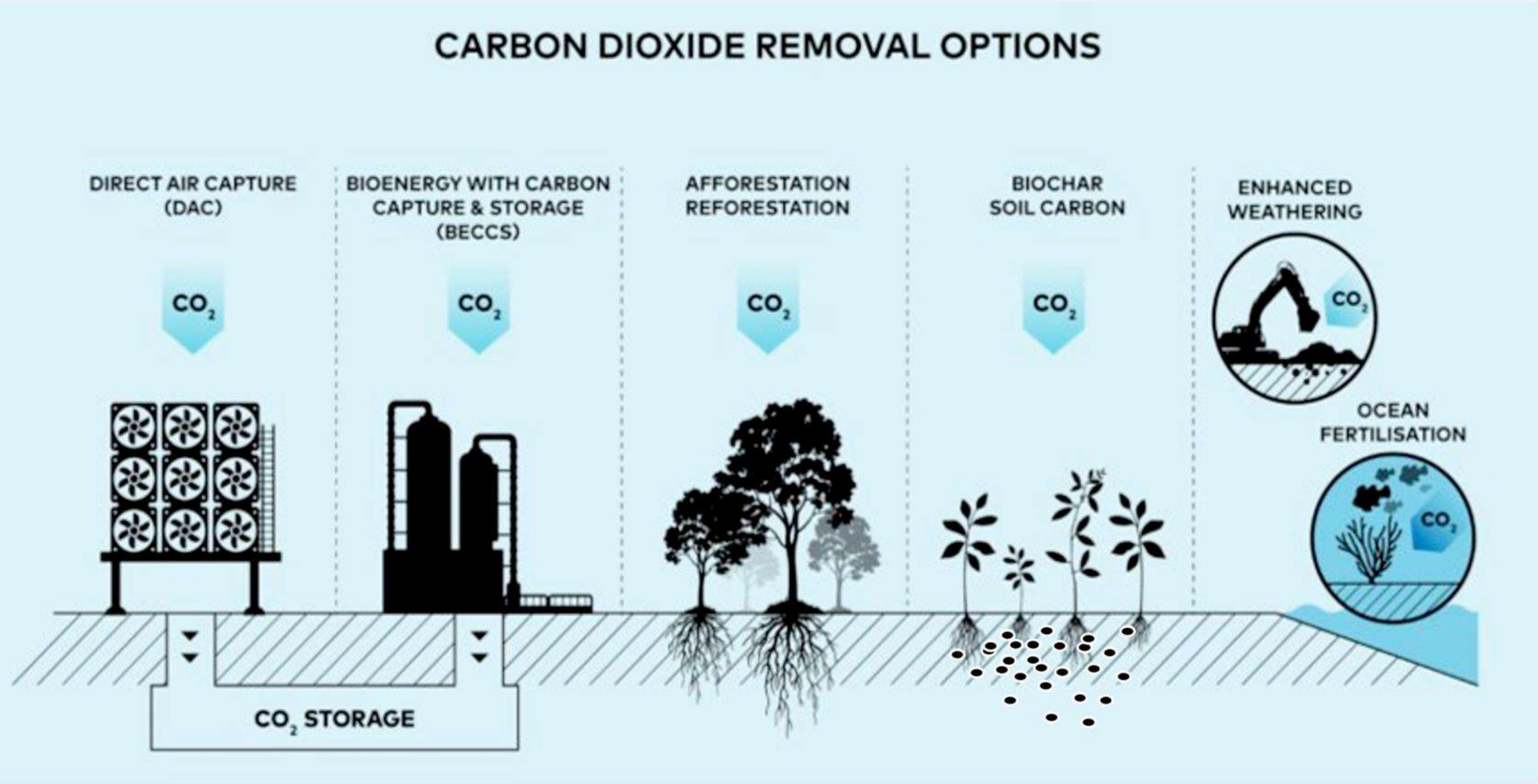

CO2
~0.2 PgC/yr
CO2 from sedimentary organic C weathering
Weathering of silicate rocks
~0.2 PgC/yr
HCO3
Ca
Mg
Organisms build calcium carbonate shells
Riverine transport of HCO3, Ca, and Mg
Org C burial
~0.2 PgC/yr
Mid-oceanic ridge
Subduction


Solar Luminosity relative to present values (S/S0)
1
0.95
0.9
0.85
0.8
0.75
0.7
CO2 Concentration relative to Present Atmospheric Level (PAL)
10000
1000
100
10
1
5
4
3
2
Billions of Years before Present (Ga)

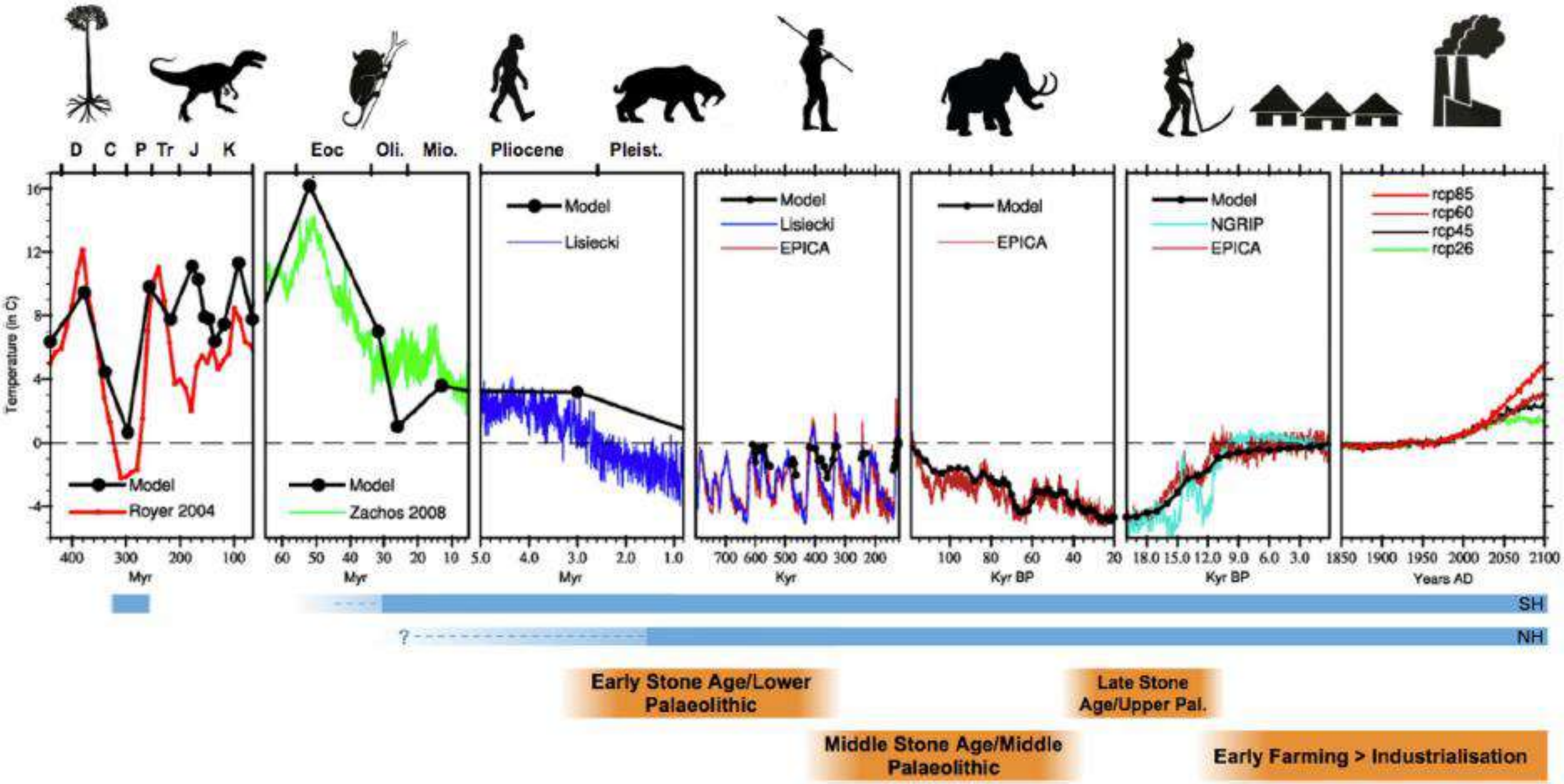

AUTO
ROOM
21 °C
CLOCK 15:24
SET 22.5 °C
SET
OK

# LONG TERM $CO_2$ CYCLE

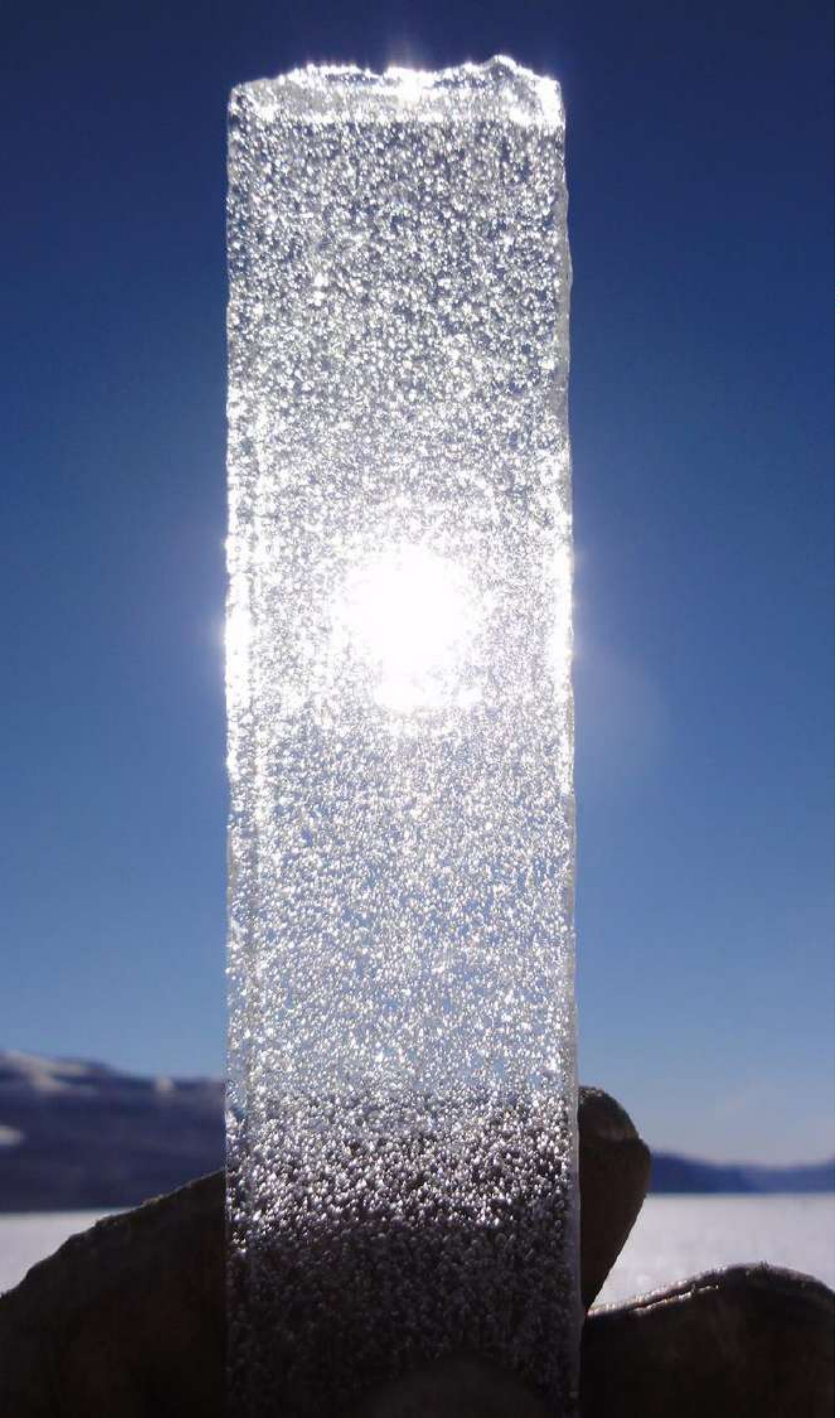


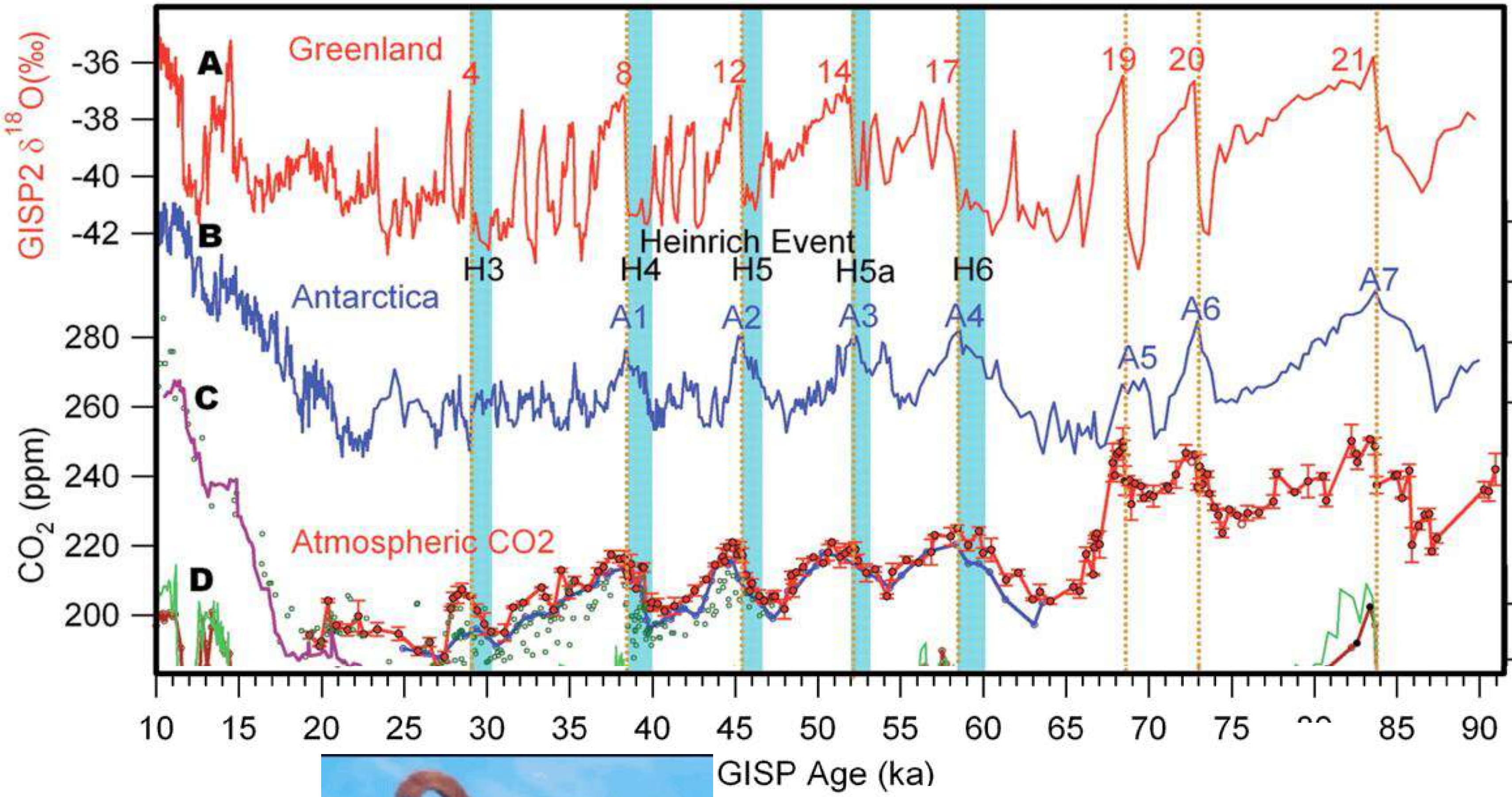

- Do the kinetics work?
- Can the sequestered C be measured?
- What are the unintended benefits? And consequences?
- What is the carbon/resource footprint of the technique itself?
- Who/What drives the C market?



D C P Tr J K
Eoc Oli. Mio. Pliocene Pleist.
Temperature (in C)
Model
Royer 2004
Zachos 2008
Lisiecki
EPICA
NGRIP
rcp85
rcp60
rcp45
rcp26
Myr
Kyr
Kyr BP
Years AD
SH
NH
Early Stone Age/Lower Palaeolithic
Middle Stone Age/Middle Palaeolithic
Late Stone Age/Upper Pal.
Early Farming > Industrialisation



# Ocean Carbon and Tipping Points




Ahn and Brooks, 2008

**Environment**

# 'Literally off the charts': global coral reef heat stress monitor forced to add new alerts as temperatures rise

**Three new levels added by US Coral Reef Watch after 'extreme' unprecedented heat, with highest alert warning of 'near complete mortality'**

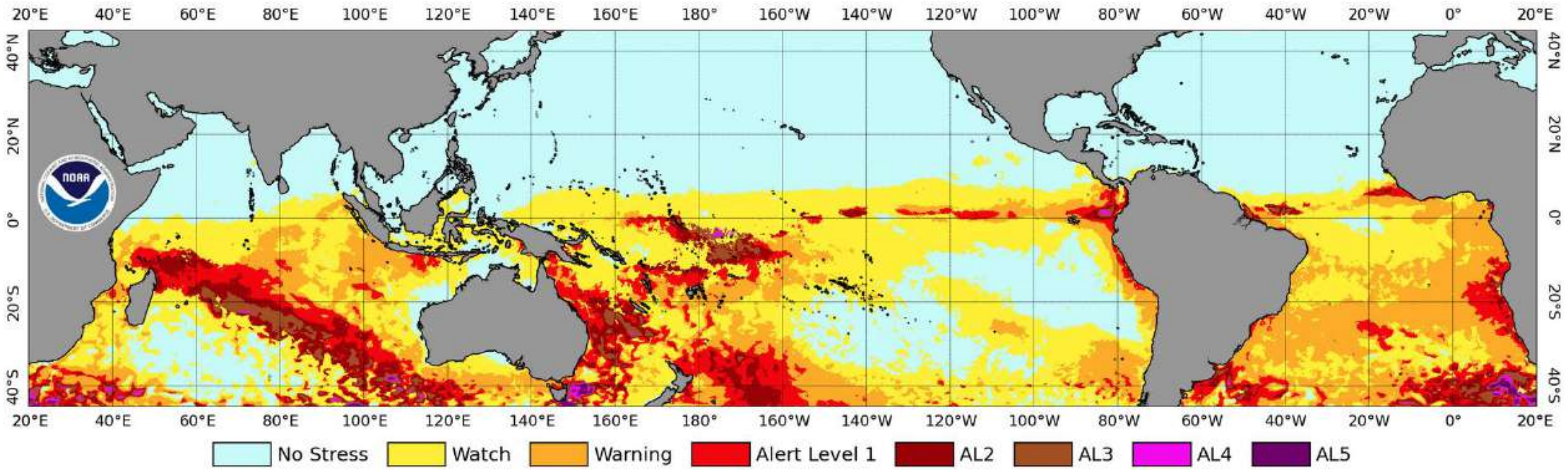
**Graham Readfearn**

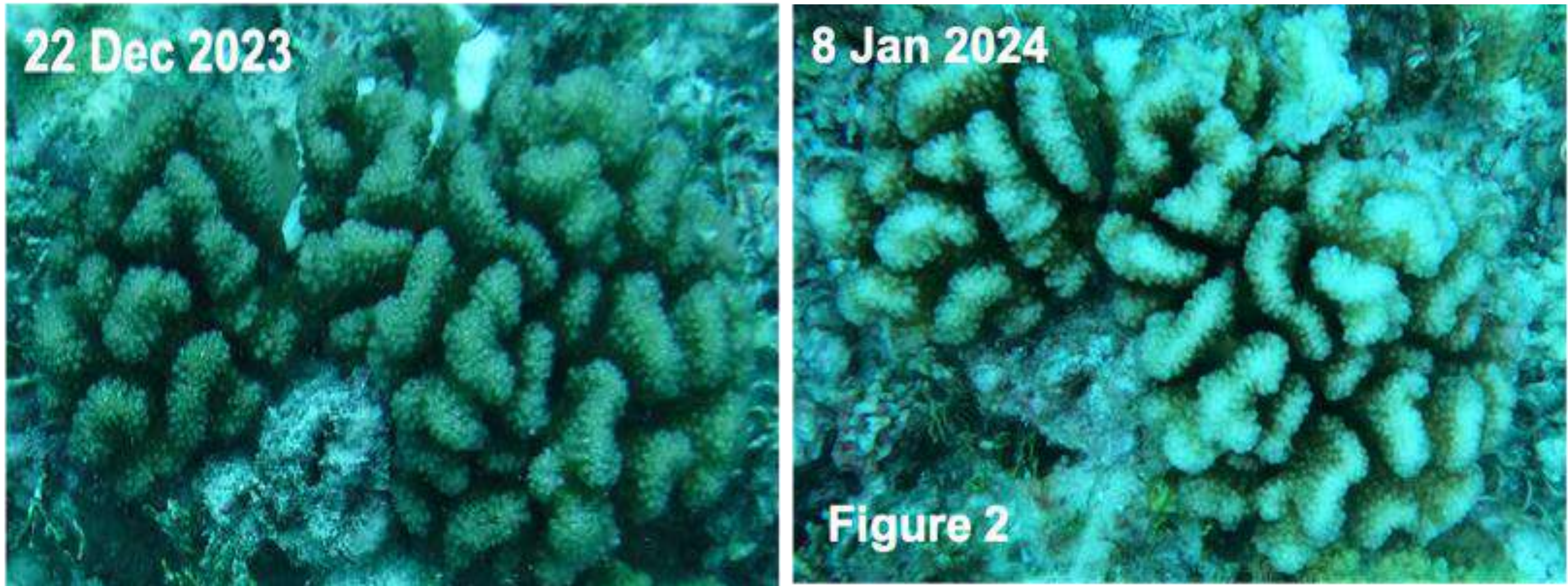
@readfearn

Wed 31 Jan 2024 14.00 GMT

## Daily Global 5km Satellite Coral Bleaching Heat Stress Alert Area

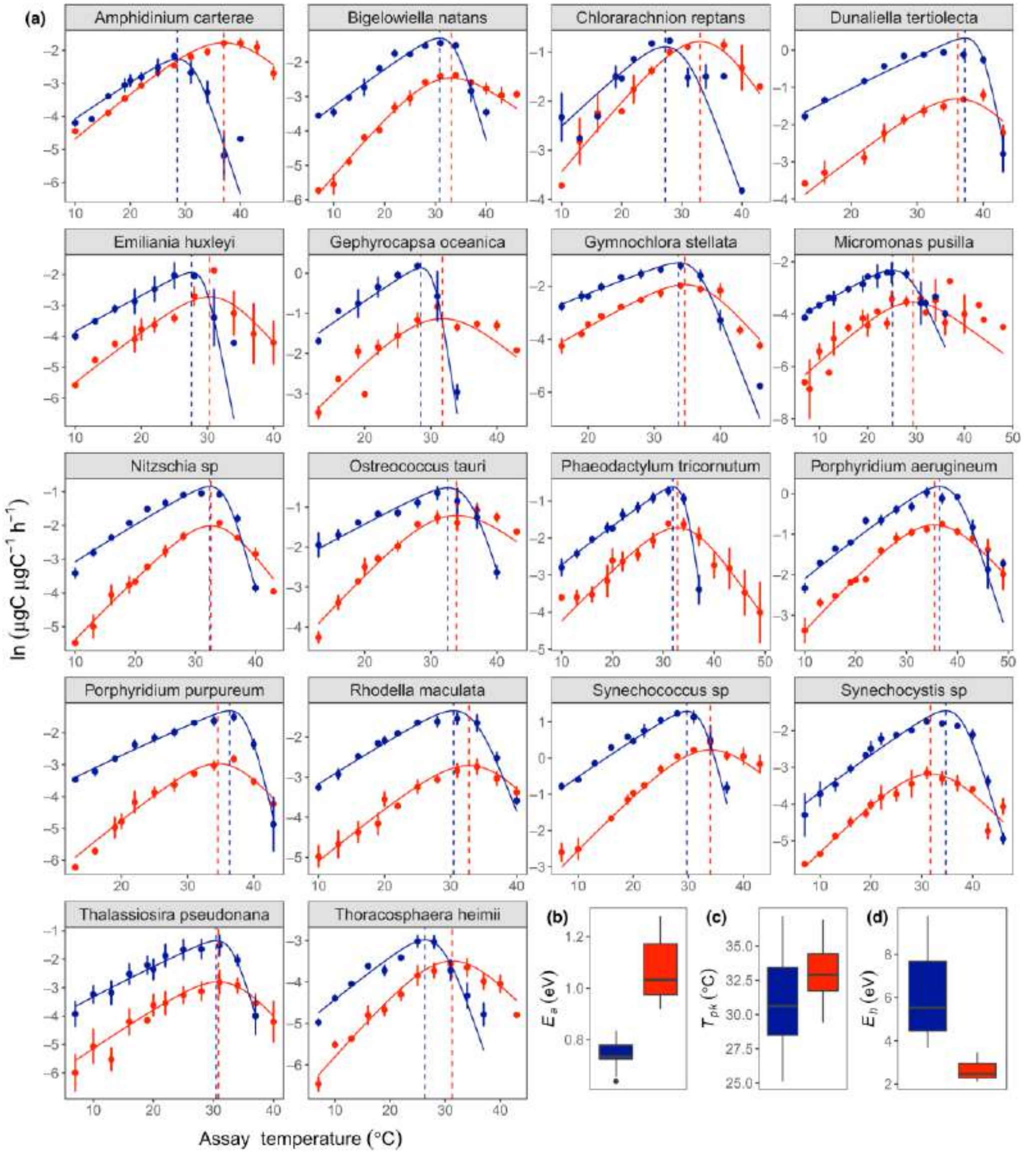
**(Version 3.1, released August 1, 2018)**



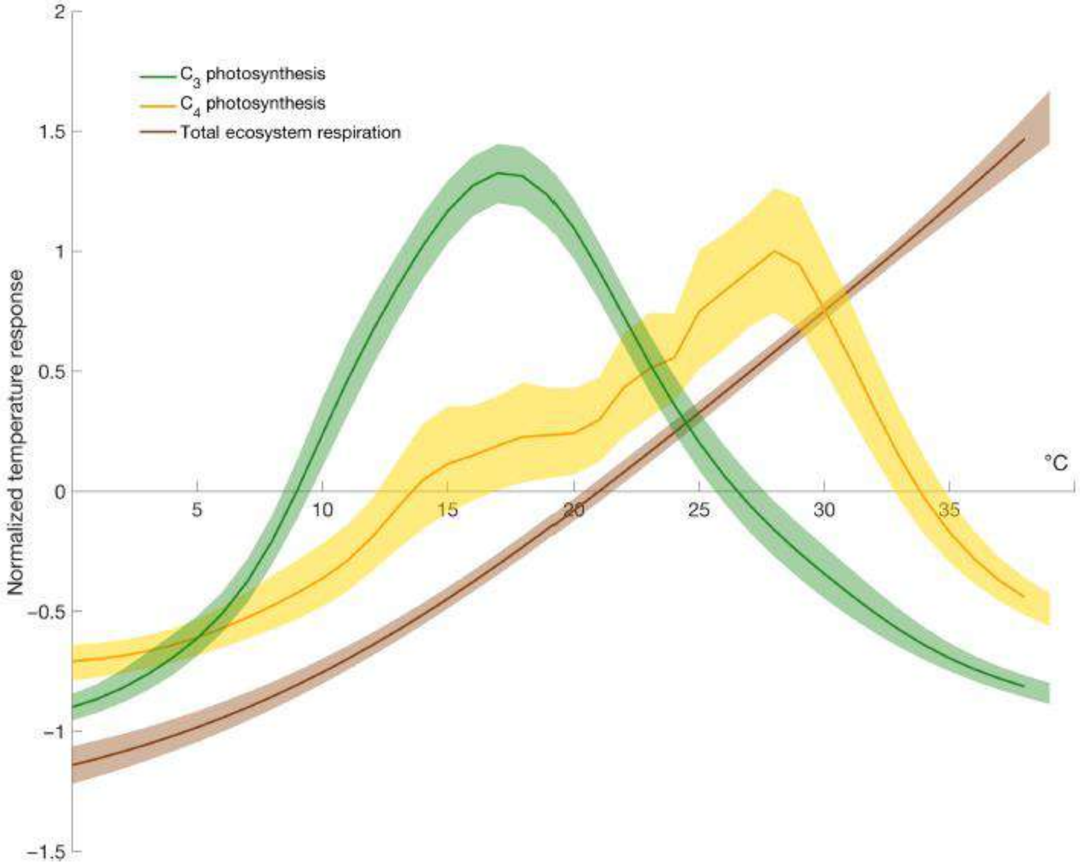
# T tipping points of Photosynthesis versus Respiration (and C sink)

Barton et al., 2020



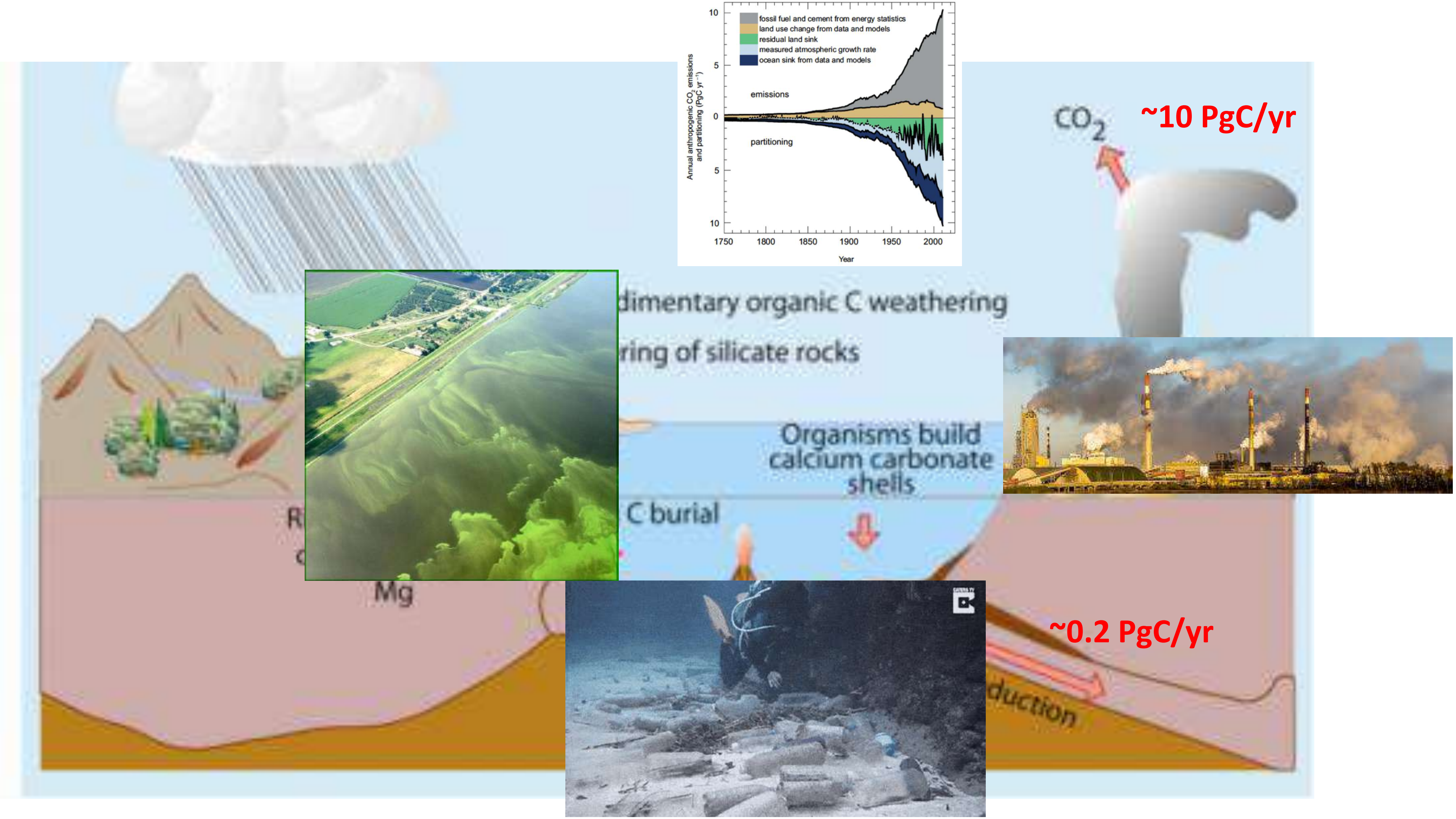

## How close are we to the temperature tipping point of the terrestrial biosphere?

**Katharyn A. Duffy[1,2]*, Christopher R. Schwalm[2,3], Vickery L. Arcus[4], George W. Koch[2], Liyin L. Liang[4,5], Louis A. Schipper[4]**

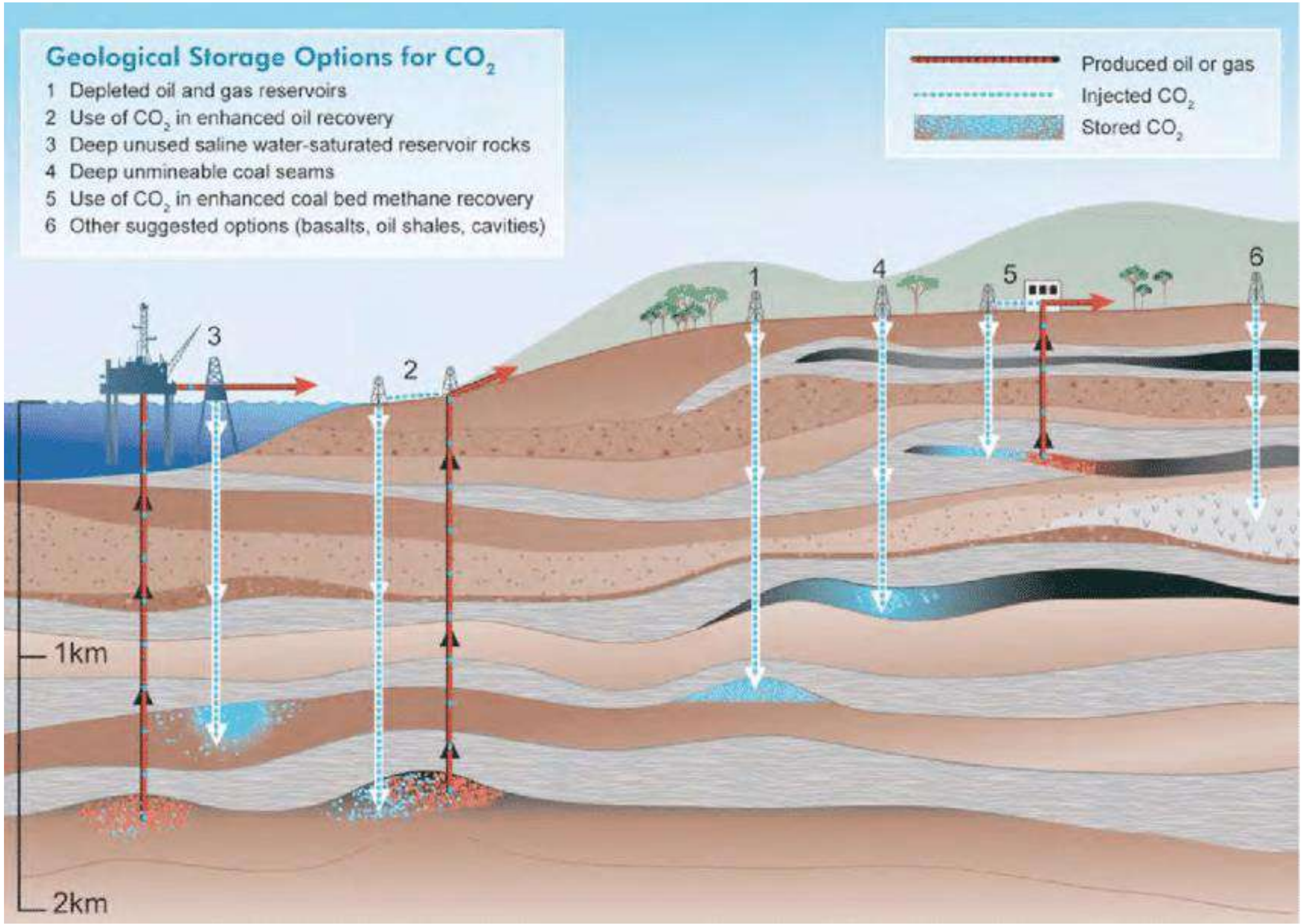


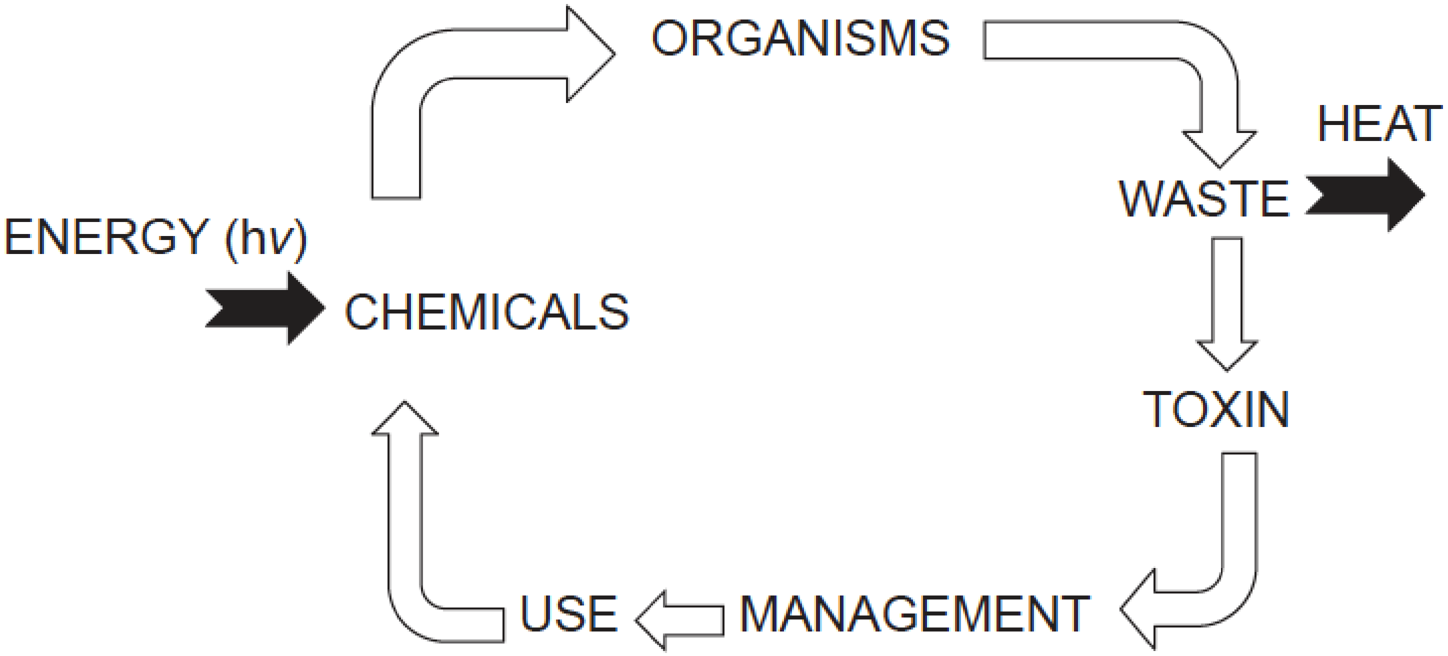



# MAD: Move Adapt or Die


fossil fuel and cement from energy statistics
land use change from data and models
residual land sink
measured atmospheric growth rate
ocean sink from data and models
emissions
partitioning
Annual anthropogenic $CO_2$ emissions and partitioning (PgC $yr^{-1}$)
10
5
0
5
10
1750
1800
1850
1900
1950
2000
Year
$CO_2$
~10 PgC/yr
dimentary organic C weathering
ring of silicate rocks
Organisms build calcium carbonate shells
C burial
Mg
duction
~0.2 PgC/yr

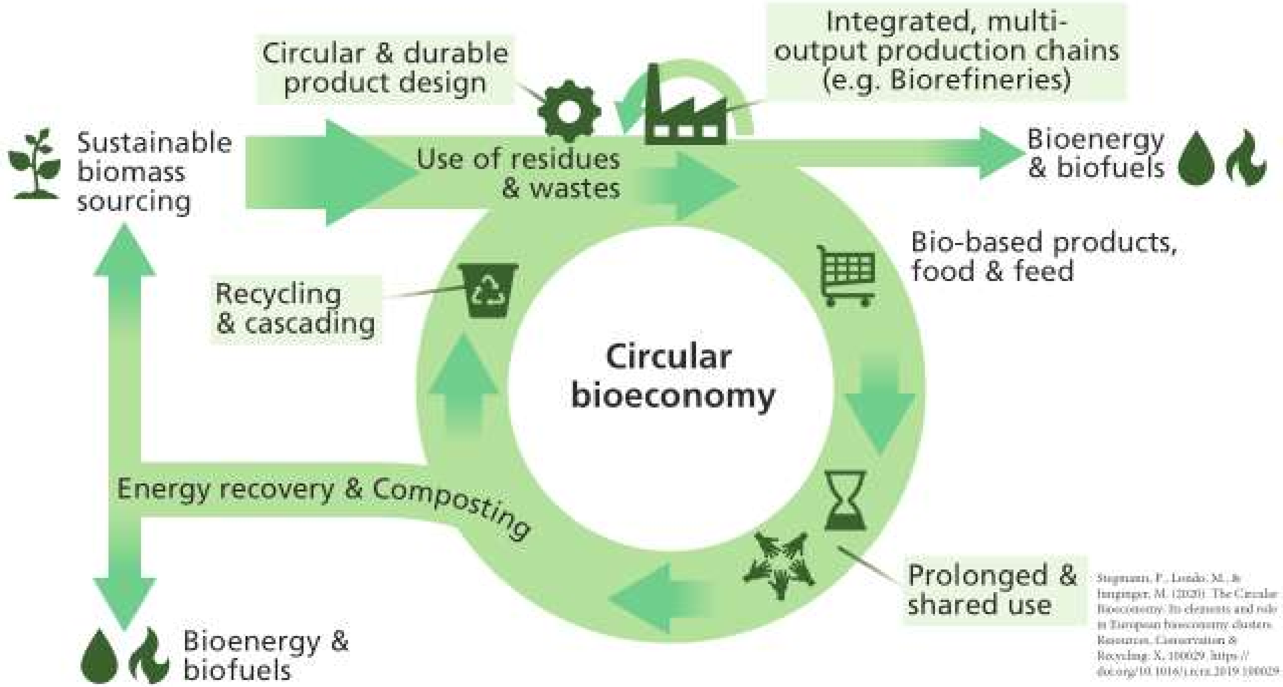
# Bung the $CO_2$ back where it came from…..



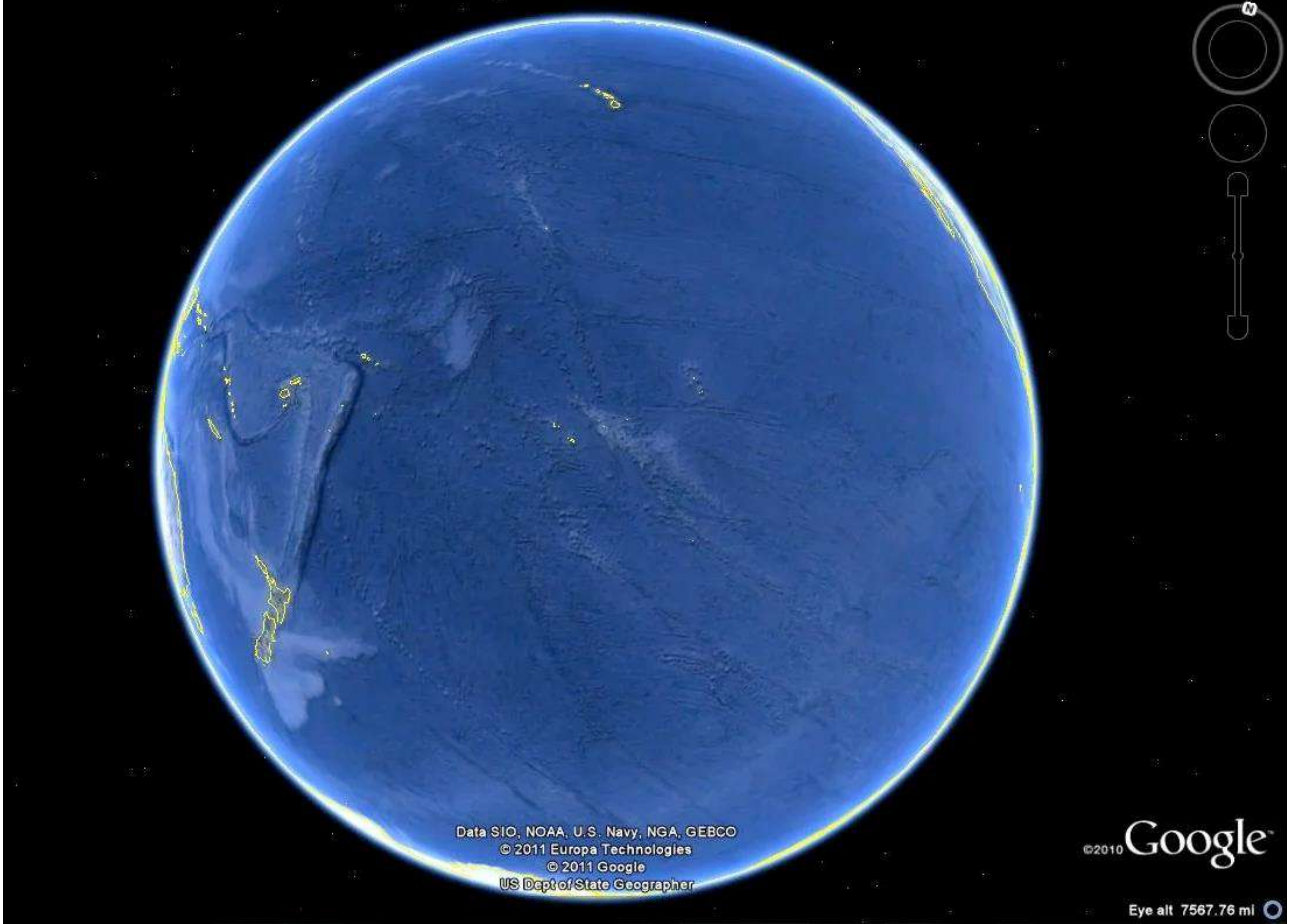



$CO_2$

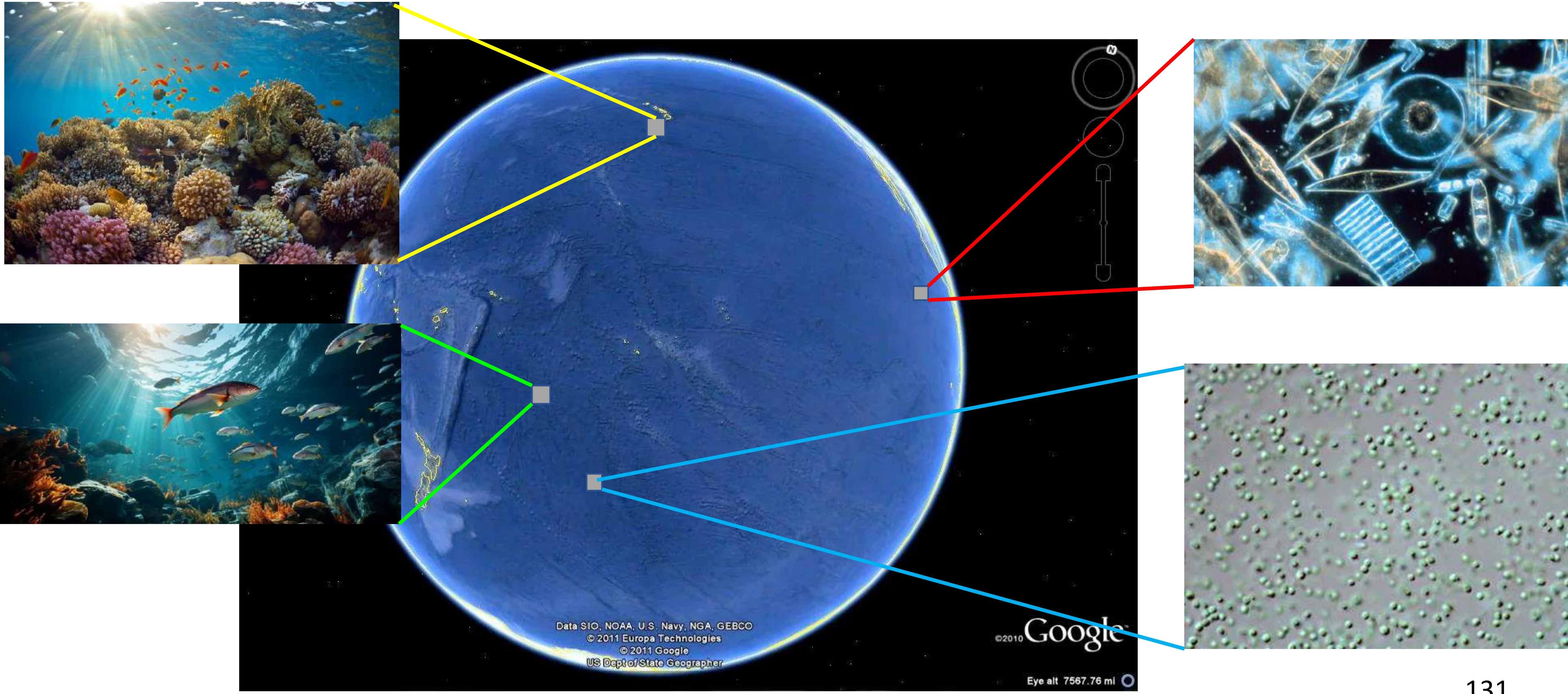
……and circularize the economy….




Stegmann, P., Londo, M., & Junginger, M. (2020). The Circular Bioeconomy: Its elements and role in European bioeconomy clusters. Resources, Conservation & Recycling: X, 100029. https:// doi.org/10.1016/j.rcrx.2019.100029


Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2011 Europa Technologies
© 2011 Google
US Dept of State Geographer
©2010 Google
Eye alt 7567.76 mi

# Google Ocean (real time who is living in each pixel)

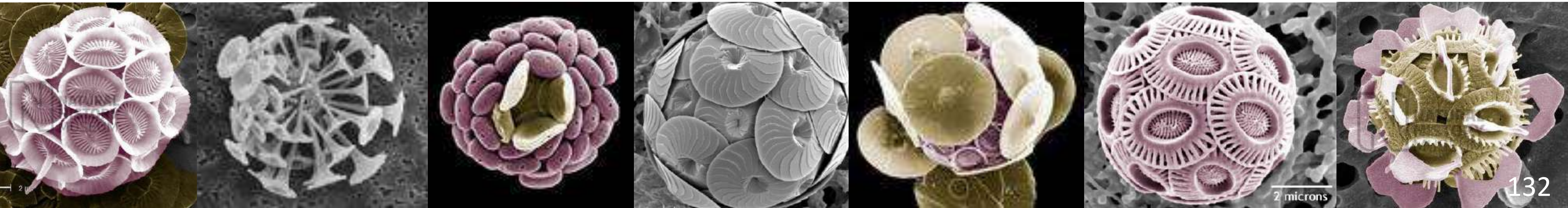





Other search engines are available….

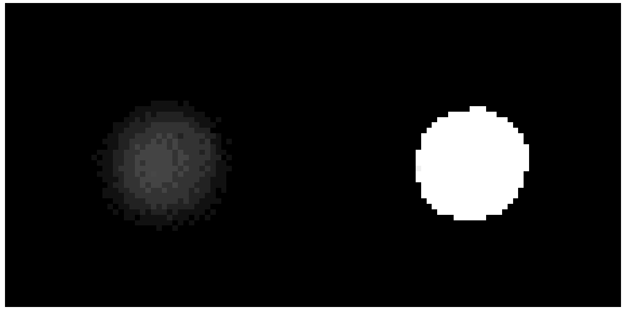
# Google Ocean

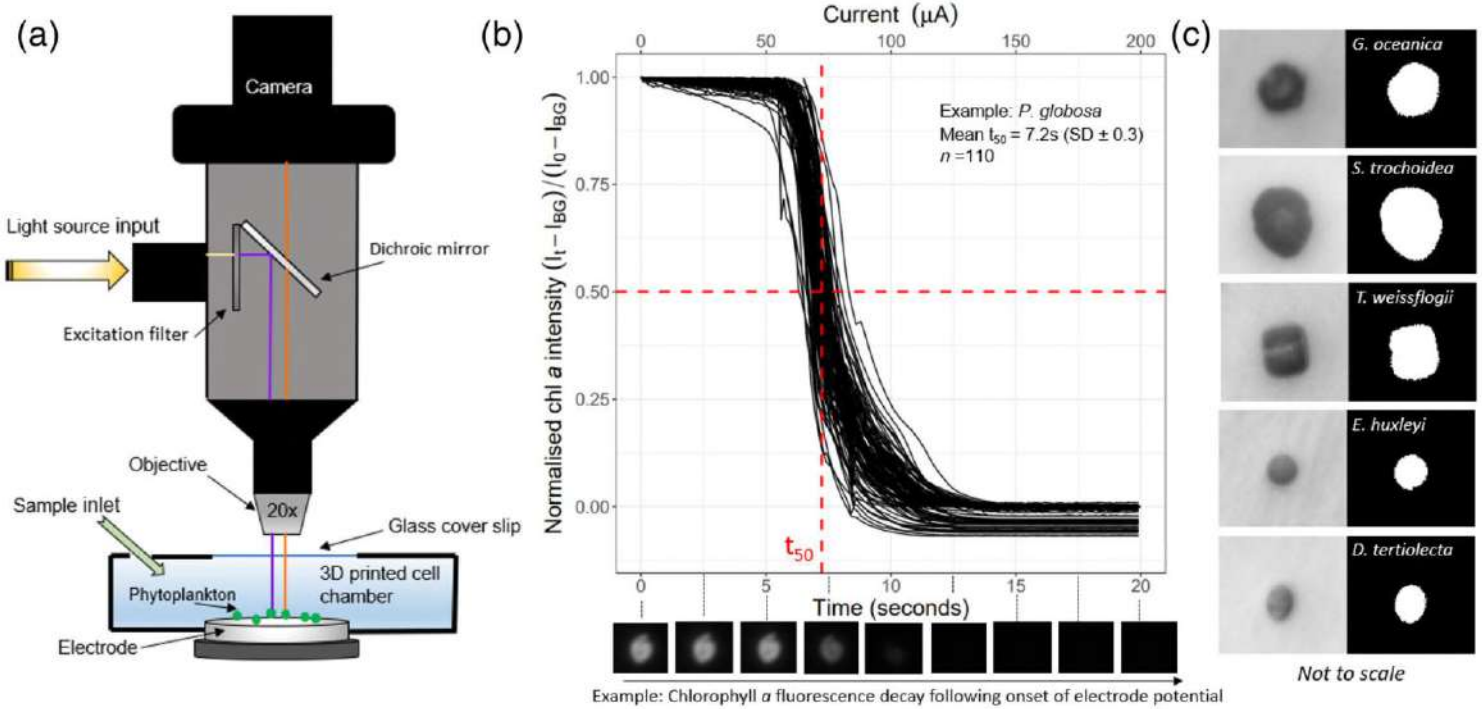
- To introduce the world to the ocean
- Driver to map the diversity of the ocean comprehensively
- Invaluable data for plankton as monitors of climate and tipping points- the sentinels of the ocean
- Invaluable data for fisheries and macrofaunal conservation
- Baseline and disturbance data for all marine use
- Carbon/Biodiversity credits



# A plankton sensor (low cost/low power)

- We monitor the chlorophyll *a* fluorescence signal of living phytoplankton cells, and measure the decay of this signal in response to electrochemically driven oxidative stress






Applying a potential to seawater sample does two things:

- $H^+$ ions generated, creating acidic conditions = dissolution of $CaCO_3$
- Oxygen radicals (or reactive oxygen species) are created (e.g. hydroxyl radicals, OH)

= oxidative destruction of Chlorophyll a

Taken from Barton *et al*., 2023, *Limnology and Oceanography: Methods*

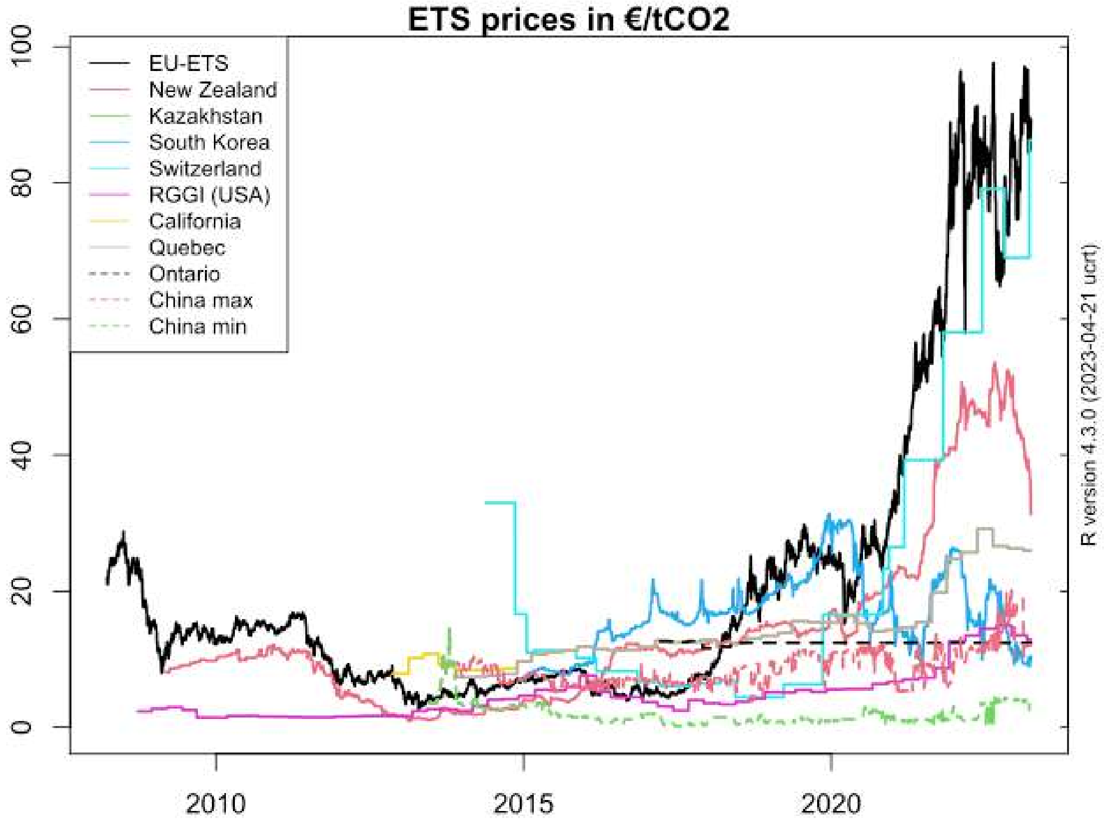
# Liquid Gold

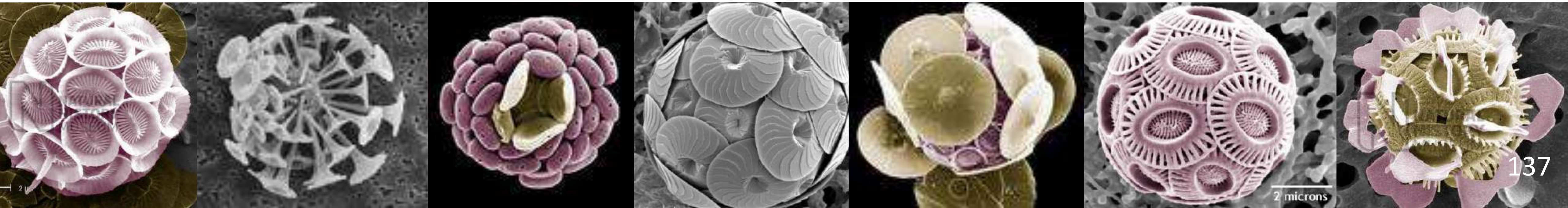
**How do we protect the valuable sea….**
**A huge sponge of our carbon and heat -all done for free**
**The poor ocean accumulates waste- it sits right in the mix**
**We must circularise flows; slow inputs- there is no quick fix**

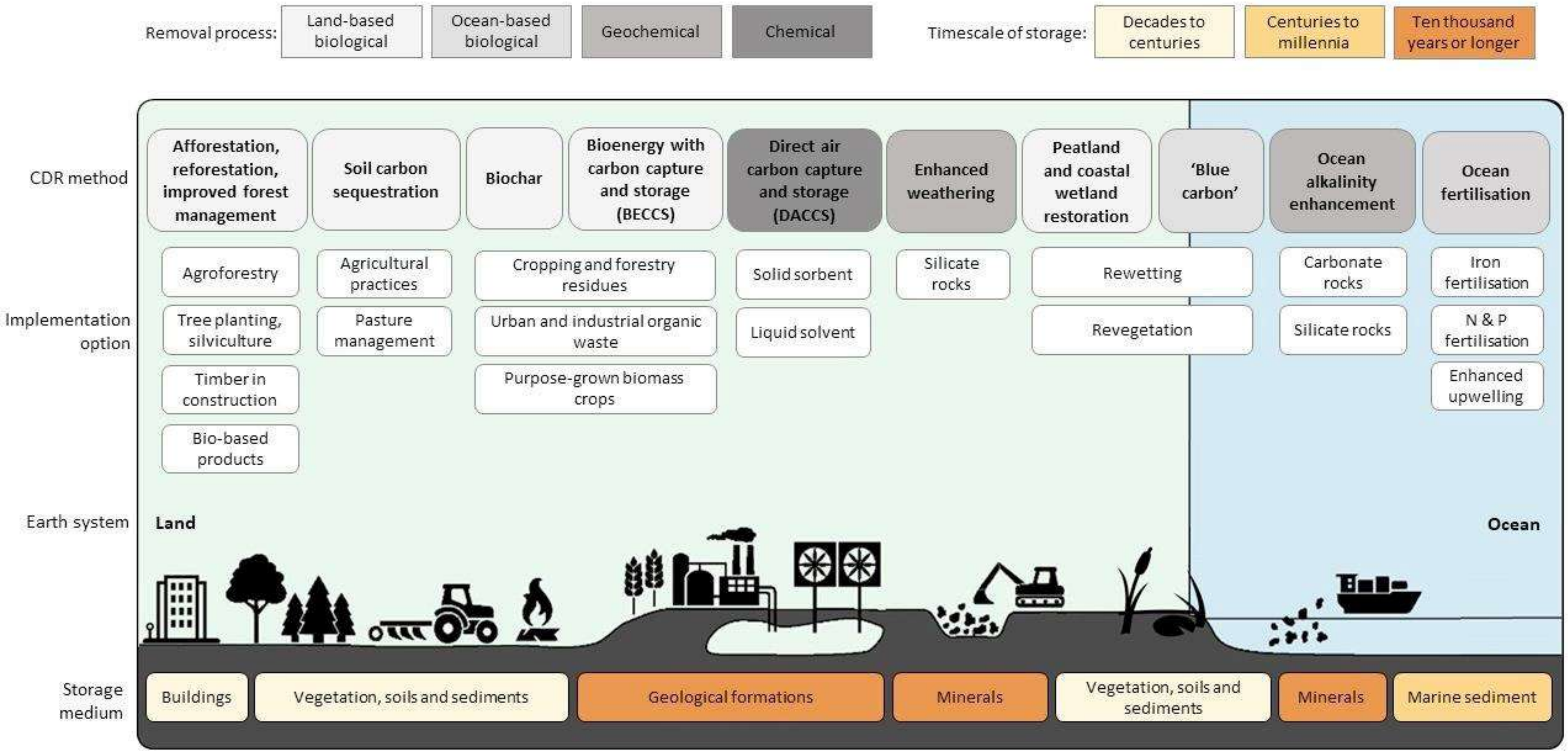
**No doubt there is gold in them thar seas,**
**Marine robots, green transport, renewable energies**
**New food, new life, awesome blue opportunities**
**But each of these uses splashes a disruptive bomb**
**Across the network of life and marine carbon**
**And these must be real time charted, valued and controlled**
**Before we can turn the blue one gold**

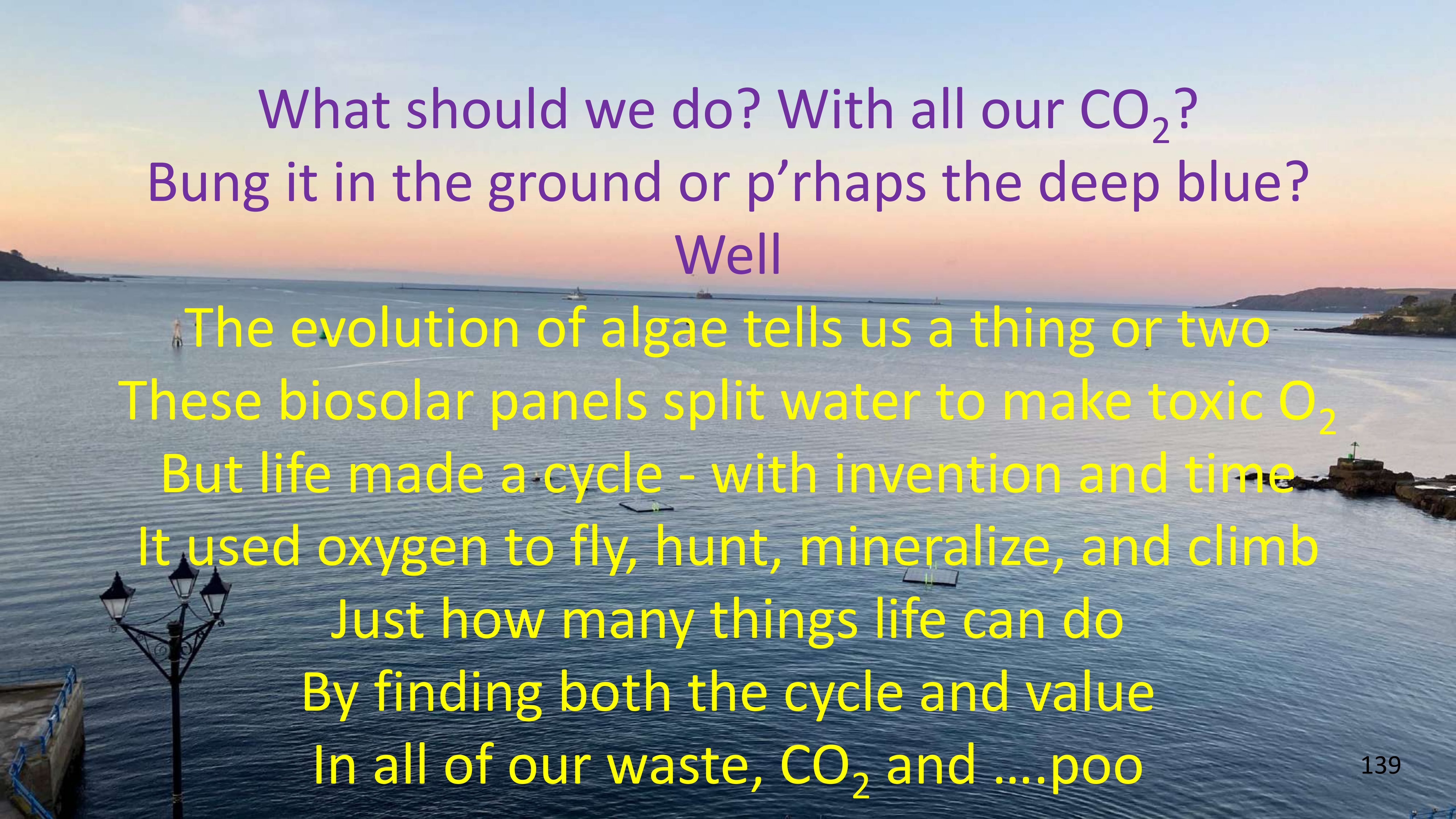
# The value of plankton to the UK

- The UK has stewardship of around 7 665 586 km$^2$ of neighbouring sea bed including *OTCD*
- UK's exclusive economic zone (EEZ) the fifth largest in the world
- 2% of the world's ocean surface (Pro rata component of the Bio Pump admittedly imperfect: 100-240 MtC/yr (£7.4-17.8 billion)
- Biotech resources of the plankton are currently underexplored

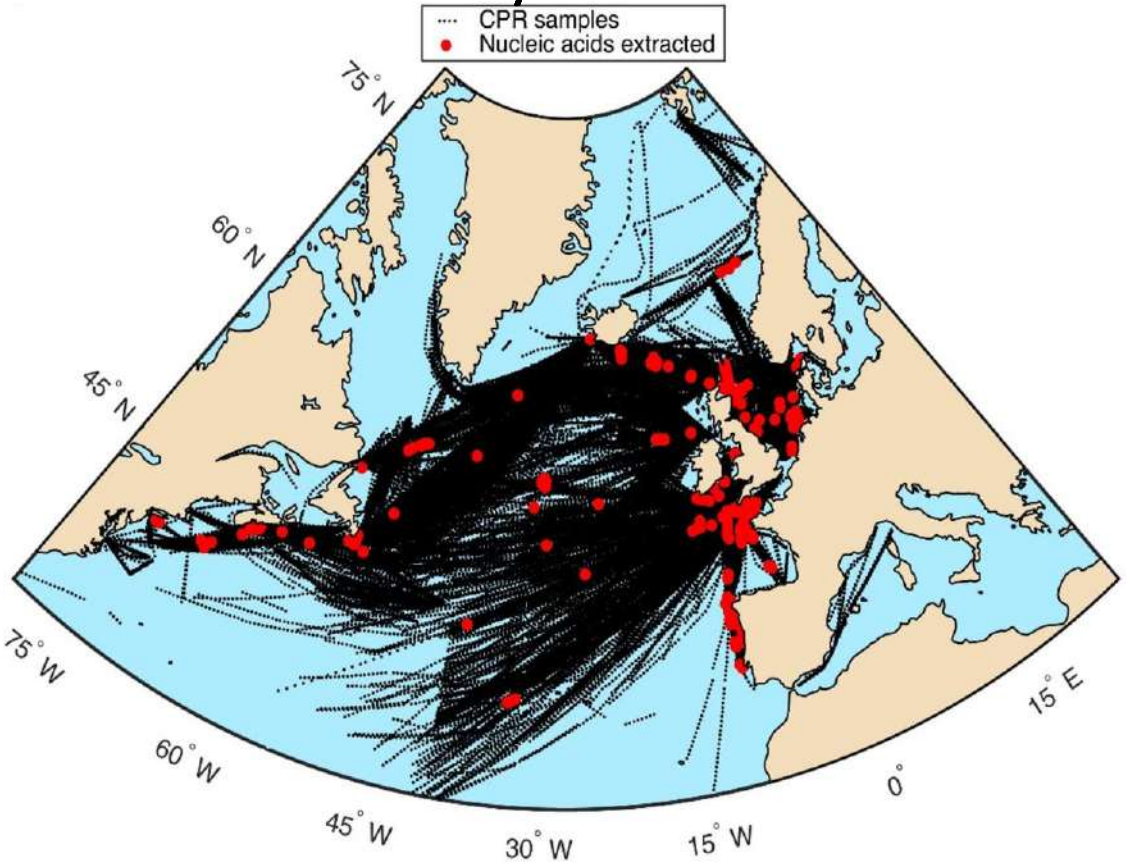


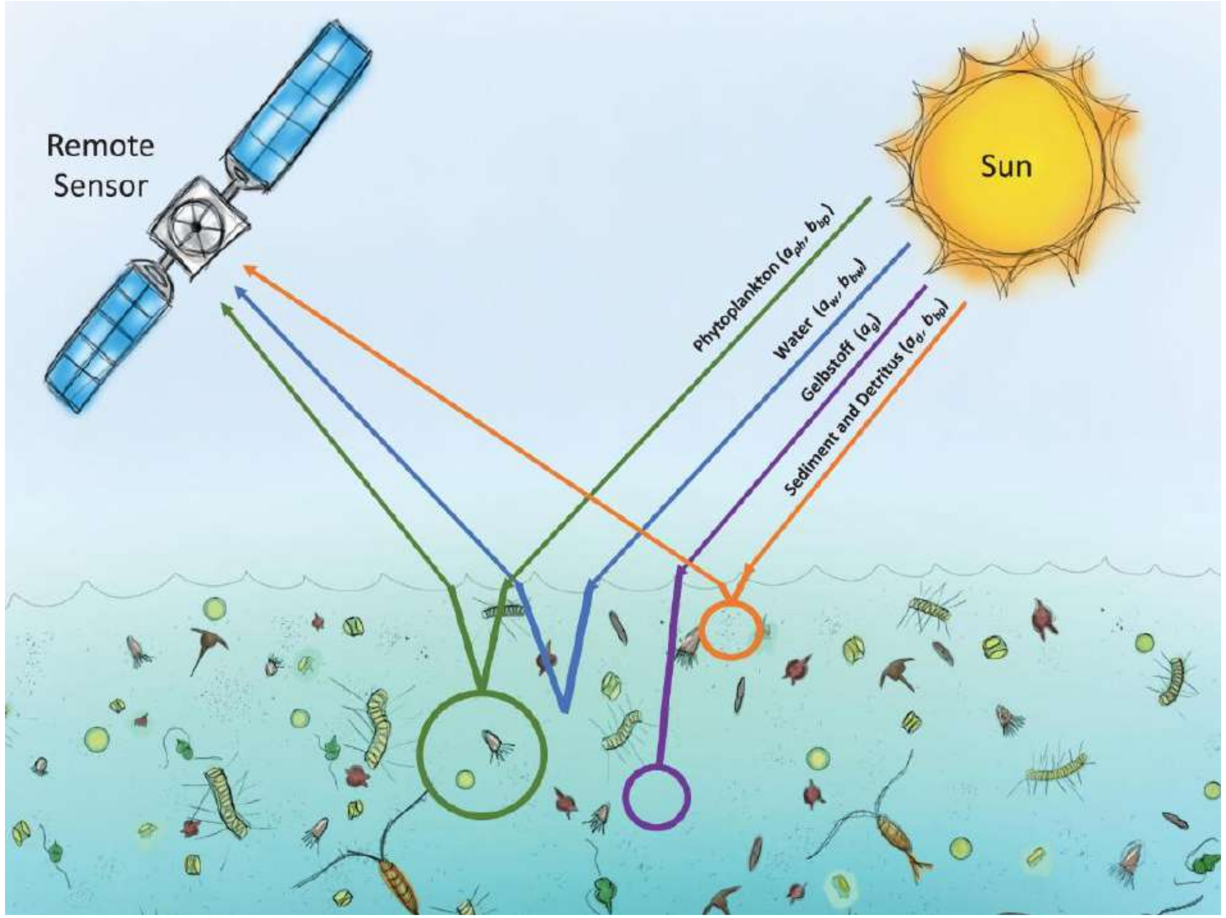

Removal process:
Land-based biological
Ocean-based biological
Geochemical
Chemical
Timescale of storage:
Decades to centuries
Centuries to millennia
Ten thousand years or longer
CDR method
Afforestation, reforestation, improved forest management
Soil carbon sequestration
Biochar
Bioenergy with carbon capture and storage (BECCS)
Direct air carbon capture and storage (DACCS)
Enhanced weathering
Peatland and coastal wetland restoration
'Blue carbon'
Ocean alkalinity enhancement
Ocean fertilisation
Implementation option
Agroforestry
Tree planting, silviculture
Timber in construction
Bio-based products
Agricultural practices
Pasture management
Cropping and forestry residues
Urban and industrial organic waste
Purpose-grown biomass crops
Solid sorbent
Liquid solvent
Silicate rocks
Rewetting
Revegetation
Carbonate rocks
Silicate rocks
Iron fertilisation
N & P fertilisation
Enhanced upwelling
Earth system
Land
Ocean
Storage medium
Buildings
Vegetation, soils and sediments
Geological formations
Minerals
Vegetation, soils and sediments
Minerals
Marine sediment


What should we do? With all our $CO_2$?
Bung it in the ground or p'rhaps the deep blue?
Well
The evolution of algae tells us a thing or two
These biosolar panels split water to make toxic $O_2$
But life made a cycle - with invention and time
It used oxygen to fly, hunt, mineralize, and climb
Just how many things life can do
By finding both the cycle and value
In all of our waste, $CO_2$ and ....poo

The CPR Survey - since 1931

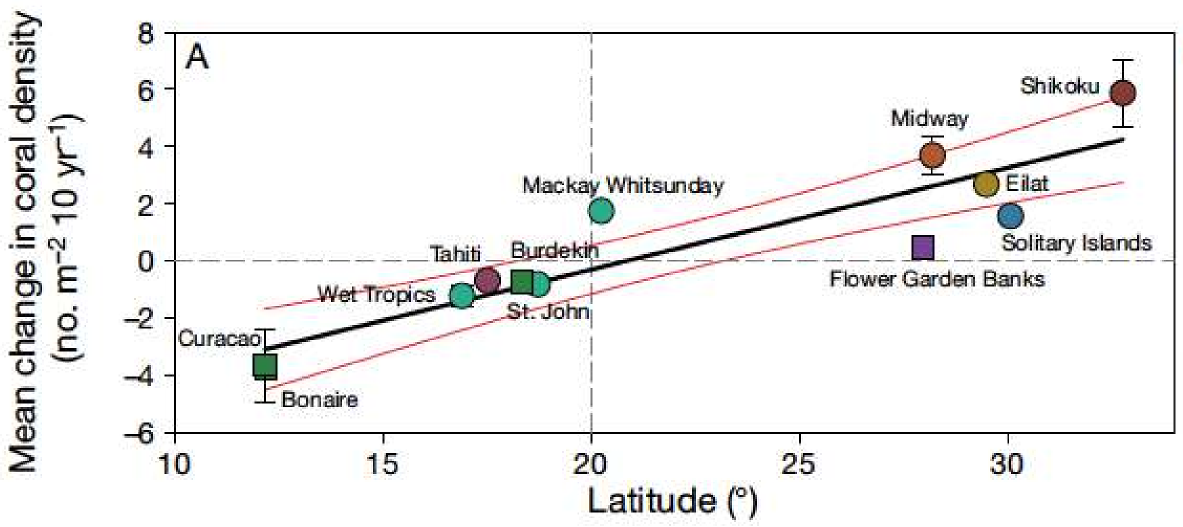



Satellites Since 1978




- Need integration of different methods (and new technologies) to capture biodiversity of the communities, to quantify abundance of different phytoplankton species/functional groups and their impact on flux of carbon

# Coral bleaching….but some hope…

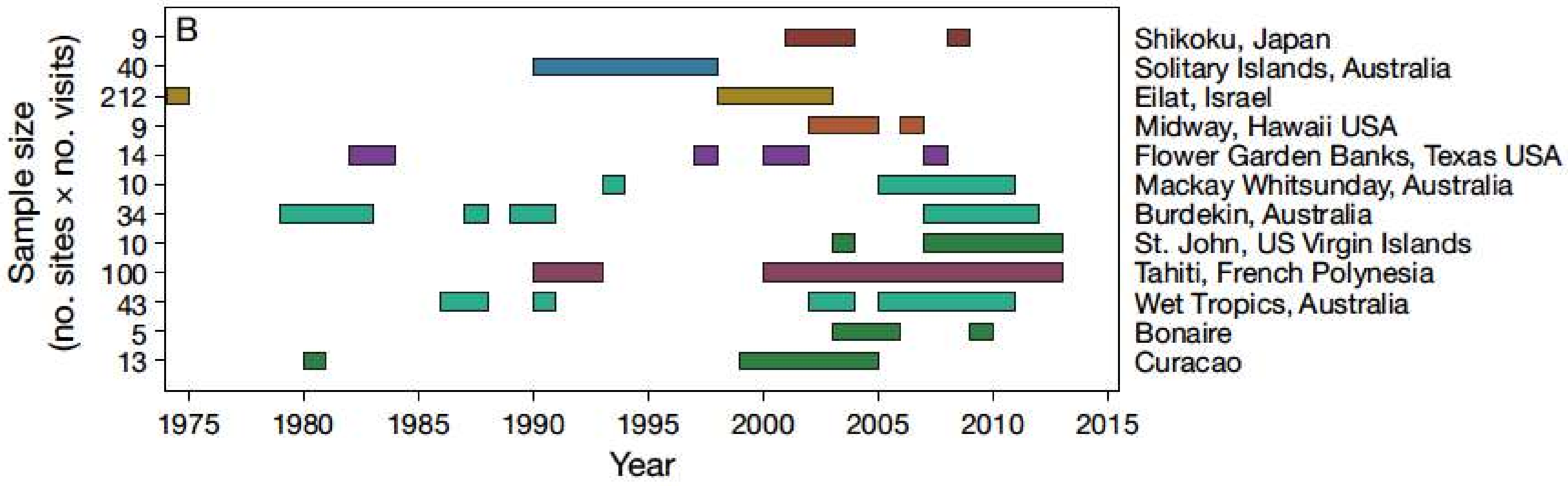



FEATURE ARTICLE



## Global biogeography of coral recruitment: tropical decline and subtropical increase

N. N. Price[1,*], S. Muko[2], L. Legendre[3], R. Steneck[4], M. J. H. van Oppen[5,6], R. Albright[5,7,18], P. Ang Jr.[8], R. C. Carpenter[9], A. P. Y. Chui[8], T.-Y. Fan[10], R. D. Gates[11], S. Harii[12], H. Kitano[13], H. Kurihara[14], S. Mitarai[15], J. L. Padilla-Gamiño[16], K. Sakai[12], G. Suzuki[17], P. J. Edmunds[9]




Tropicalisation of the subtropics…

# Carbon versus biodiversity?

ARTICLE

https://doi.org/10.1038/s43247-022-00625-0 OPEN

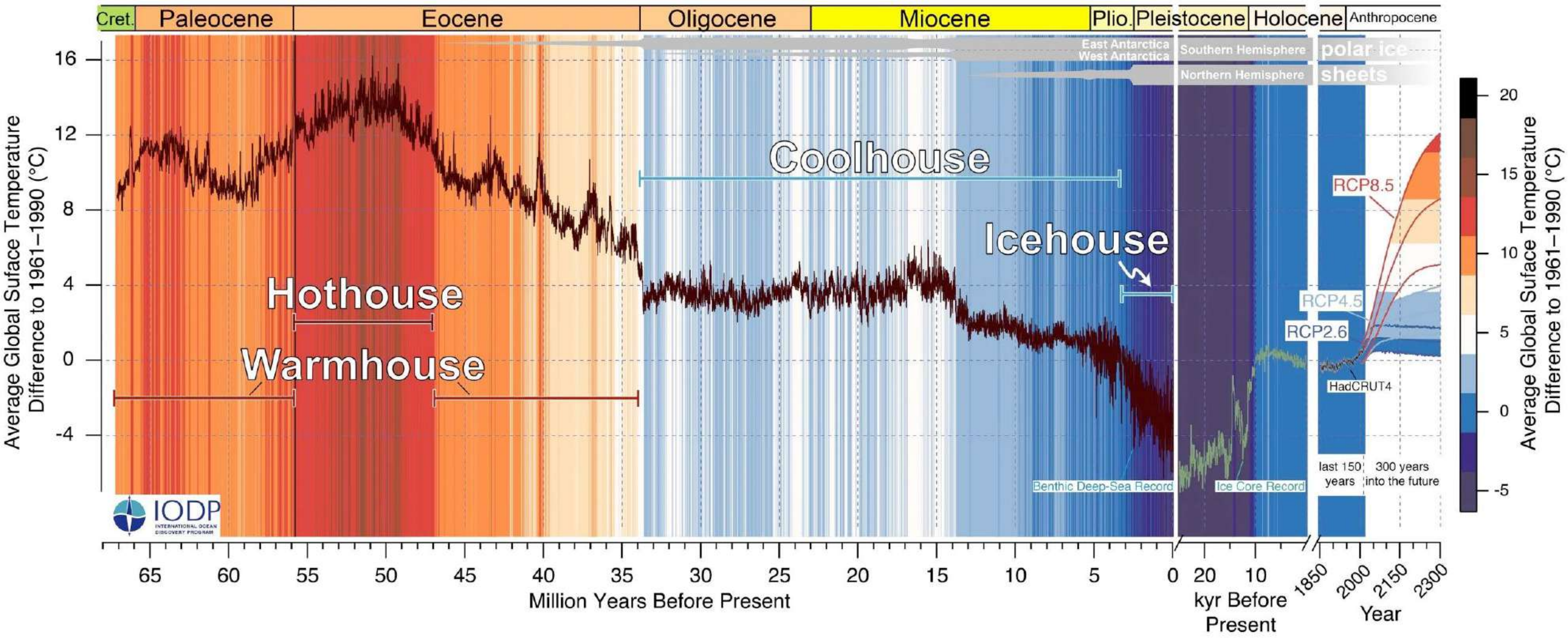
## Offshore wind farms are projected to impact primary production and bottom water deoxygenation in the North Sea

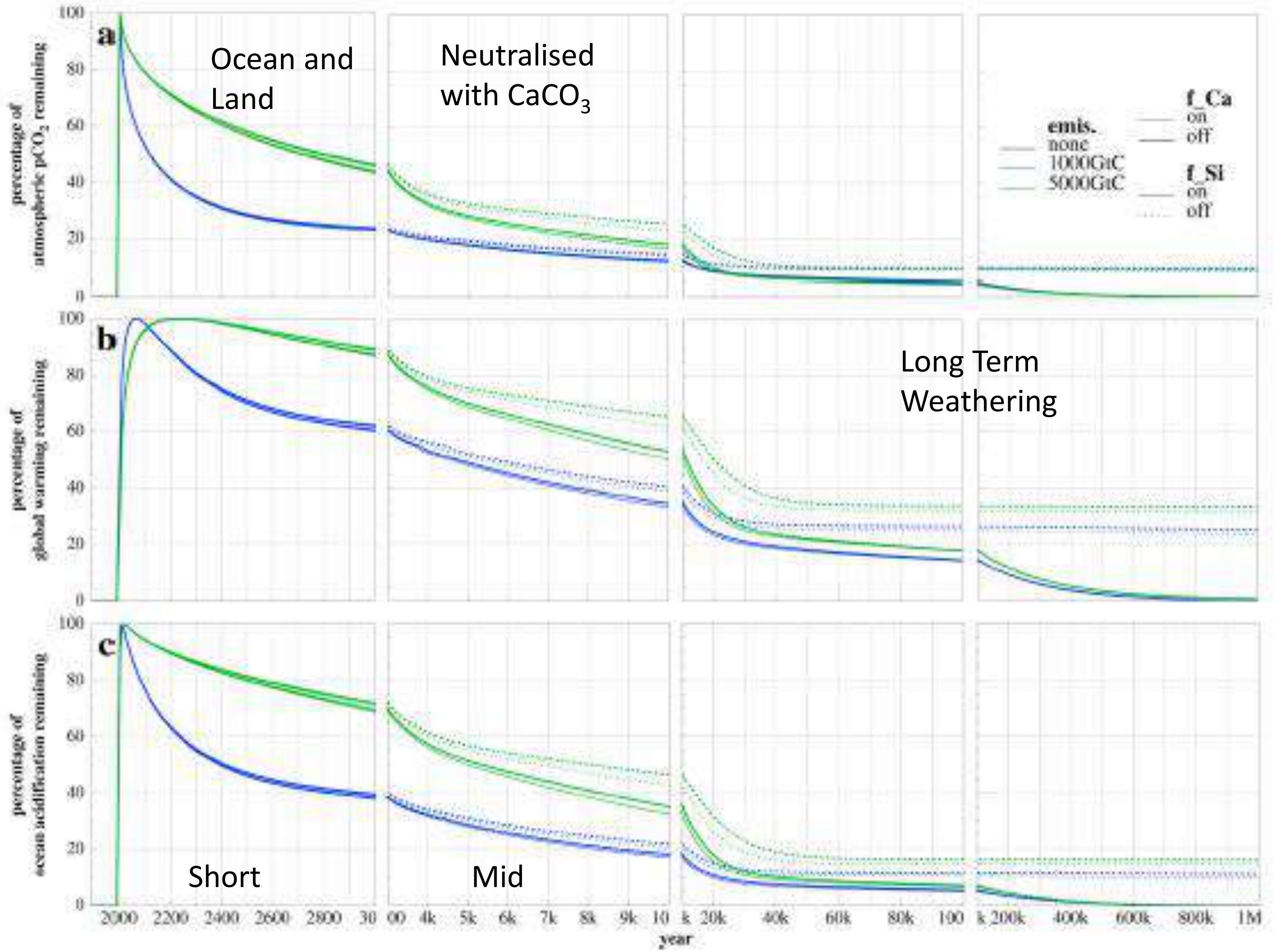
Ute Daewel[1]✉, Naveed Akhtar[1], Nils Christiansen[1] & Corinna Schrum[1,2]

**Clean Energy +**

**Carbon Pump +**

**Benthic Biodiversity -**

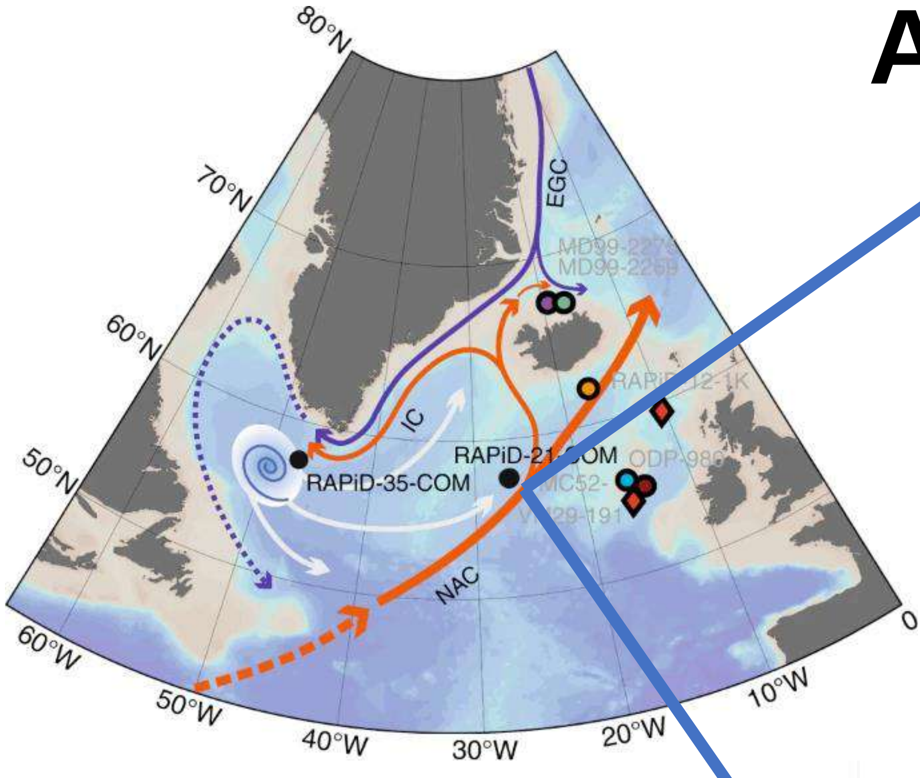

Cret.
Paleocene
Eocene
Oligocene
Miocene
Plio.
Pleistocene
Holocene
Anthropocene
East Antarctica
West Antarctica
Southern Hemisphere
Northern Hemisphere
polar ice sheets
Average Global Suface Temperature Difference to 1961–1990 (°C)
Coolhouse
Icehouse
Hothouse
Warmhouse
RCP8.5
RCP4.5
RCP2.6
HadCRUT4
Benthic Deep-Sea Record
Ice Core Record
last 150 years
300 years into the future
IODP
Million Years Before Present
kyr Before Present
Year



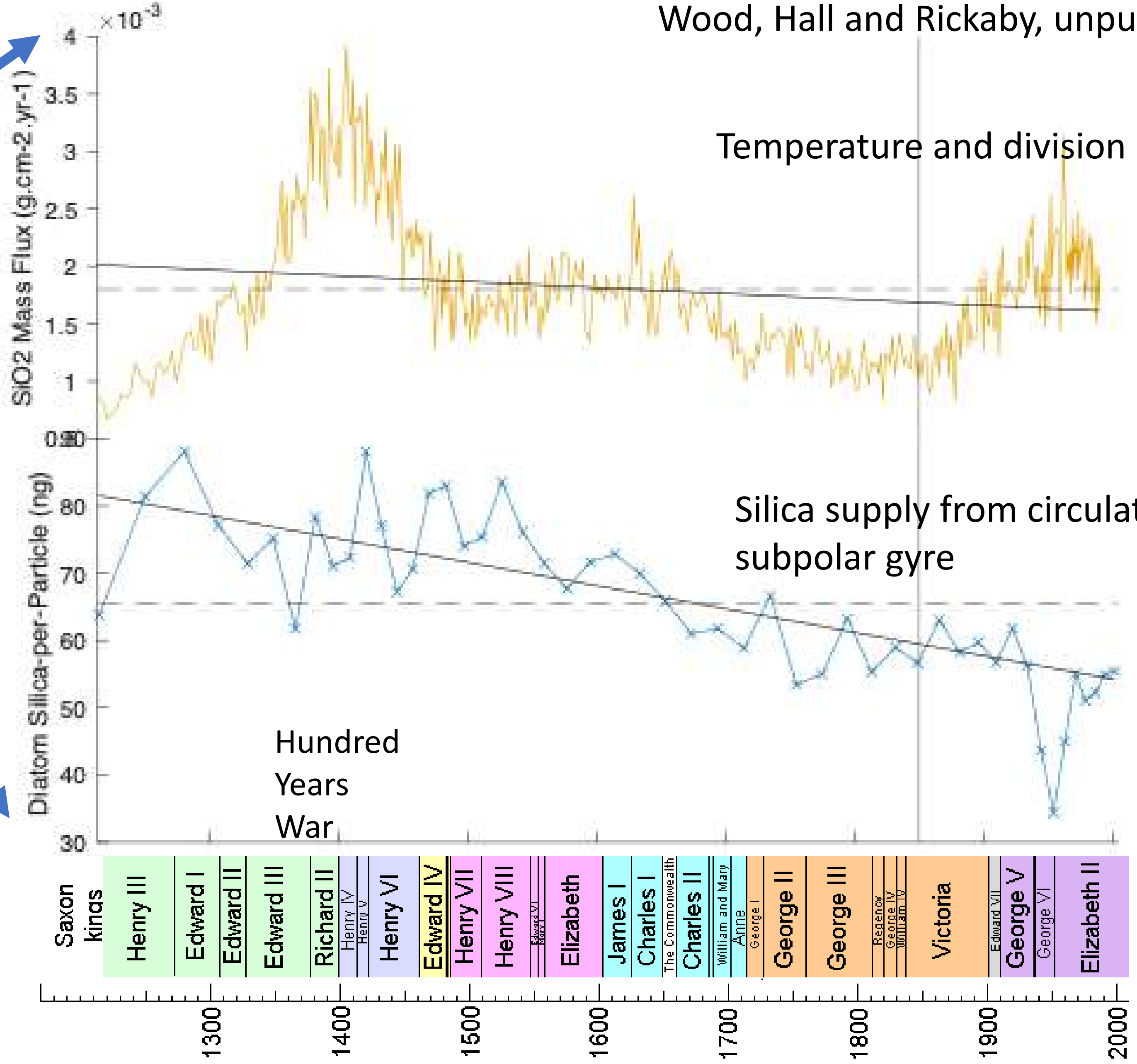



Colbourn et al., 2015

# A Variable Biological Pump




Wood, Hall and Rickaby, unpublished



# Move, Adapt or Die (MAD)

i) PETM extinctions benthic forams and polward range shifts in dinos, mammals, reptiles, plants and high community turnover
ii) >4oC cooler EO boundary, extinction many European terrestrial mammals and globally marine invertebrates
iii)Late Mio cooling, thermophilous plants shifted southwards and finally went extinct

iv) More than half of cool temperature Euroepan tree genera did not survive glacial cycles starting end Pliocene
v) An adaptive mutation of heamoglobin enabled mammoths to tolerate v low Ts at high latitude
vi) More than 70& megafauna in the Americas and Australia and 40% in Eurasia underwent extinction (5-10 ka) but climate or human?
vii) Plants in N. America migrated northwards between 450 and 2200 km in <10kyrs under a warming of 5oC

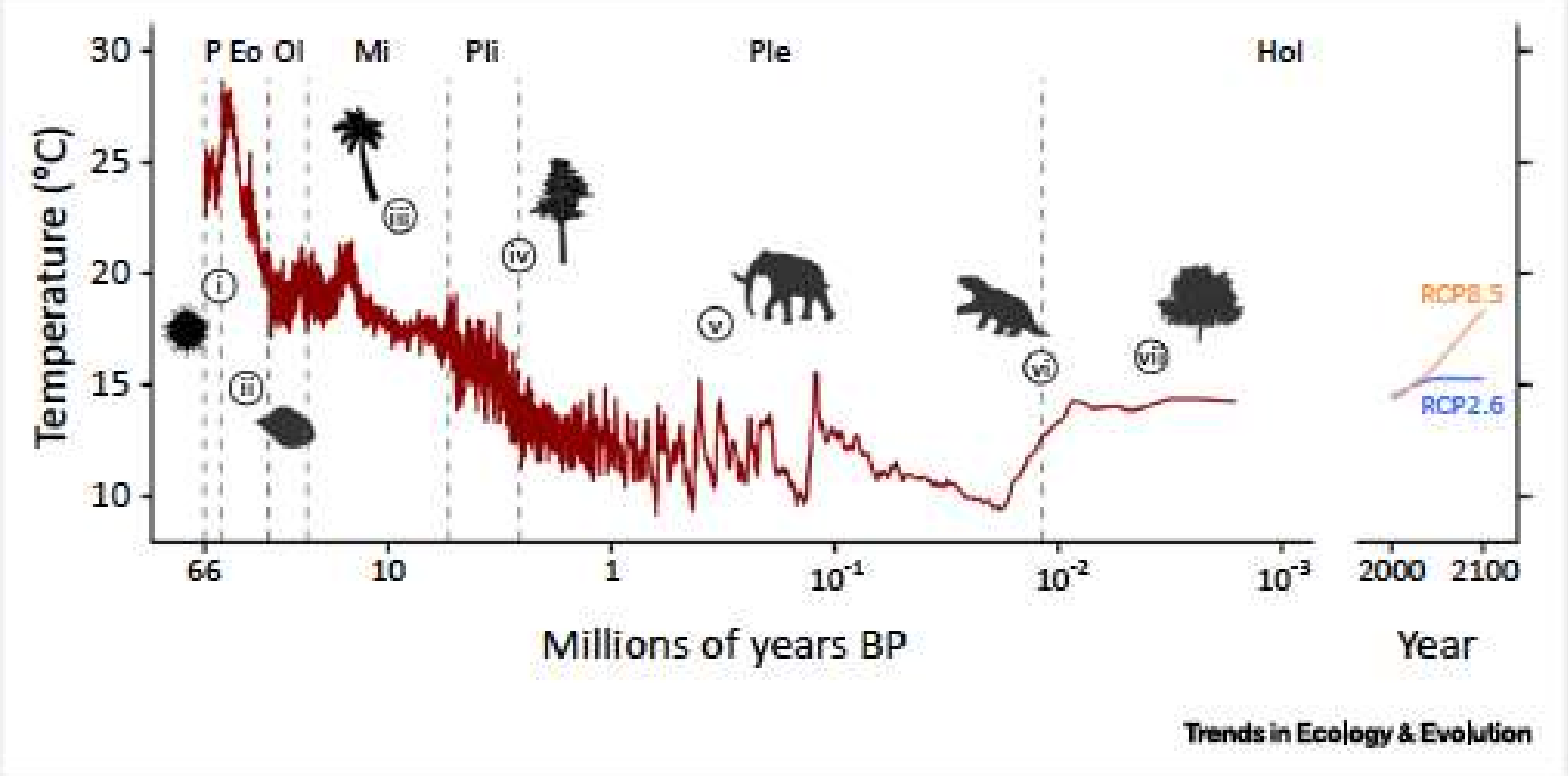
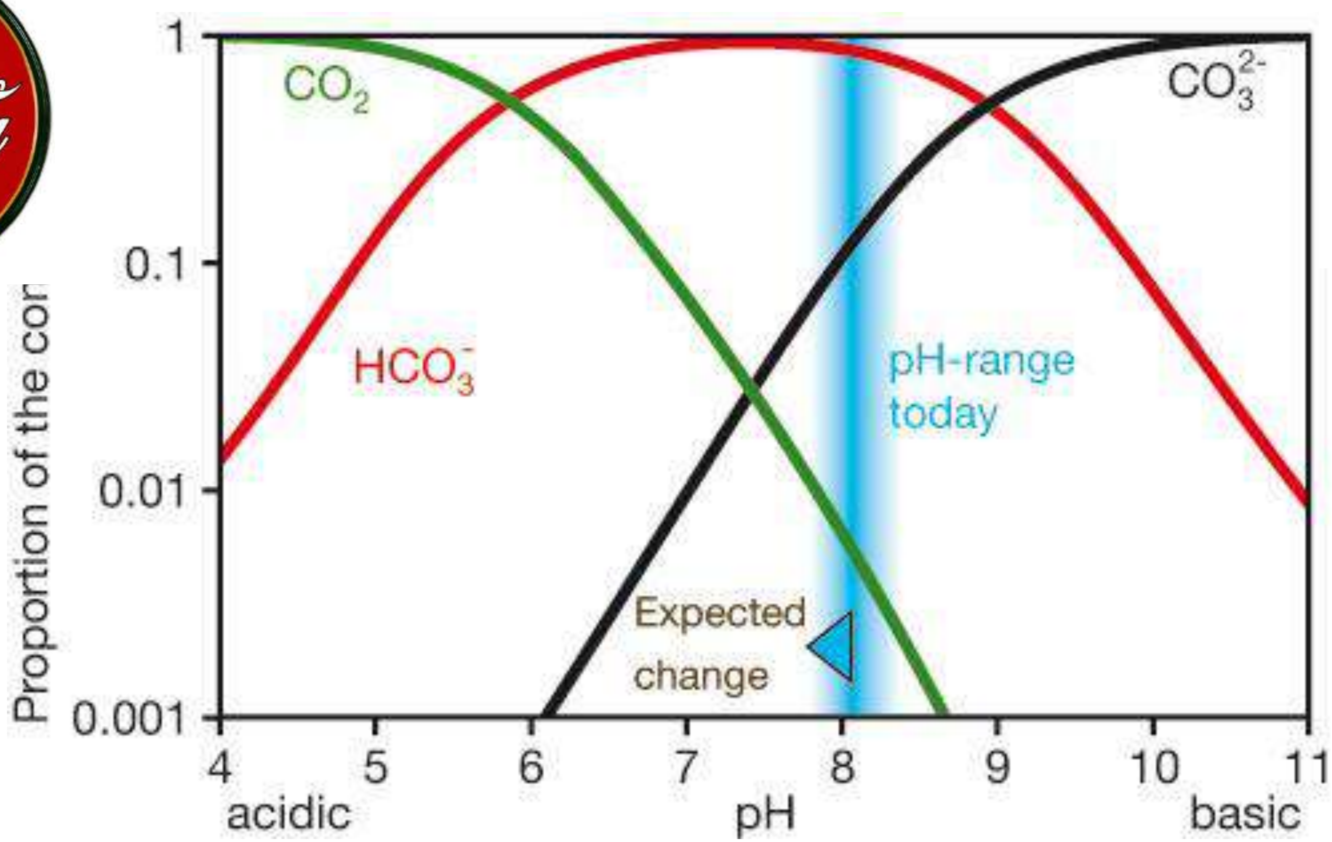



Figure I. Future Climate Forcing will Surpass those of the Previous Several Million Years [2]. Abbreviations: Eo, Eocene, Hol, Holocene; Mi, Miocene, Ol, Oligocene, P, Palaeocene, Pli, Pliocene, Ple, Pleistocene.

$CO_2$ (acid) + $CO_3^{2-}$ (alkali) + $H_2O$ = $2HCO_3^-$





$CO_2$ used for photosynthesis

$CO_3^{2-}$ used for calcification ($CaCO_3$)

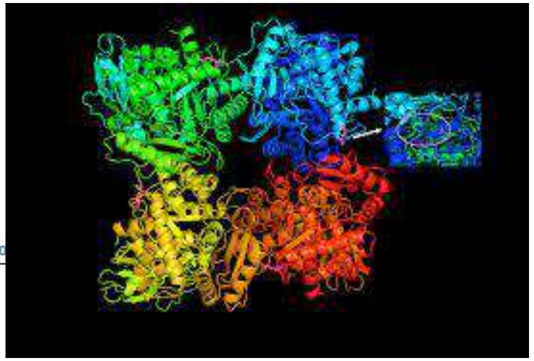
# $CO_2$ Fertilisation

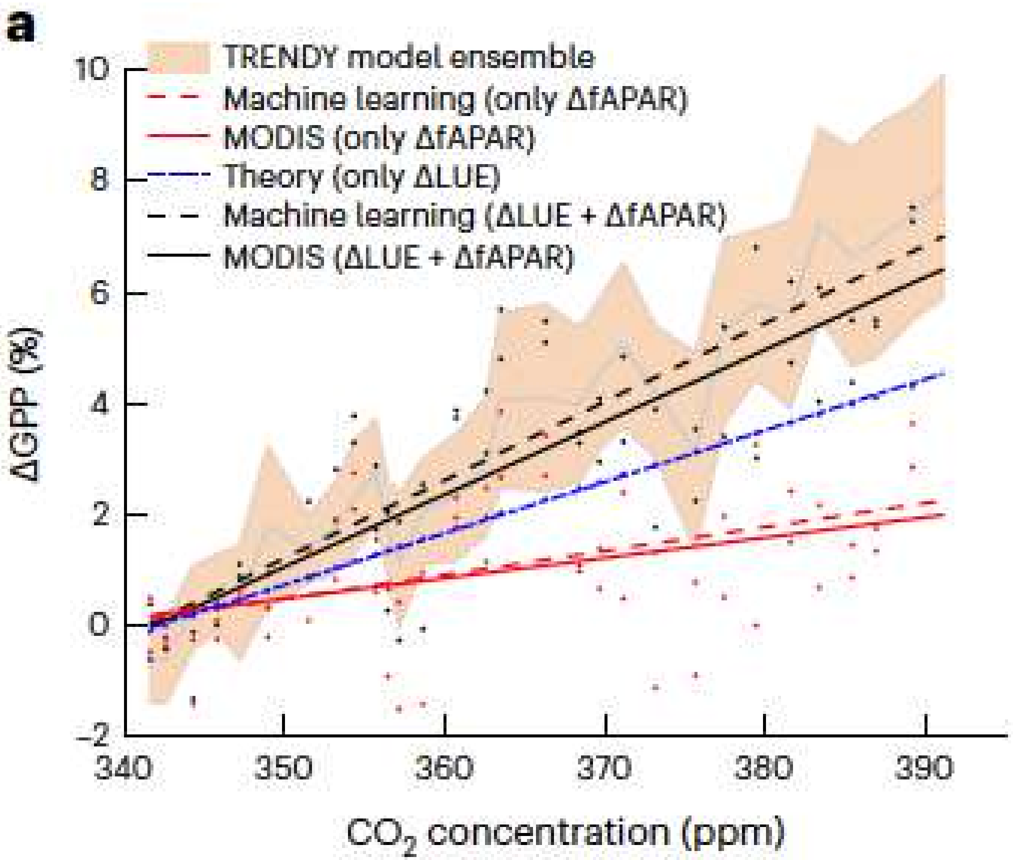
nature climate change

Article

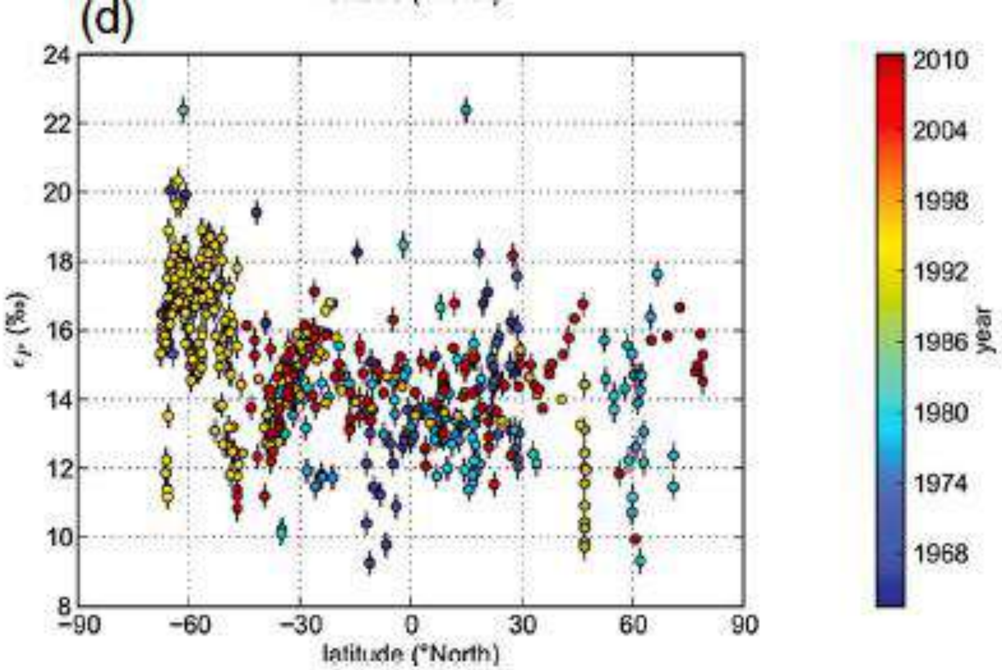
https://doi.org/10.1038/s41558-023-0

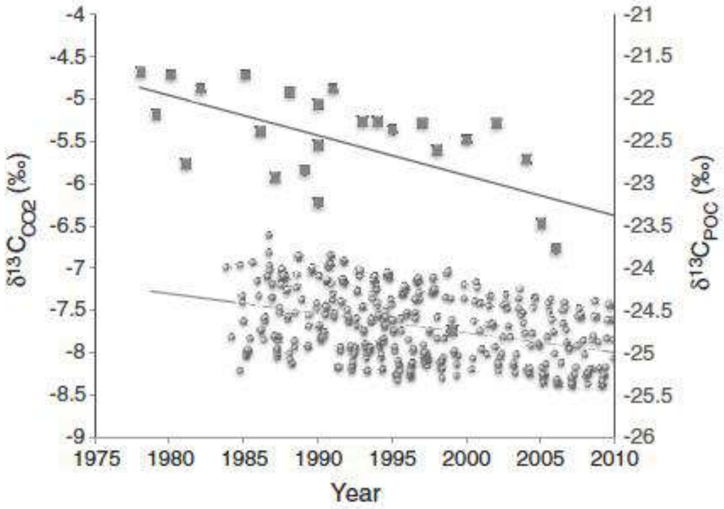
**A constraint on historic growth in global photosynthesis due to rising $CO_2$**






Land




Marine

**Evidence for changes in carbon isotopic fractionation by phytoplankton between 1960 and 2010**

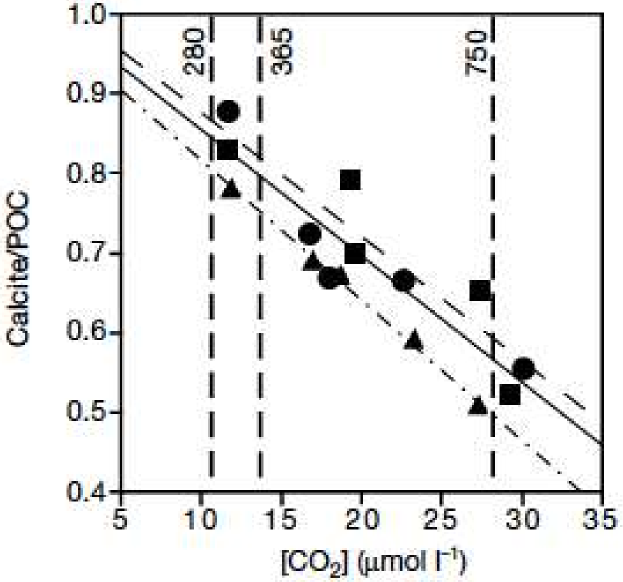
J. N. Young,[1,2] J. Bruggeman,[1] R. E. M. Rickaby,[1] J. Erez,[3] and M. Conte[4]

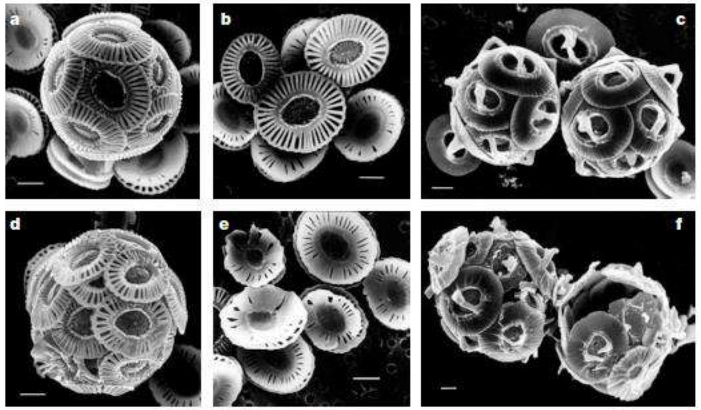
# Ocean Acidification

Or higher…………..?

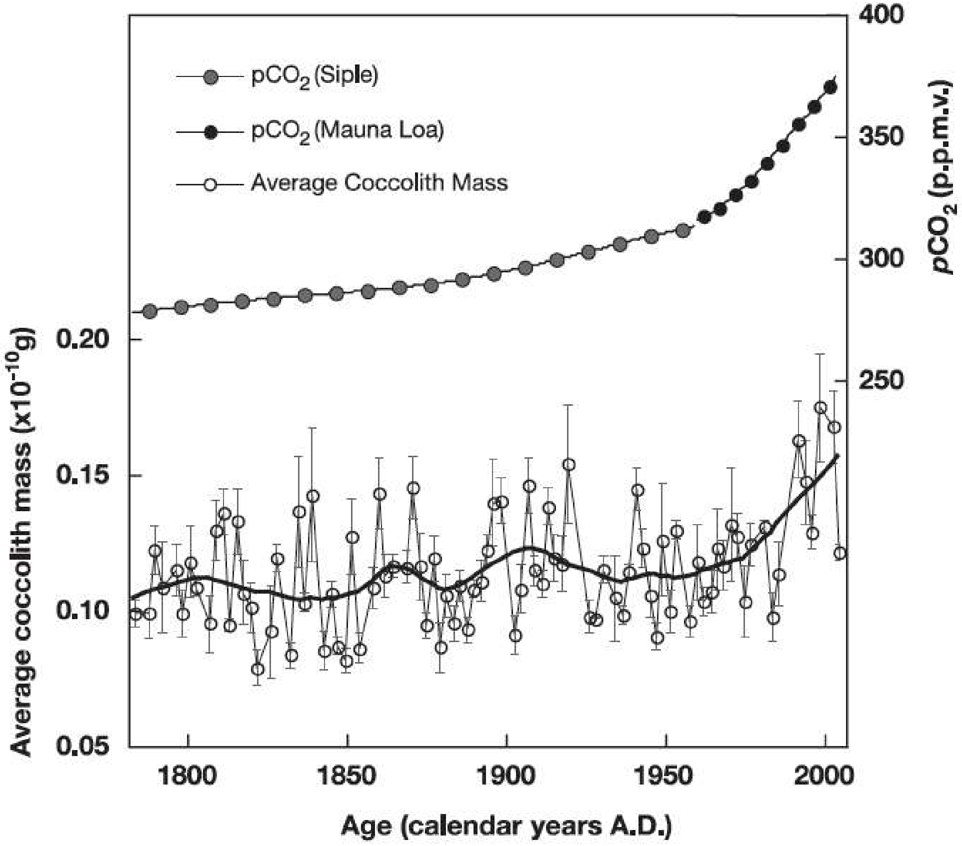
## Reduced calcification of marine plankton in response to increased atmospheric $CO_2$

Ulf Riebesell *, Ingrid Zondervan*, Björn Rost*, Philippe D. Tortell†, Richard E. Zeebe*‡ & François M. M. Morel†




Lower calcification……….?



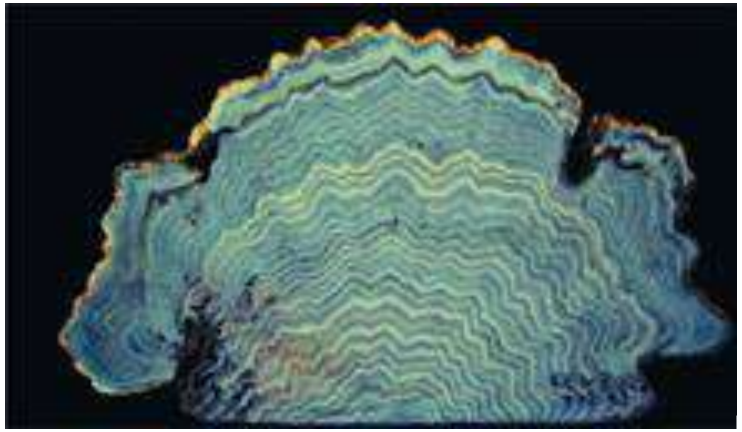

## Phytoplankton Calcification in a High-$CO_2$ World

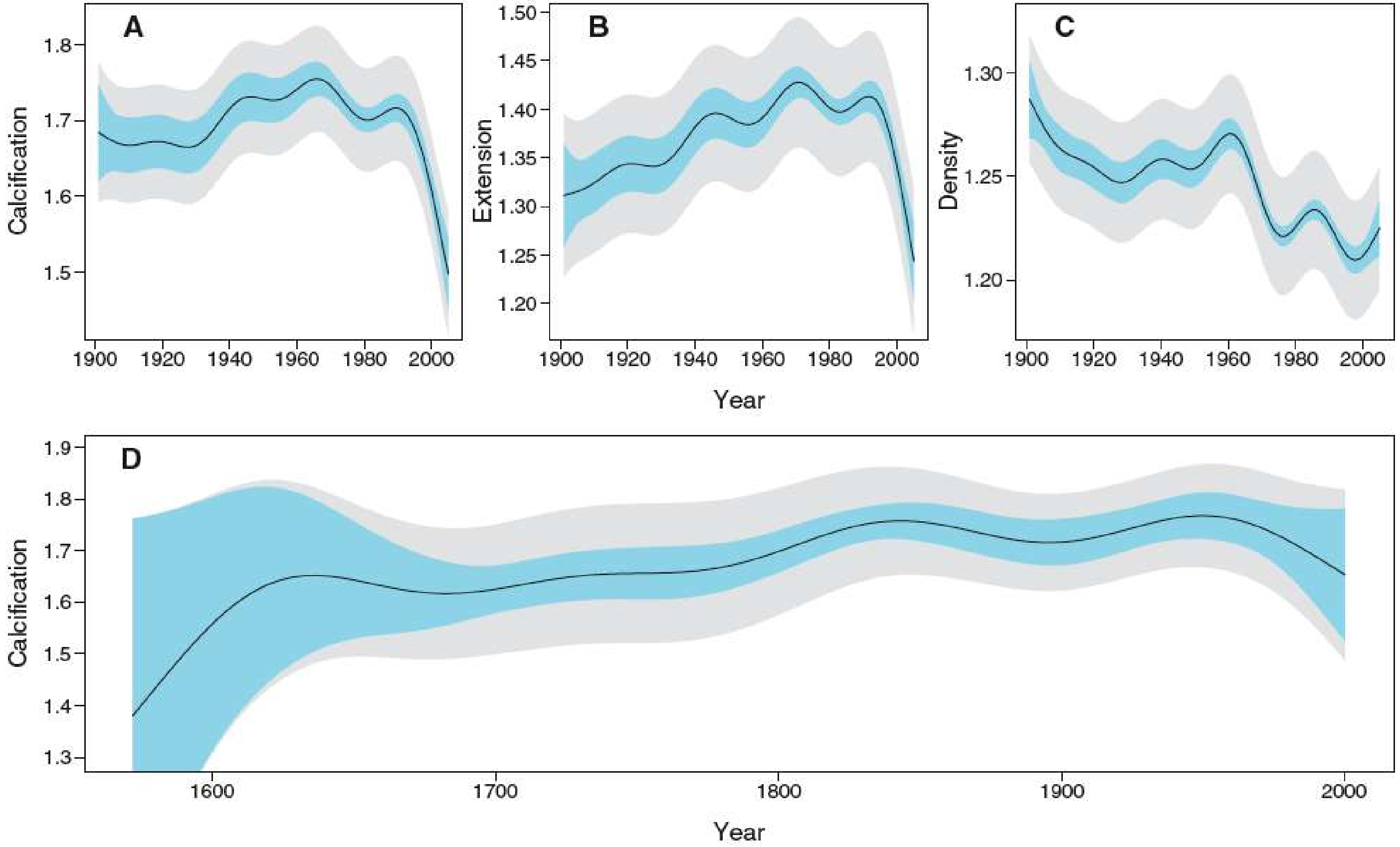
M. Debora Iglesias-Rodriguez,[1*] Paul R. Halloran,[2*] Rosalind E. M. Rickaby,[2] Ian R. Hall,[3] Elena Colmenero-Hidalgo,[3†] John R. Gittins,[1] Darryl R. H. Green,[1] Toby Tyrrell,[1] Samantha J. Gibbs,[1] Peter von Dassow,[4] Eric Rehm,[5] E. Virginia Armbrust,[5] Karin P. Boessenkool[3]

De'Ath et al., 2009

# Declining Coral Calcification on the Great Barrier Reef

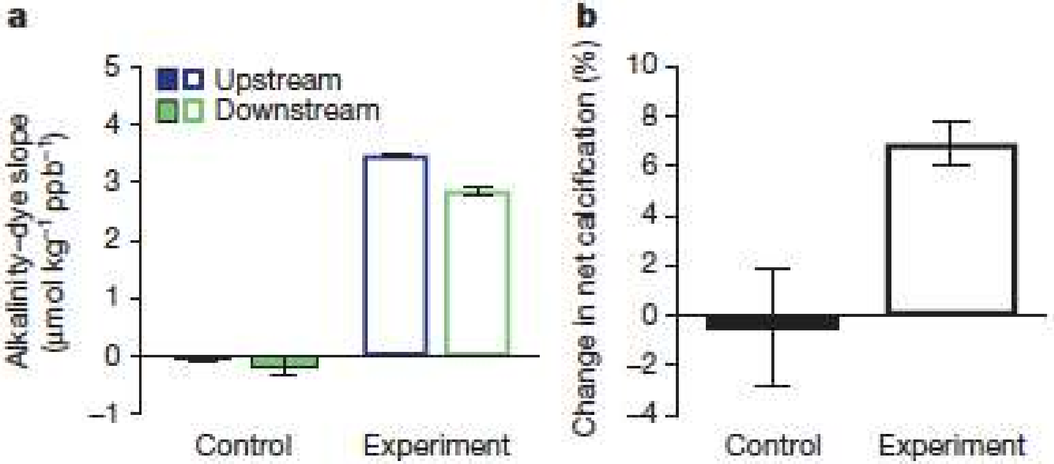
Glenn De'ath,* Janice M. Lough, Katharina E. Fabricius





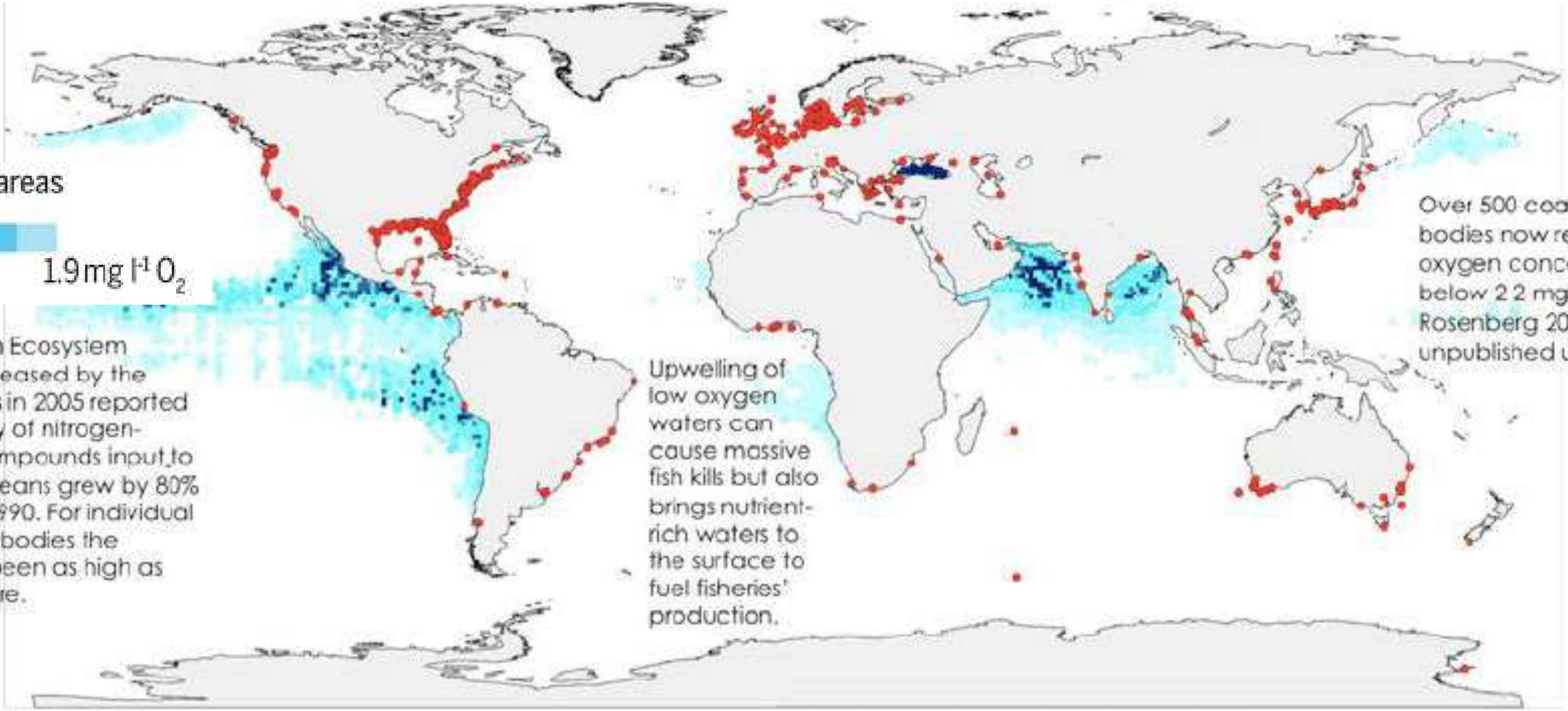

# Reversal of ocean acidification enhances net coral reef calcification

Rebecca Albright[1], Lilian Caldeira[1], Jessica Hosfelt[2], Lester Kwiatkowski[1], Jana K. Maclaren[1,3], Benjamin M. Mason[4], Yana Nebuchina[1], Aaron Ninokawa[2], Julia Pongratz[1,5], Katharine L. Ricke[1,6], Tanya Rivlin[7,8], Kenneth Schneider[1,9], Marine Sesboüé[1], Kathryn Shamberger[10,11], Jacob Silverman[12], Kennedy Wolfe[13], Kai Zhu[1,14,15] & Ken Caldeira[1]




Certainly impacts on coral reef calcification

# Ocean Deoxygenation




51

**Declining oxygen in the global ocea and coastal waters**

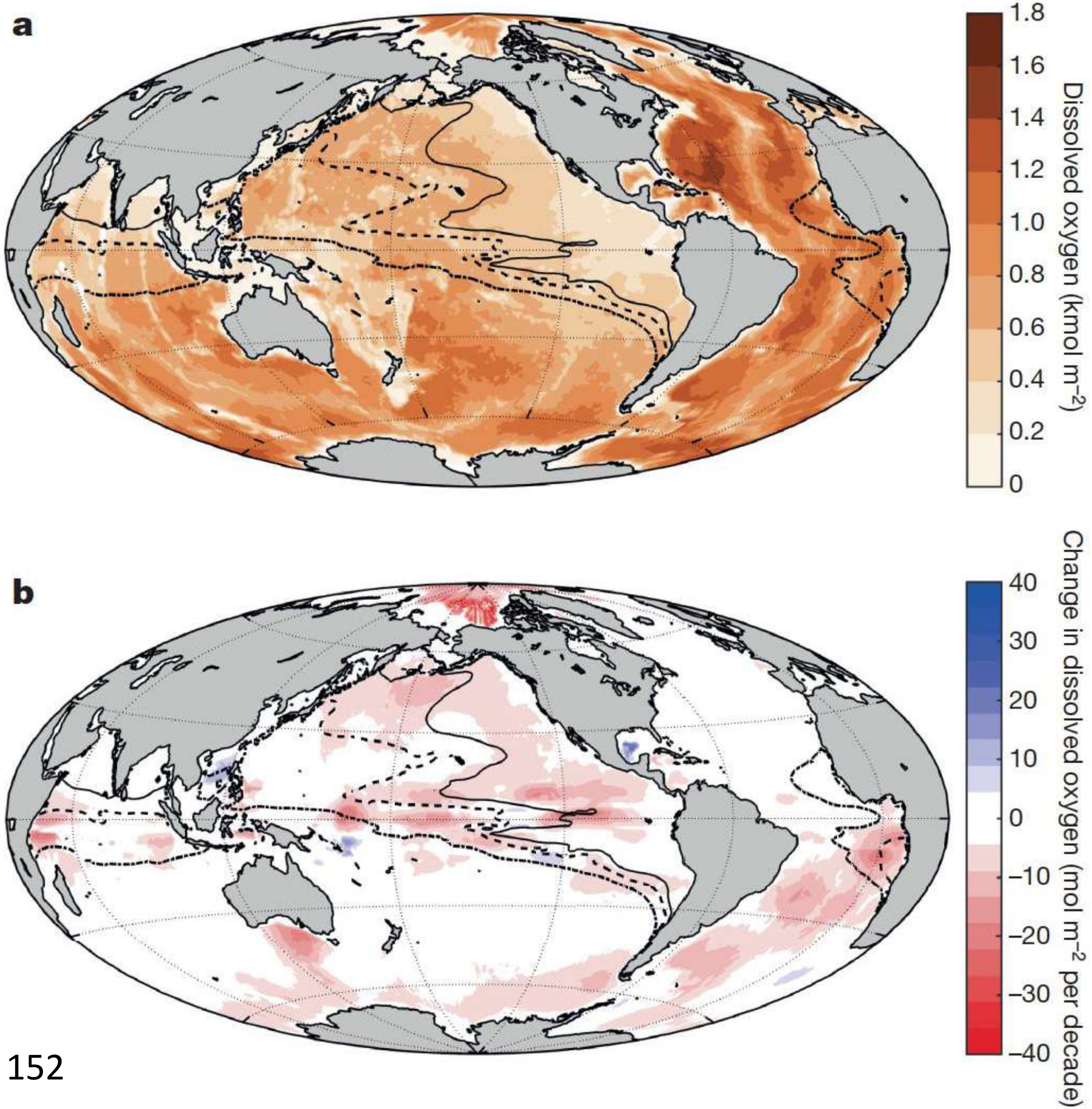
Denise Breitburg,* Lisa A. Levin, Andreas Oschlies, Marilaure Grégoire,

# Observable trends

**Table 1 | Oxygen content and change per basin**

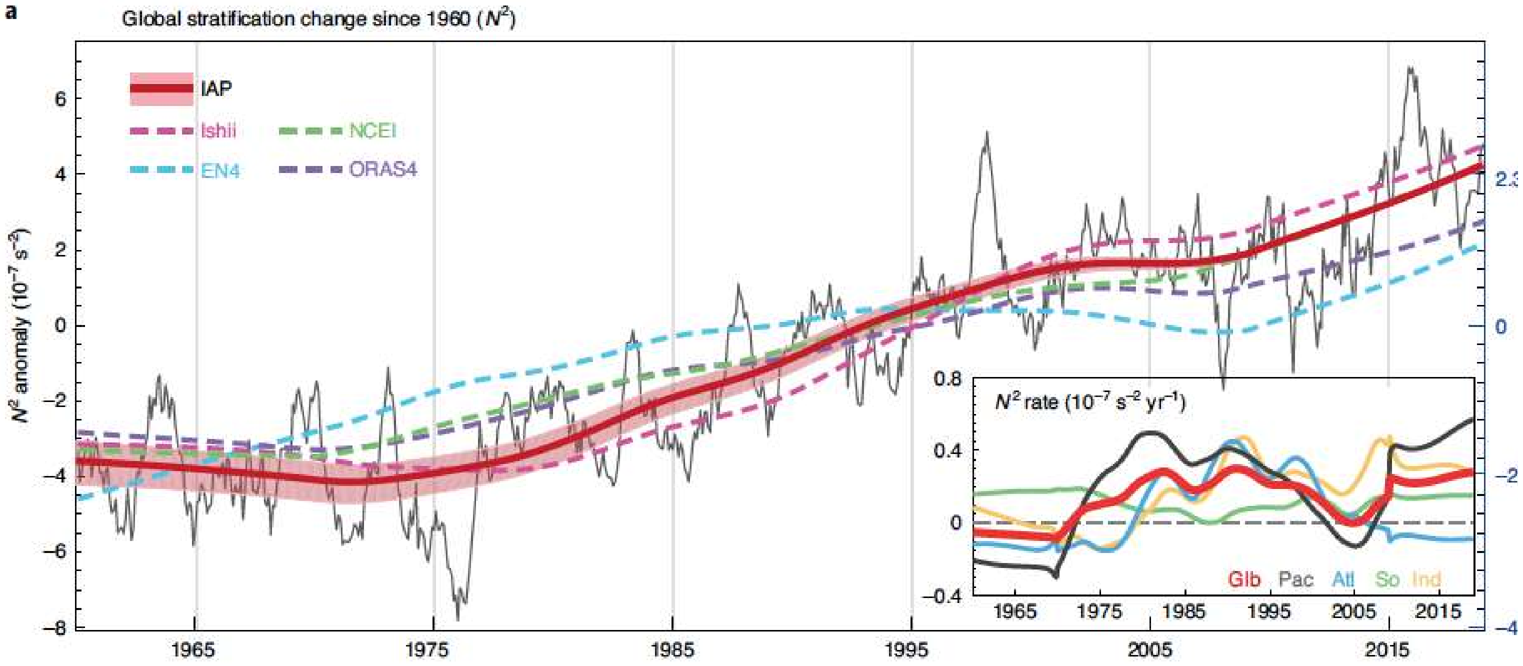
| Basin | Oxygen content (Pmol) | Oxygen change (Tmol per decade) | Change as percentage of global change | Volume as percentage of global ocean volume |
|---|---|---|---|---|
| Arctic Ocean | 4.7±0.2 | −73±30 | 7.6±3.1 | 1.2 |
| North Atlantic | 26.9±0.1 | −9±19 | 0.9±1.9 | 8.5 |
| Equatorial Atlantic | 15.9±0.0 | −72±20 | 7.5±2.1 | 5.7 |
| South Atlantic | 22.4±0.1 | −119±27 | 12.4±2.8 | 7.8 |
| North Pacific | 24.5±0.1 | −173±40 | 18.0±4.2 | 16.3 |
| Equatorial Pacific | 25.5±0.4 | −210±125 | 21.9±13.0 | 16.3 |
| South Pacific | 33.1±0.1 | −71±37 | 7.4±3.9 | 14.3 |
| Equatorial Indian Ocean | 10.7±0.1 | −55±49 | 5.7±5.1 | 6.6 |
| South Indian Ocean | 26.1±0.1 | −27±34 | 2.8±3.5 | 10.2 |
| Southern Ocean | 37.6±0.1 | −152±47 | 15.8±4.9 | 13.1 |
| **Total** | **227.4±1.1** | **−961±429** | **100** | **100** |

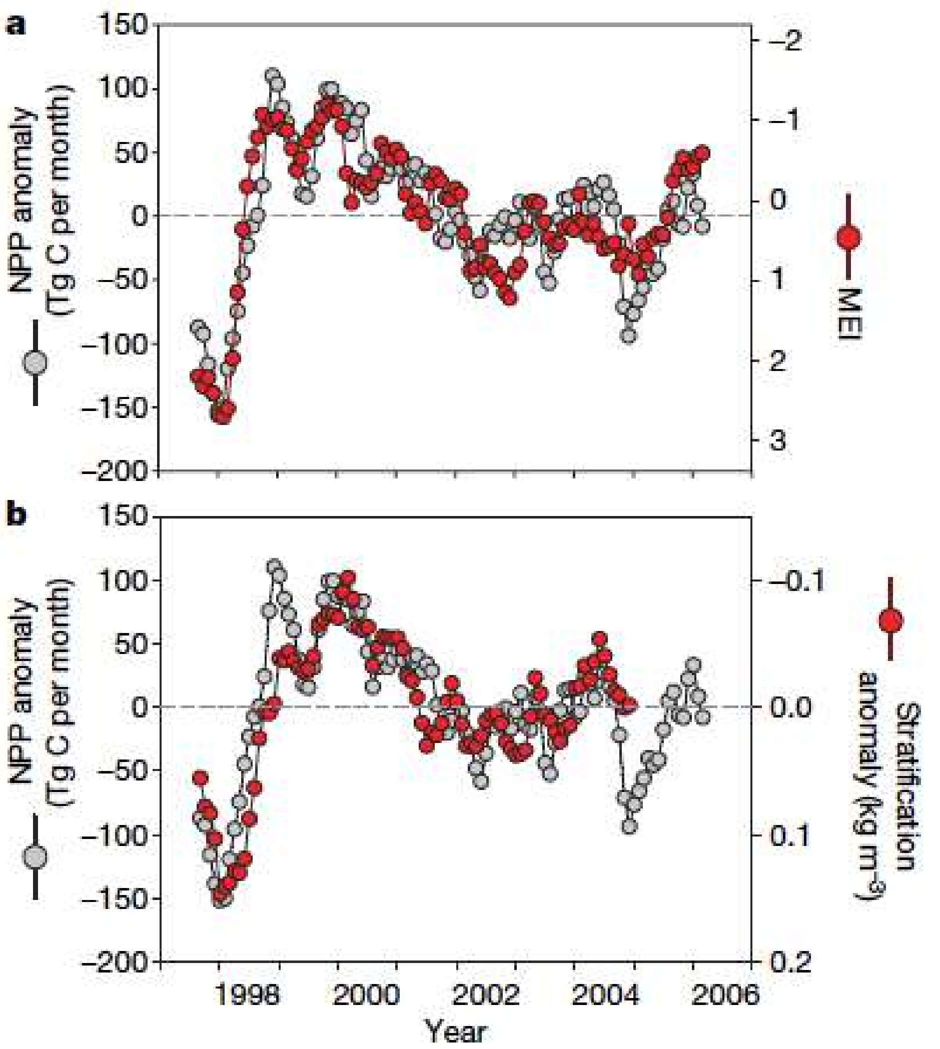
Trends that are more significant than two standard errors are marked in light grey. See Extended Data Table 1 for an extended version of this table.



# Increasing ocean stratification over the past half-century

Guancheng Li[1,2,3], Lijing Cheng[1,2,3] ✉, Jiang Zhu[1,2,3] ✉, Kevin E. Trenberth[4], Michael E. Mann[5] and John P. Abraham[6]



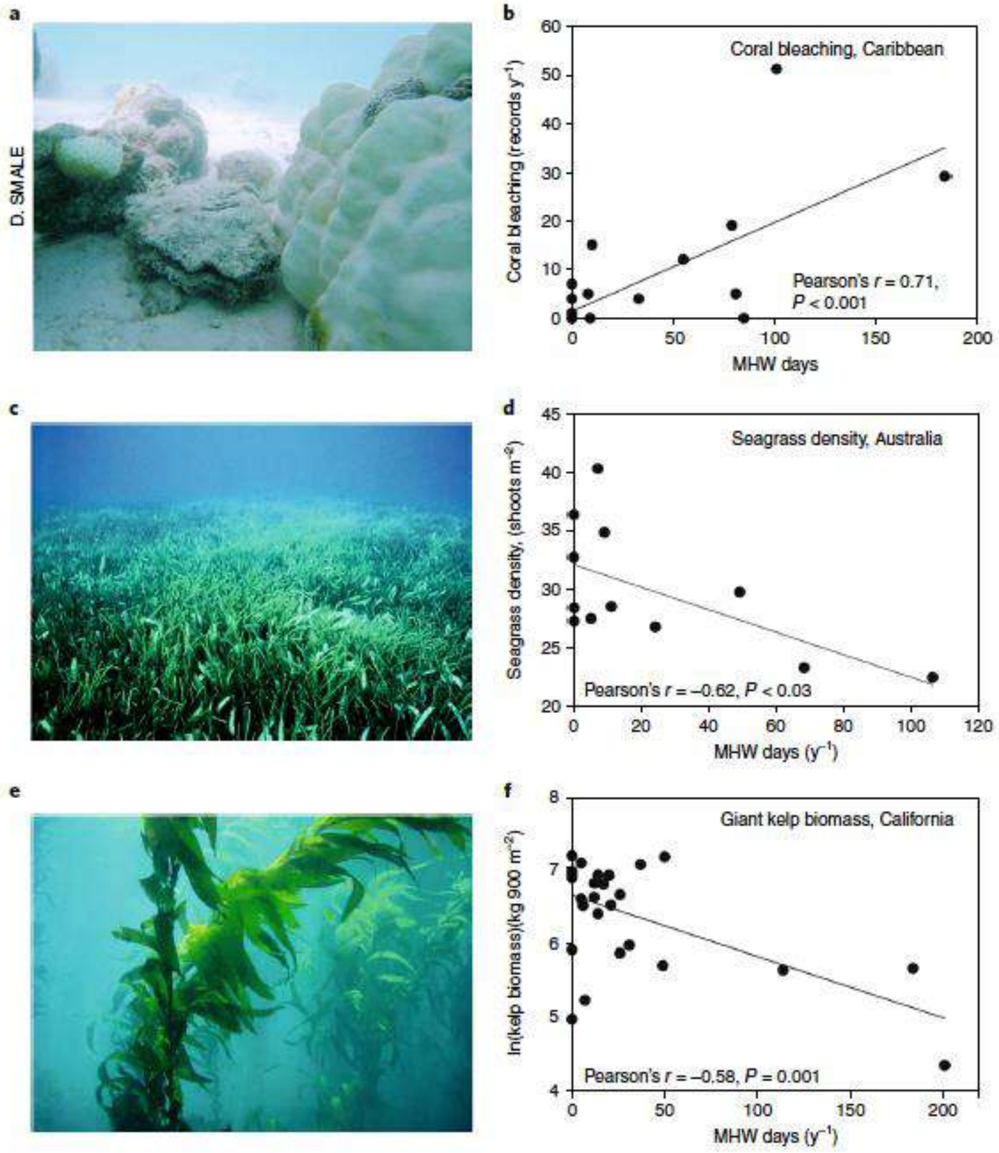

# Climate-driven trends in contemporary ocean productivity

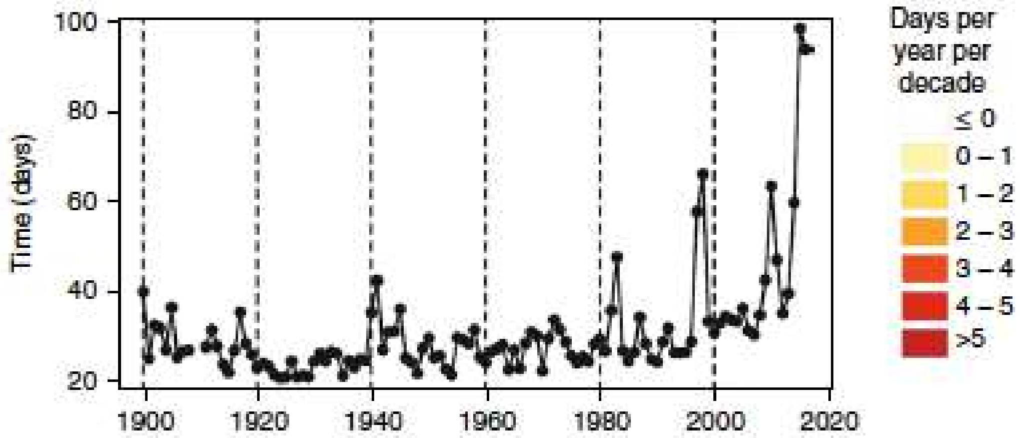
Michael J. Behrenfeld[1], Robert T. O'Malley[1], David A. Siegel[3], Charles R. McClain[4], Jorge L. Sarmiento[5], Gene C. Feldman[4], Allen J. Milligan[1], Paul G. Falkowski[6], Ricardo M. Letelier[2] & Emmanuel S. Boss[7]

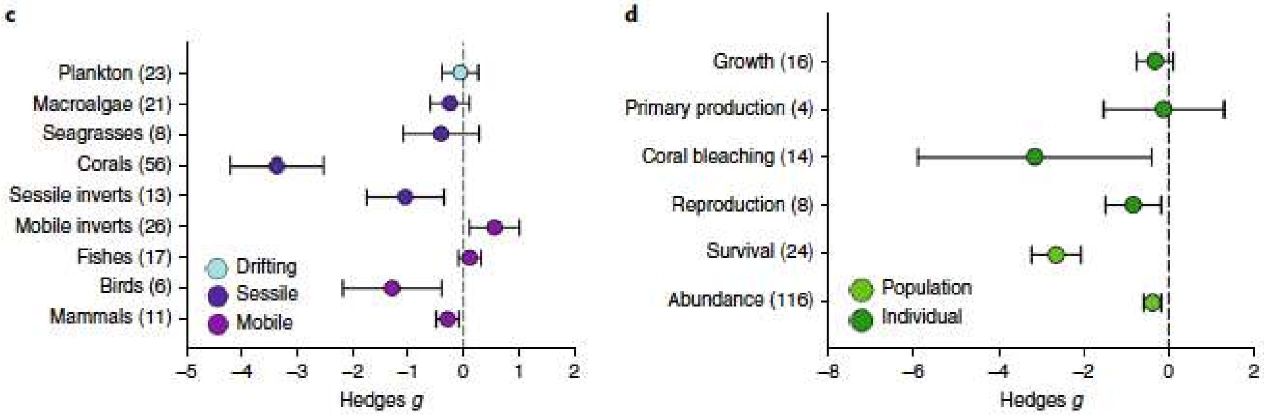
# Marine Heatwaves

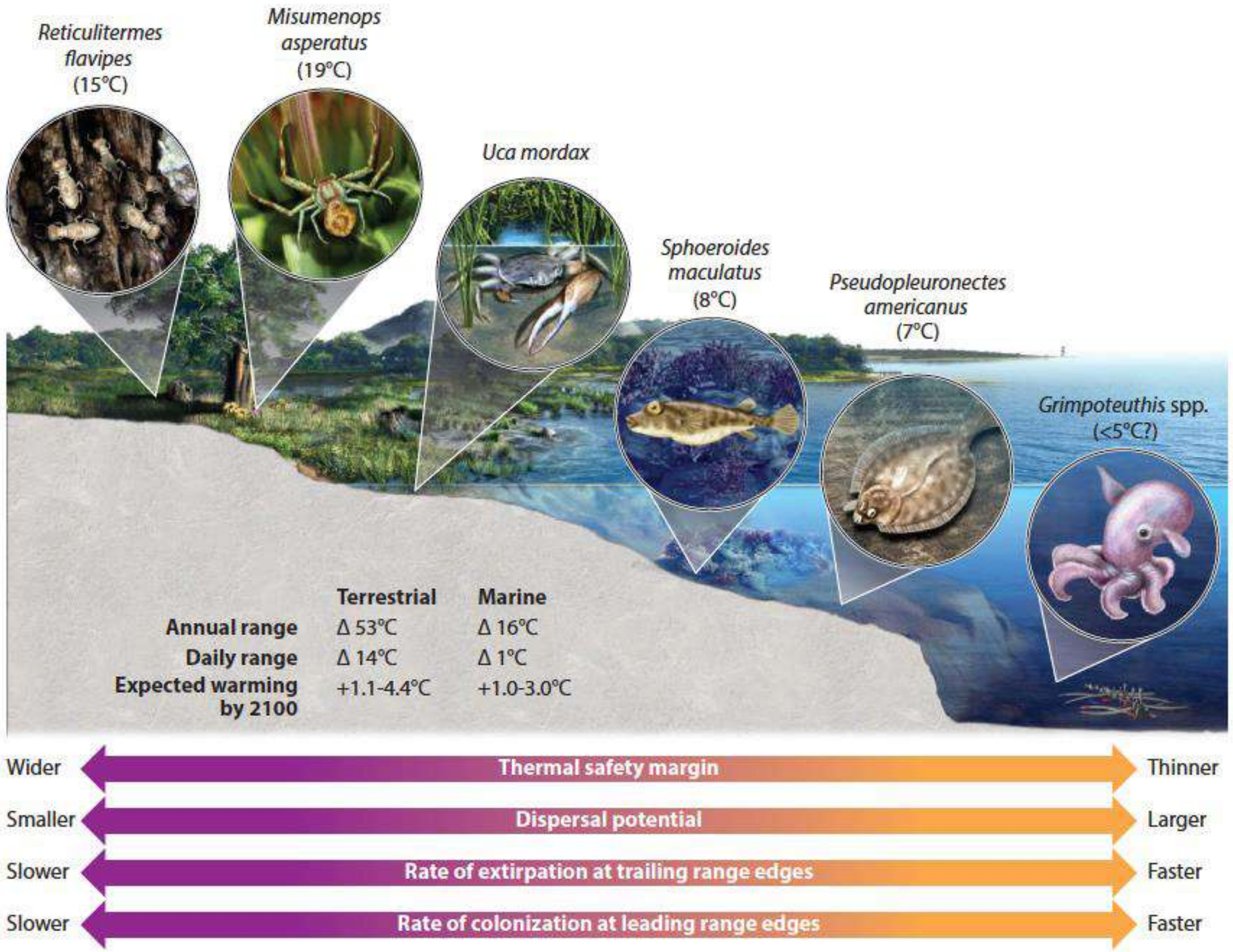
LETTERS
https://doi.org/10.1038/s41558-019-0412-1
nature climate change

## Marine heatwaves threaten global biodiversity and the provision of ecosystem services



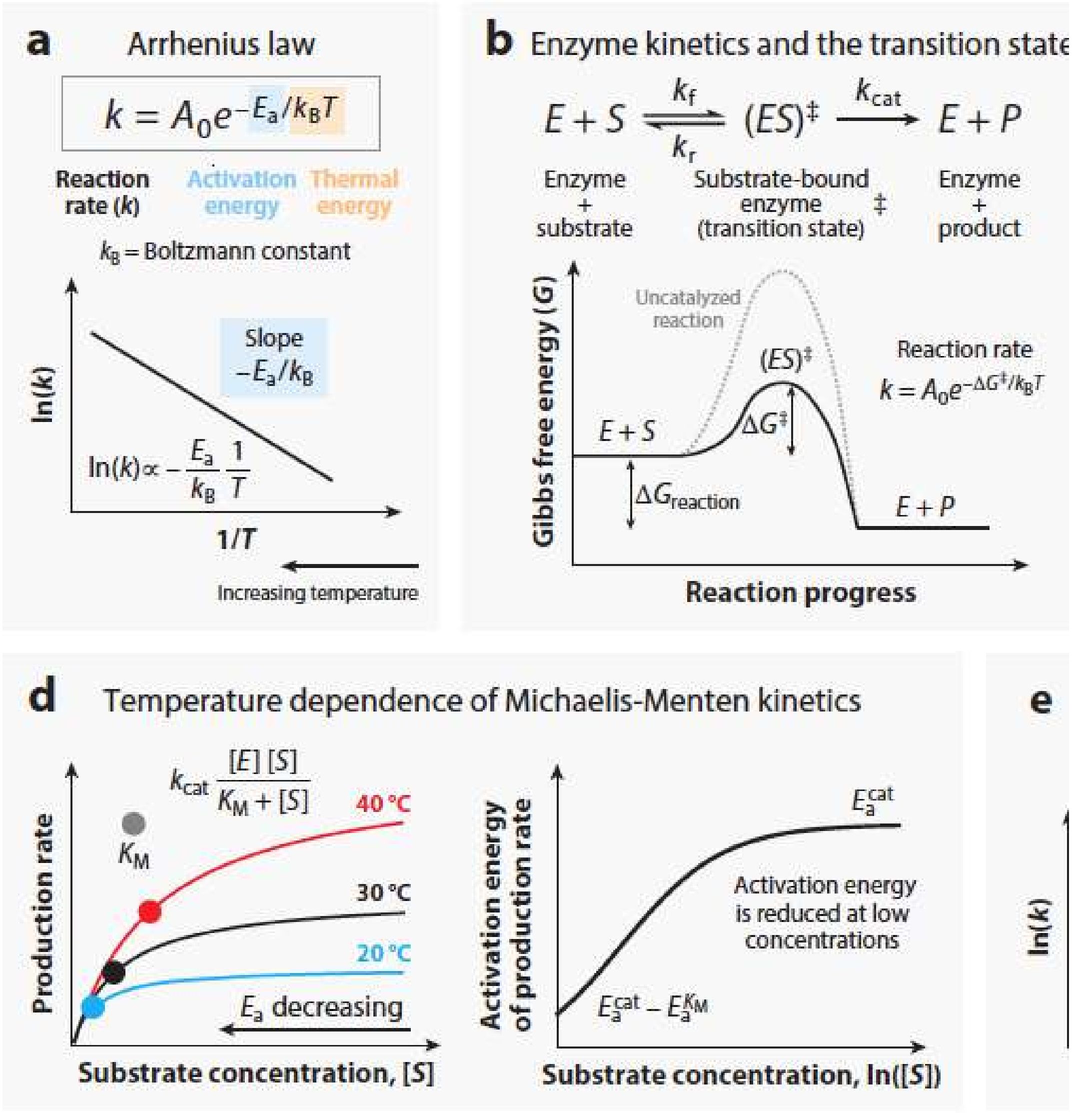






gure 6

comparative view of climate change vulnerability from terrestrial to marine ecosystems. Representative species are shown with th ermal safety margins. The thermal safety margin is a relative (not absolute) proxy for the amount of warming an organism can lerate. Lower annual and daily temperature variation in the ocean has left many marine species less evolutionarily conditioned to th climate warming, which is reflected in narrower safety margins. These vulnerabilities are exacerbated by reduced access to the fuges in the ocean. The numbers at the bottom show the average annual and daily range of temperatures from local monitoring tions, as well as the expected warming by 2100. The examples here are drawn from the east coast of North America, including ather stations and oceanographic buoys in South Carolina. Illustration by N.R. Fuller of Sayo-Art LLC.

# Temperature effects at the level of the enzyme/cell




Enzymes reduce the Activation energy of a reaction for biological temperatures and so enhance the rate

Temperature speeds up the rate of the reaction and provides more thermal energy

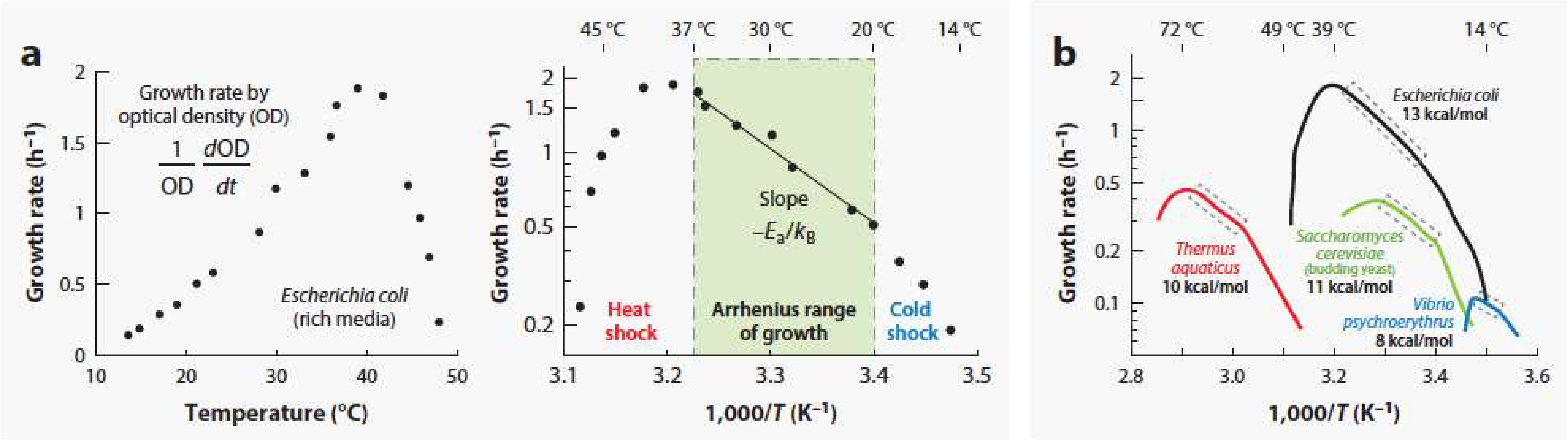
But enzymes have thermal limits: the rate is catalyzed to an optima until the enzyme loses structure/denatures

Membrane fluidity is also strongly T-dependent

*Annual Review of Biophysics*

# The Effects of Temperature on Cellular Physiology

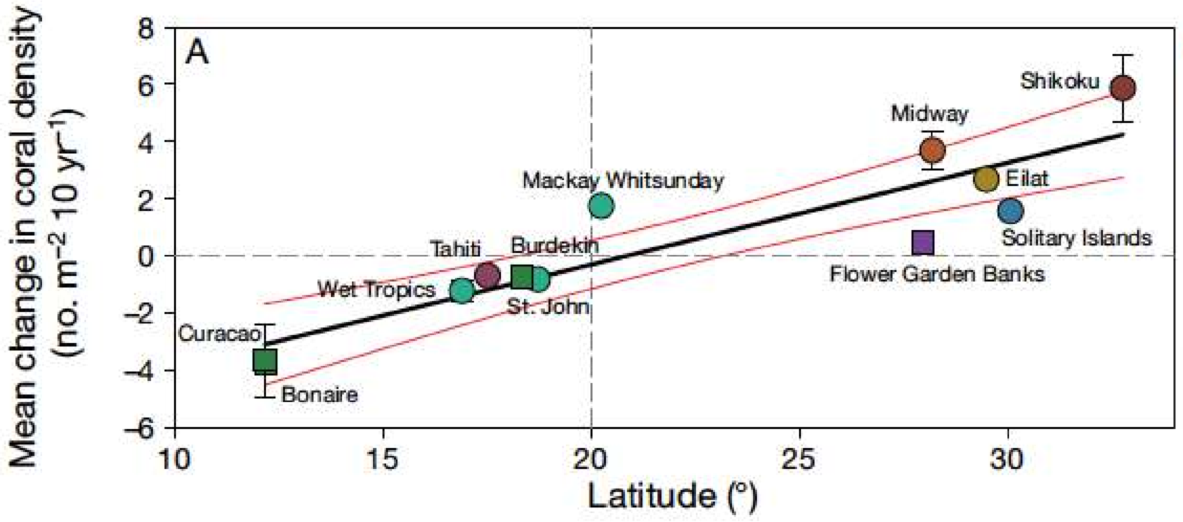
Benjamin D. Knapp[1] and Kerwyn Casey Huang[1,2,3,4]

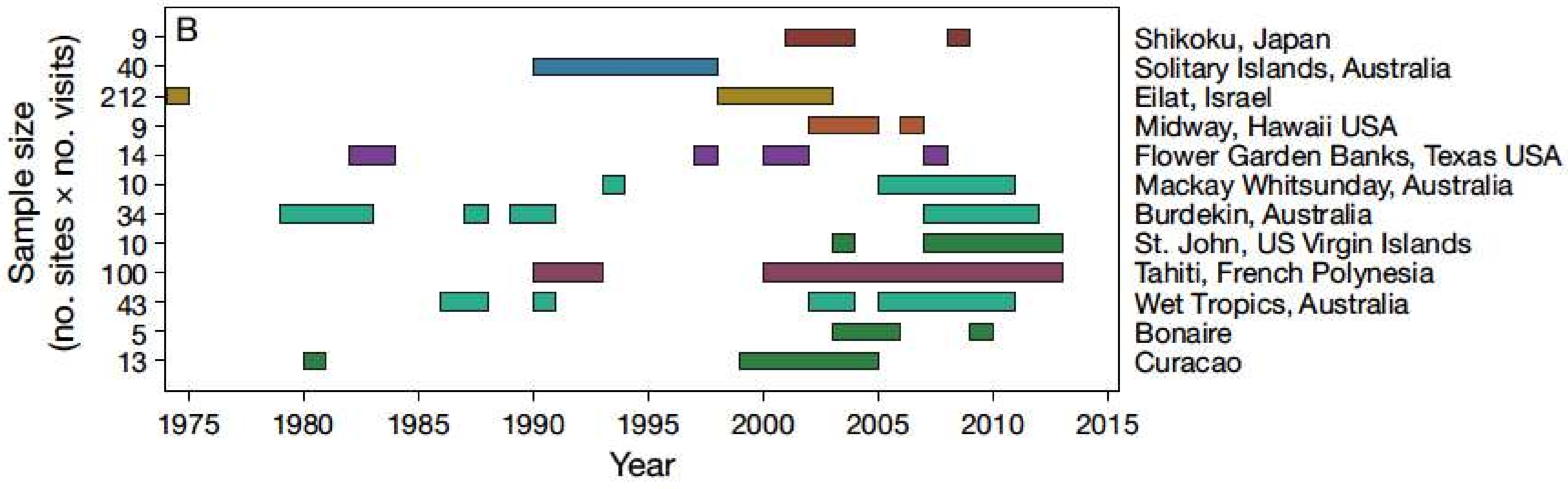



## Figure 2

Cellular growth rates obey species-specific Arrhenius laws. (*a*) Growth rates of *Escherichia coli* in rich medium were measured at various temperatures (*left*). An Arrhenius plot [log(growth rate) versus $1/T$] reveals a range of temperatures (20–37°C) over which the data are approximately linear, a so-called Arrhenius range (*right*). Temperatures above and below the Arrhenius range produce a heat- and cold-shock response, respectively. Data from Reference 54. (*b*) Bacterial and eukaryotic species possess Arrhenius ranges (*dotted boxes*)

# Coral bleaching….but some hope…




FEATURE ARTICLE



## Global biogeography of coral recruitment: tropical decline and subtropical increase

N. N. Price[1,*], S. Muko[2], L. Legendre[3], R. Steneck[4], M. J. H. van Oppen[5,6], R. Albright[5,7,18], P. Ang Jr.[8], R. C. Carpenter[9], A. P. Y. Chui[8], T.-Y. Fan[10], R. D. Gates[11], S. Harii[12], H. Kitano[13], H. Kurihara[14], S. Mitarai[15], J. L. Padilla-Gamiño[16], K. Sakai[12], G. Suzuki[17], P. J. Edmunds[9]



Tropicalisation of the subtropics…

# Climate Change at the level of the organism/ecosystem

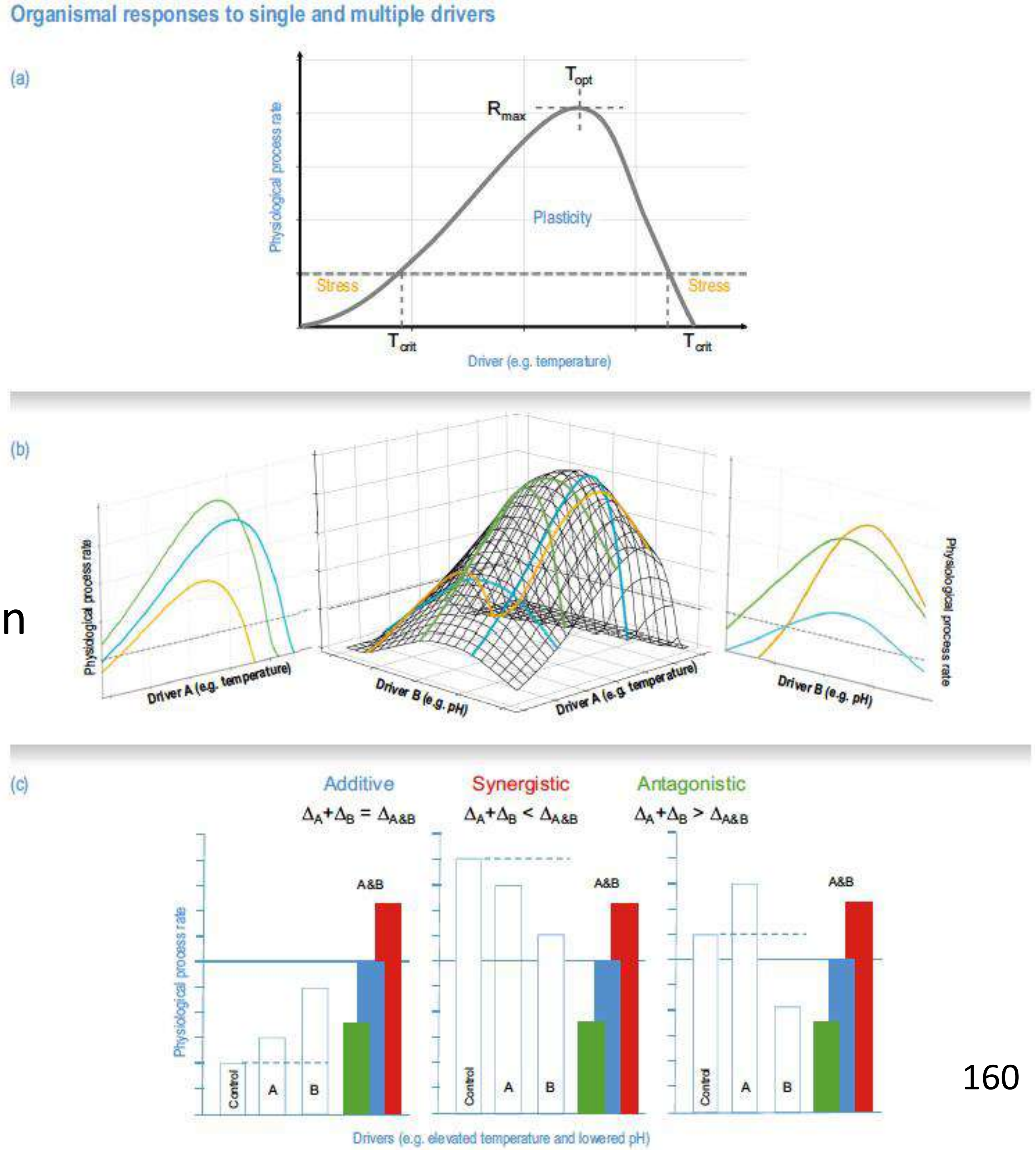
- Latitudinal Migration
- Ecosystem Restructure
- Phenological mismatch

# Organism Impacts realized through Niches

The response curve for one driver can depend on other drivers (e.g. T and pH)

Impacts of multiple drivers can be additive, synertistic, or ntagonistic ie cumulative effect is equal to, larger than or smaller than the sumof the individual effects

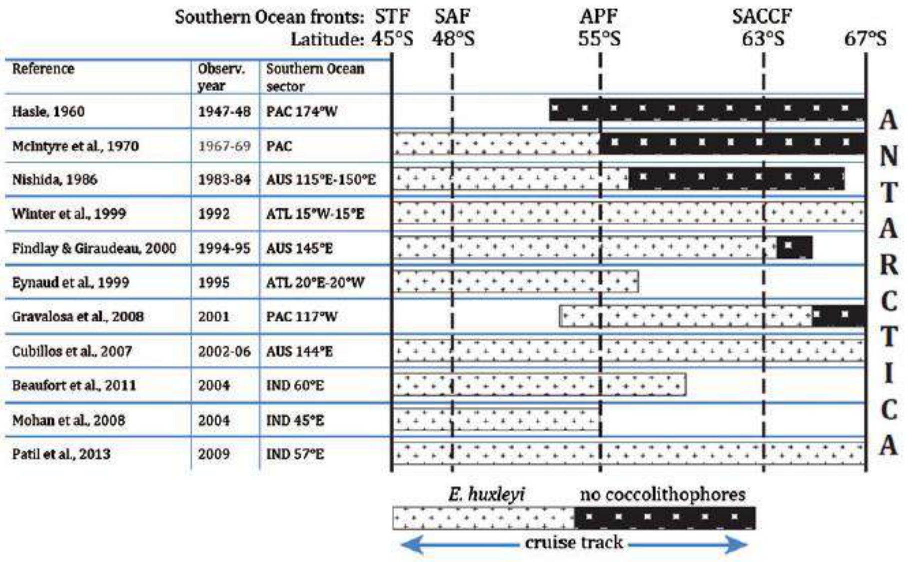
But modelling latitudinal range based on niche alone neglects biotic interactions, evolutionary change and dispersal ability

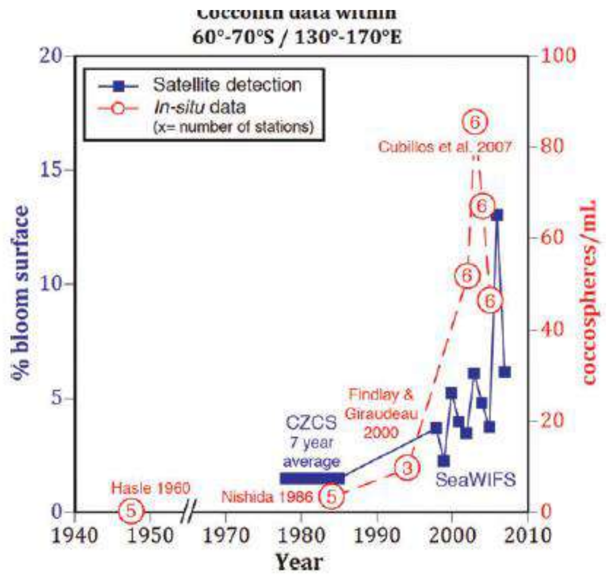



IPCC

# Latitudinal Shifts

- Help species maintain their niche
- But unless other dependent/ant species move concurrently leads to changes in ecosystem structure
- Can run out of thermal room (either poleward, with depth or with altitude)




Poleward expansion of the coccolithophore *Emiliania huxleyi*

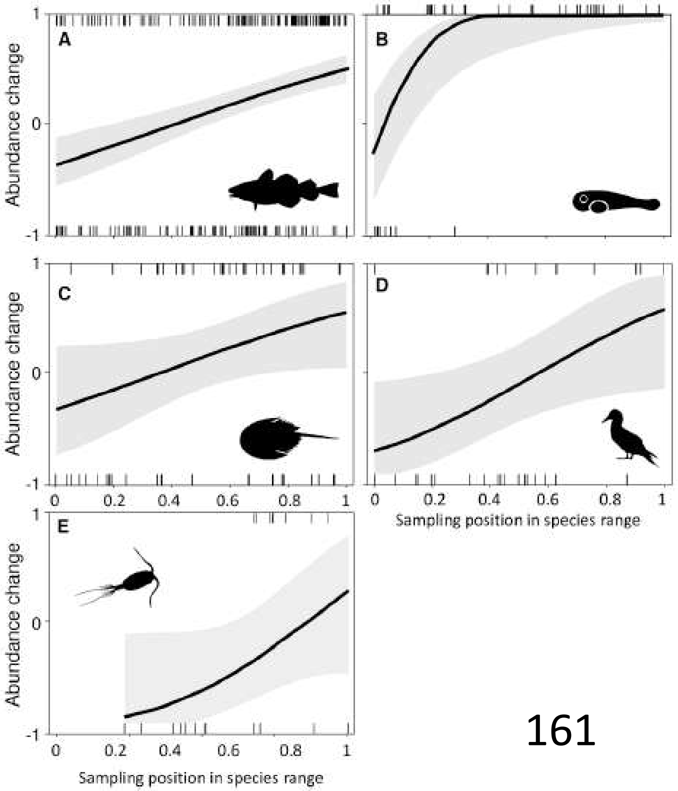

AMOS WINTER[1]*, JORIJNTJE HENDERIKS[2], LUC BEAUFORT[3], ROSALIND E. M. RICKABY[4] AND CHRISTOPHER W.



Current Biology


**Climate Change Drives Poleward Increases and Equatorward Declines in Marine Species**

range of species. Our results show that abundance increases have been most prominent where sampling has taken place at the poleward side of species ranges, and abundance declines have been most prominent where sampling has taken place at the equatorward side of species ranges. These data pro-



# Phenology mismatch

## Climate change: Seasonal shifts causing 'chaos' for UK nature

27 December 2023

Climate

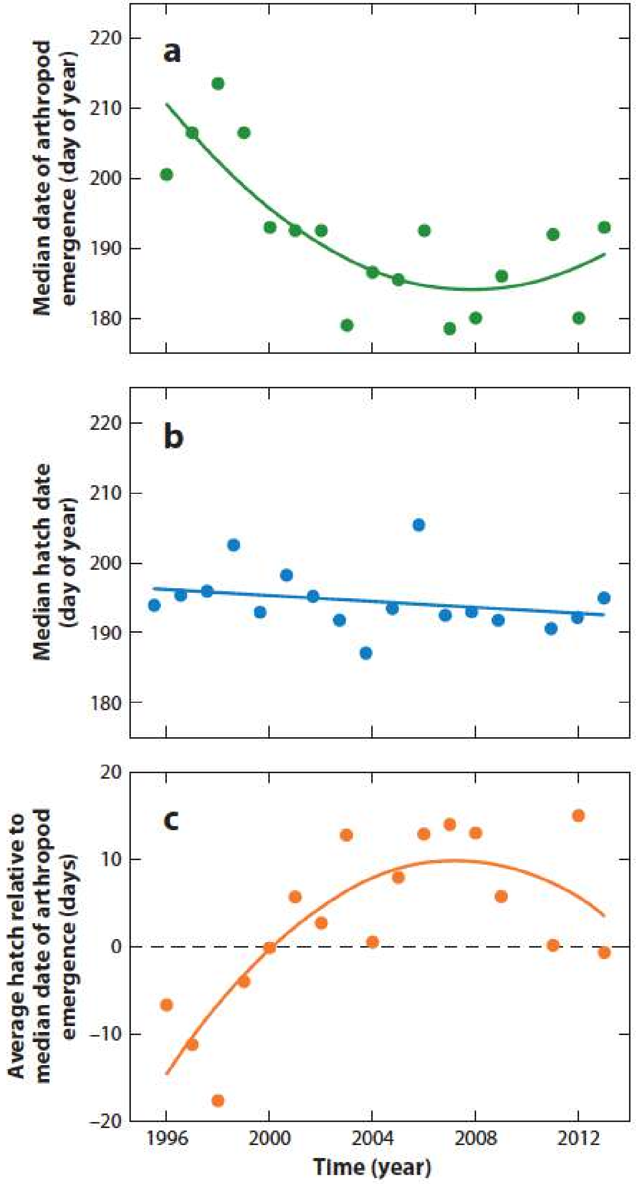

Changing seasons are affecting the reproductive cycle of animals like red deer

Warm temperatures have prompted some shrubs to come into bloom early, making them susceptible to sudden cold snaps - affecting pollinators, and the birds that feed on their seeds (and Ros' pear tree).

The UK's most iconic tree, the oak, could be particularly hard hit ….Cold snaps are getting shorter- often doesn't leave enough time to kill off diseases.
-the oak processionary moth, which has been steadily migrating northwards, whose caterpillars infest oak trees, thrive in these shorter cold spells making the oaks more vulnerable to attack from other parasites,…

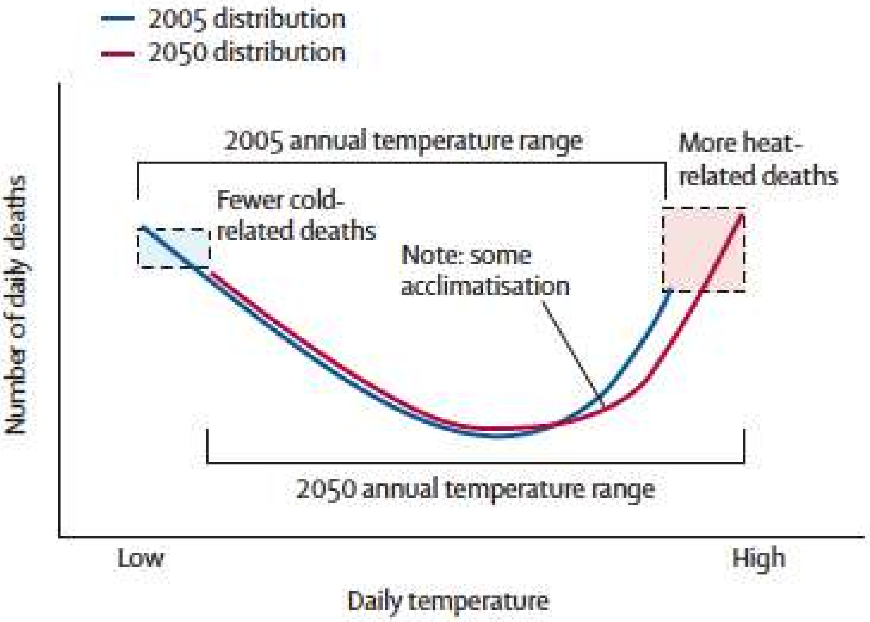
Warmer winters also impact heathlands allowing the heather beetle to kill off huge areas of heather. Animals which hibernate, like dormice, are especially threatened. They emerge from their winter sleep earlier and can quickly use up their vital remaining stores of energy.

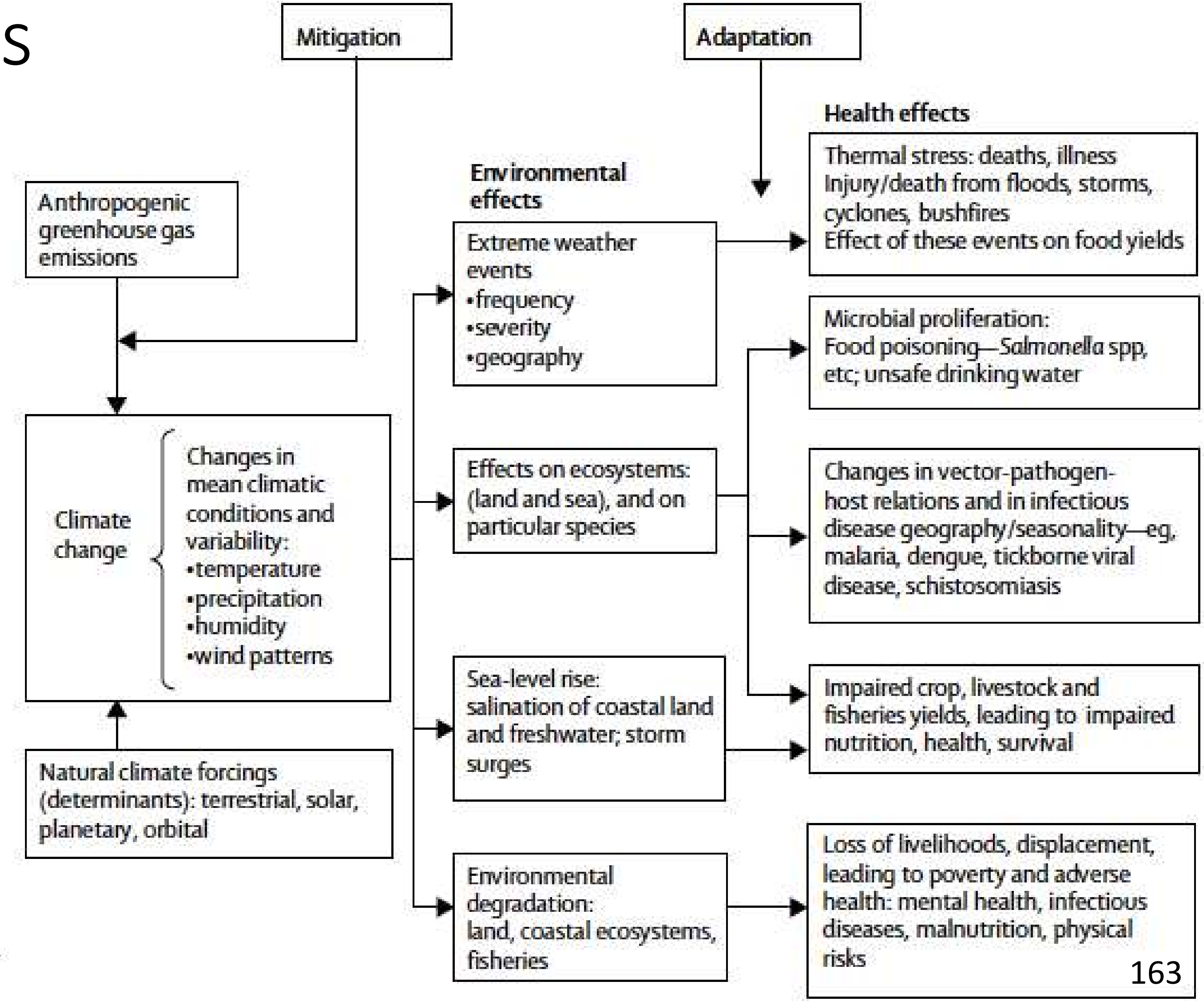
Greenland Duckling hatching and insect mismatch



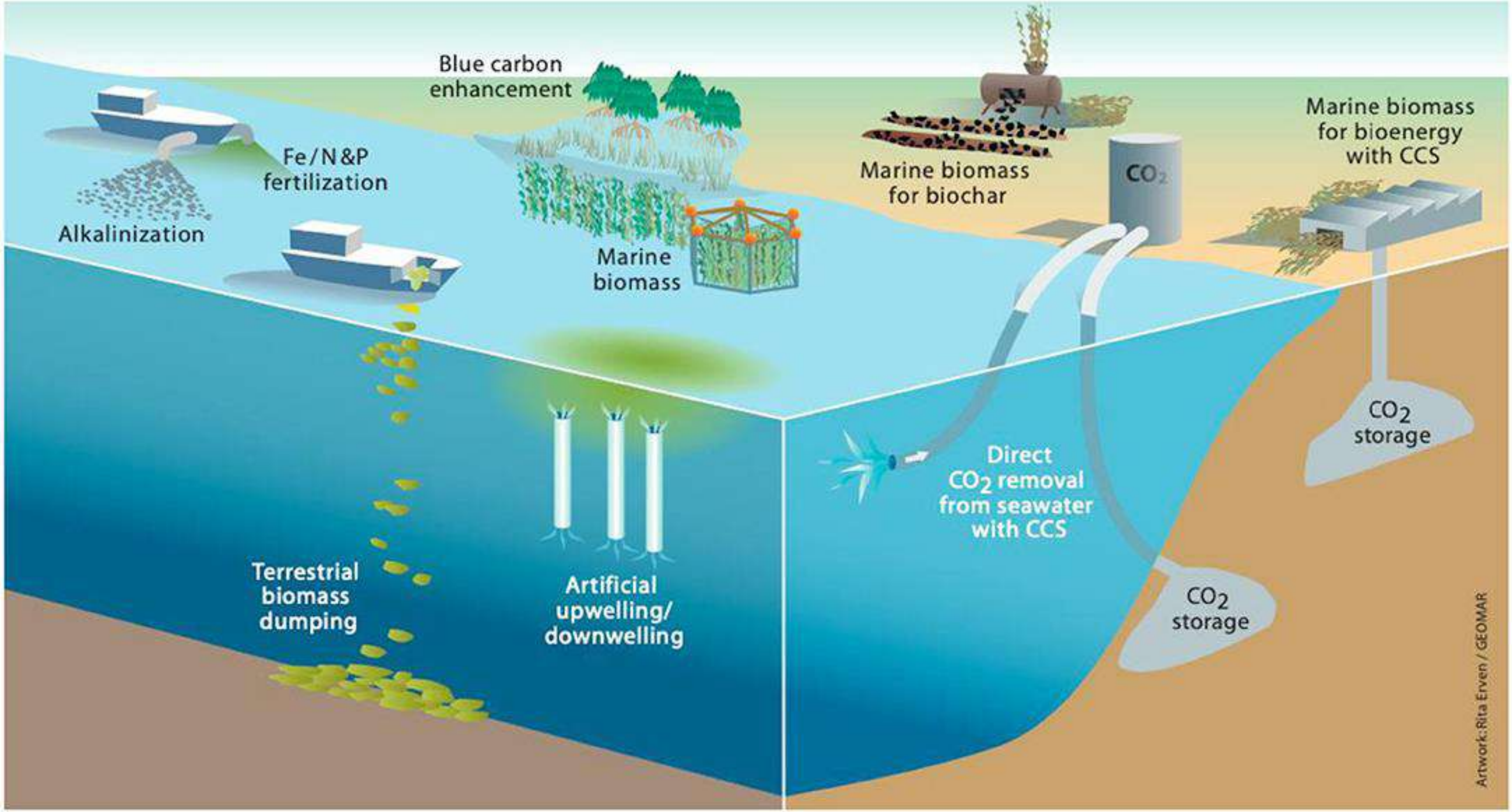
# Impact on Humans

- Disease
- Fire
- Sealevel rise (displacement)
- Food/Agriculture
- Heat Stress



# Human Interventions: Unintended Consequences

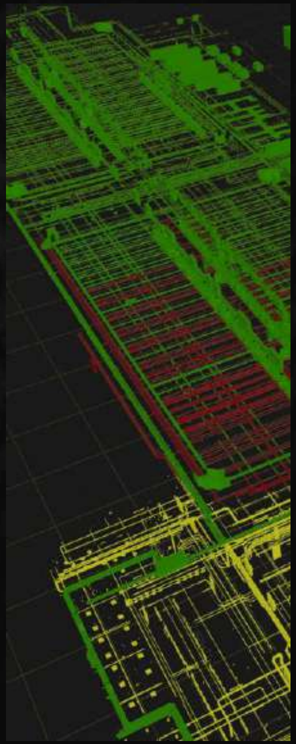


XYZ Reality

XYZ™

# THE FUTURE **OF CONSTRUCTION**

Enabling construction partners around the world to build it right, first time.




XYZ


ATOM

# DELIVERING QUALITY AND ACCURACY

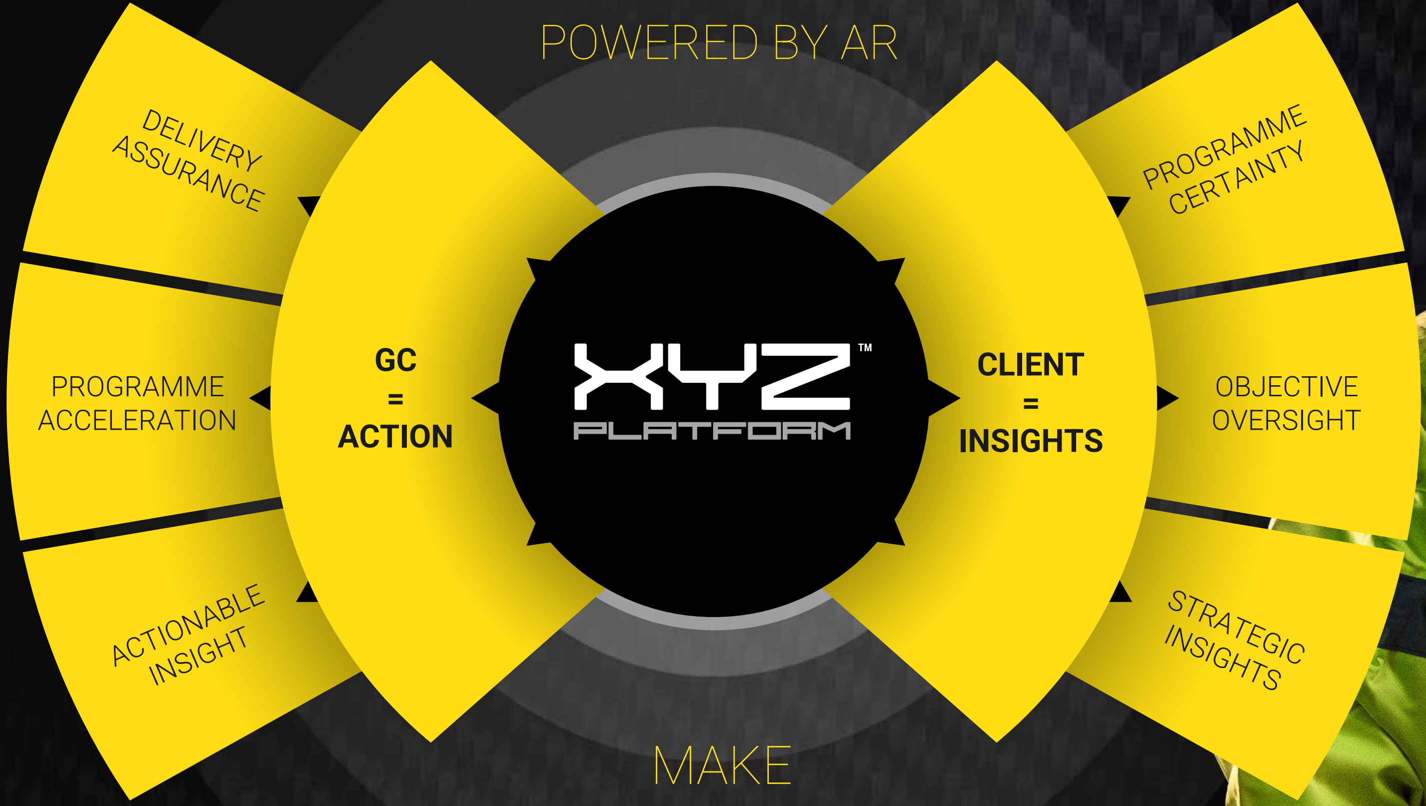
Proactively instead of reactive approach to quality

Build it right, first time philosophy

Reduction in preventable rework to under 1%

Catching issues at their lowest value stage

# END-TO-END
# PROJECT CONTROLS
POWERED BY AR




MAKE
# INFORMED DECISIONS

OBJECTIVE & REAL-TIME

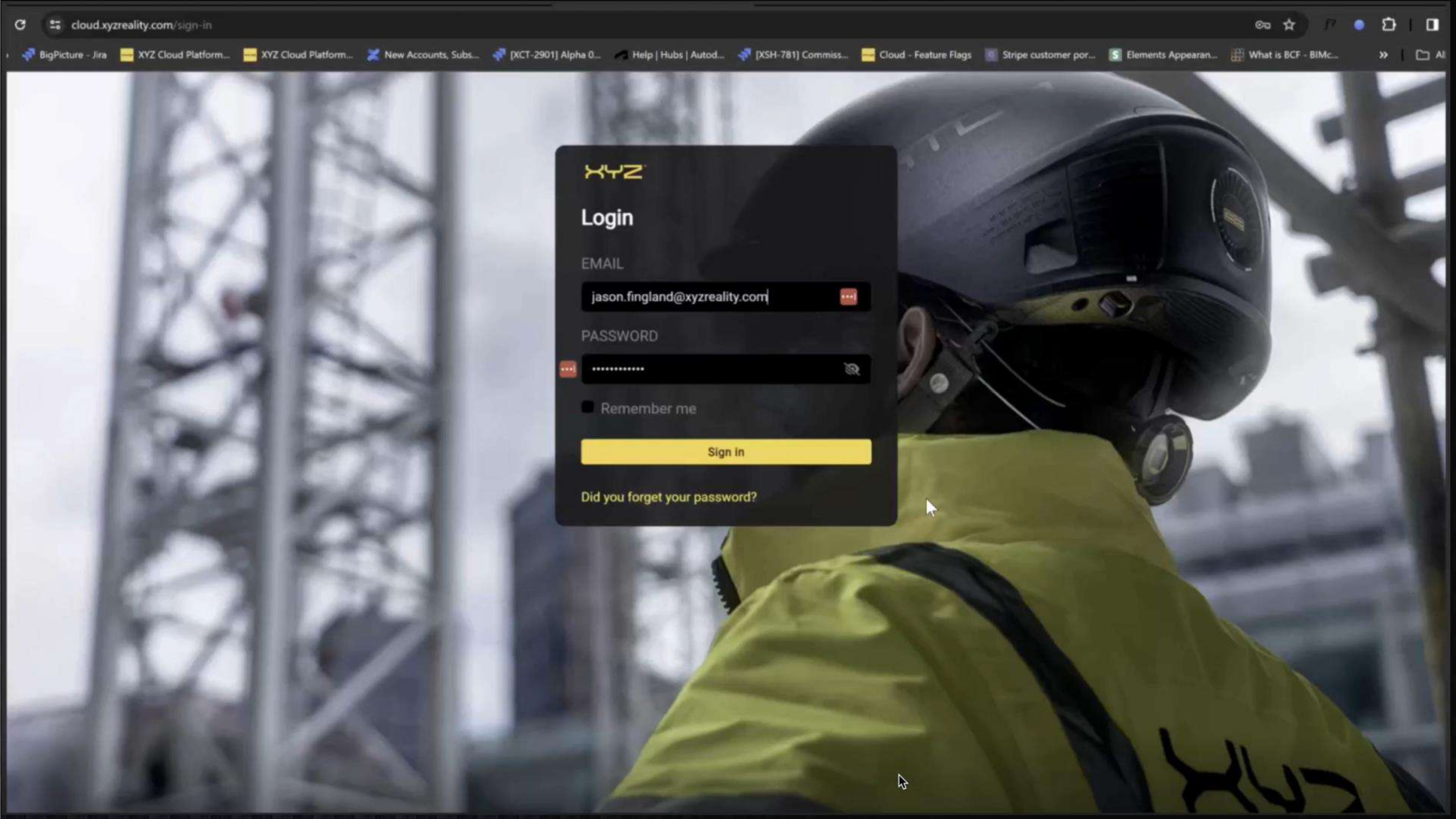
# SINGLE SOURCE OF TRUTH PLATFORM

**PROJECT CONTROLS** DASHBOARD

**SCHEDULES LINKED** TO MODELS

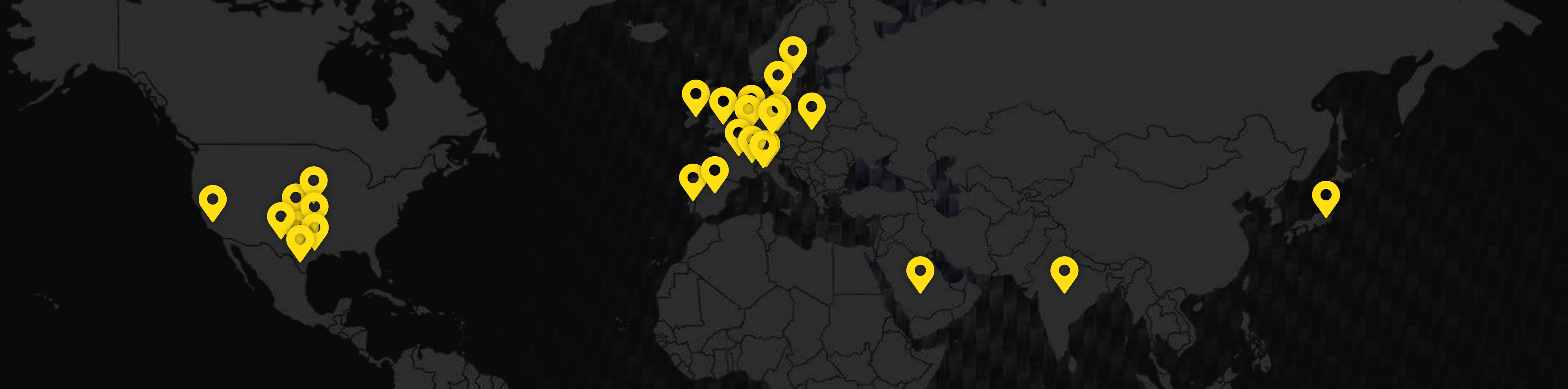
**REAL-TIME TRACKING** CAPABILITIES

**PORTFOLIO ANALYSIS** & VISIBILITY


cloud.xyzreality.com/sign-in
BigPicture - Jira
XYZ Cloud Platform...
XYZ Cloud Platform...
New Accounts, Subs...
[XCT-2901] Alpha 0...
Help | Hubs | Autod...
[XSH-781] Commiss...
Cloud - Feature Flags
Stripe customer por...
Elements Appearan...
What is BCF - BIMc...
XYZ
Login
EMAIL
jason.fingland@xyzreality.com
PASSWORD
Remember me
Sign in
Did you forget your password?

## GLOBAL DELIVERY
PROJECT CONTROLS

## DEPLOYED WITH LARGEST
HYPERSCALERS AND TIER 1 DEVELOPERS
**AROUND THE WORLD**



**$100M+**

Costs avoided for partners

**$12Bn +**

Global mega projects

**16,000**

Critical worker days saved

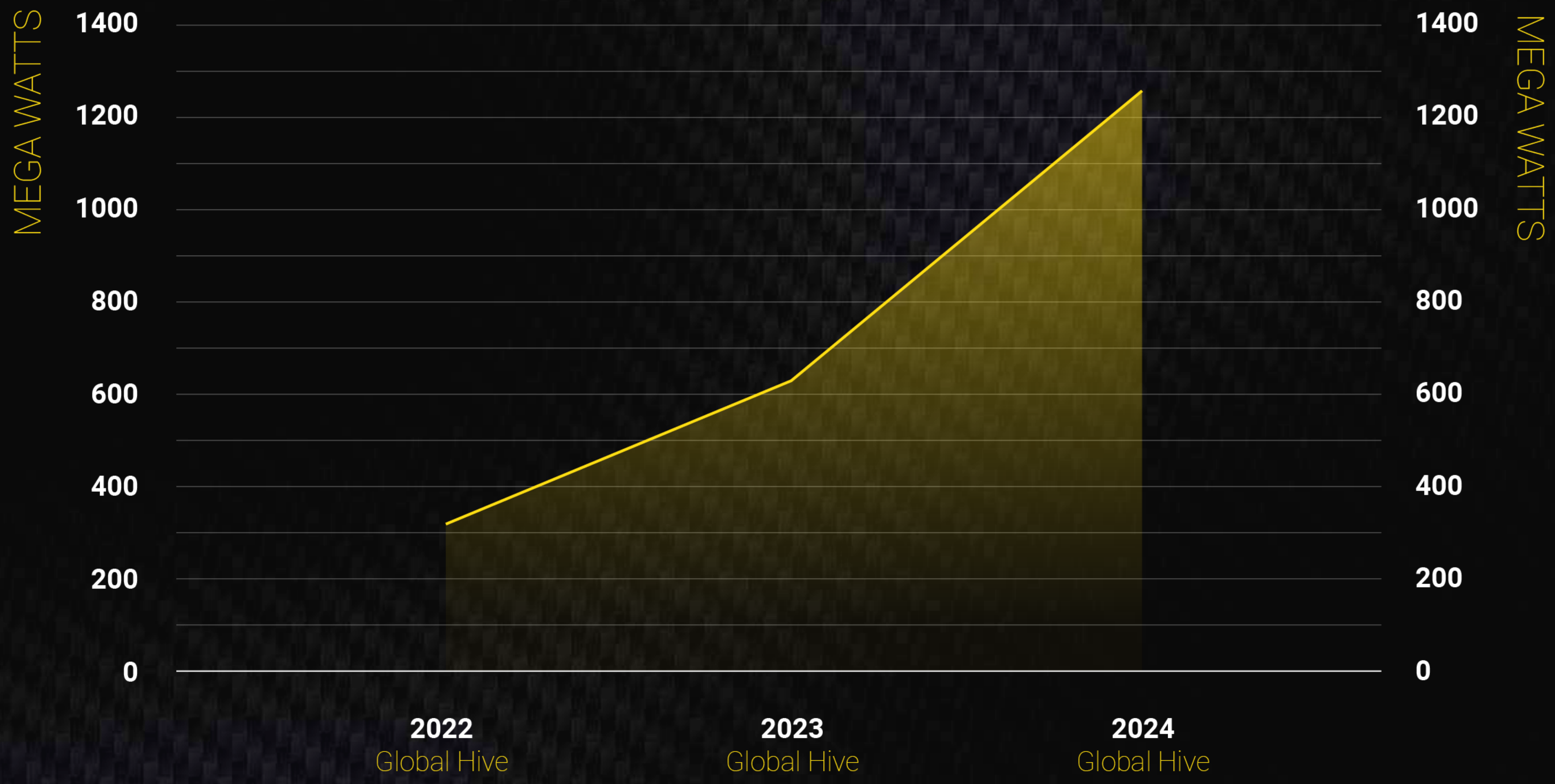
**300,000**

Program hours saved

SPEED & QUALITY ARE **NO LONGER MUTUALLY EXCLUSIVE**

Year on Year

# XYZ™ GLOBAL GROWTH IN MEGA WATTS




XYZ™

ROADMAP TO THE VISION

# WHERE ARE WE?

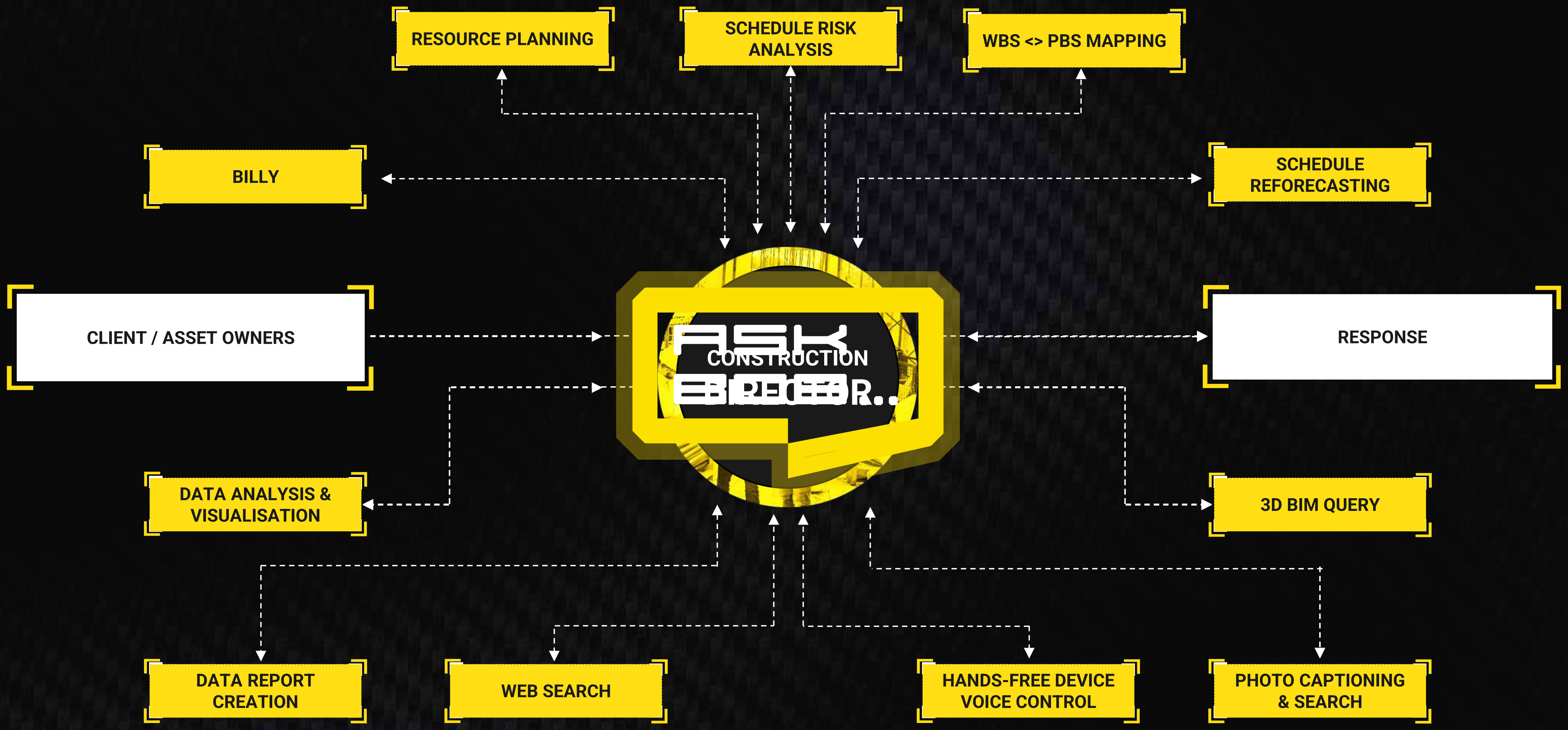
1. PROJECT CONTROLS DASHBOARD
2. PORTFOLIO VISITBILITY AND TRACKING
3. PLATFORM OPTIMISATION THROUGH AI
4. ACTIVITY AND INSPECTION AUTOMATION THROUGH AI
5. PREDICTABLE RISK AND SCENARIO ANALYSIS

# MY MATE Bob

…who the hell is BOB?

**PERSONAL**
DIGITAL CONSTRUCTION
**DELIVERY DIRECTOR**


ASK
BOB...


RESOURCE PLANNING
SCHEDULE RISK ANALYSIS
WBS <> PBS MAPPING
BILLY
SCHEDULE REFORECASTING
CLIENT / ASSET OWNERS
ASK
CONSTRUCTION
RESPONSE
DATA ANALYSIS & VISUALISATION
3D BIM QUERY
DATA REPORT CREATION
WEB SEARCH
HANDS-FREE DEVICE VOICE CONTROL
PHOTO CAPTIONING & SEARCH

XYZ™

## Impactful issue detected on your project

| | |
|---|---|
| Project | DC1-LONDON |
| Package | Busbar |
| Team | PHILLIPS CONTRACTING PLC |

**Overview**

Busbar in delay. Impact to critical path.

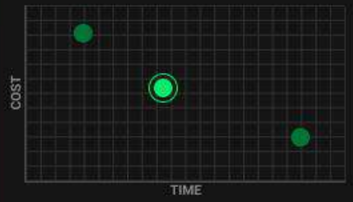
**View project**

XYZ

DC1-LONDON

BOB

## Suggested plans based on your model




Plan 1 | Plan 2 | Plan 3

Based on historical performance across your supply chain, a 24 month duration at a total cost of $670m is to be expected based on this suggested design.

DURATION

**24 Month plan**

COST PER MEGAWATT

**$13.4M** /MW

TOTAL COST

**$670m**

Create schedule

## Schedule

Schedule only | Gantt only | Schedule & Gantt

| Activity name | Start | End | Discipline | Cost |
|---|---|---|---|---|
| Procurement | 02/02/25 | 14/10/25 | Procurement | $46.9m |
| Design | 02/02/25 | 03/12/25 | Design | $33.5m |
| Construction | 11/08/25 | 02/02/27 | - | $509.2m |
| CSA | 16/10/25 | 02/02/27 | CSA | $178.2m |
| Mechanical | 21/04/26 | 02/02/27 | Mechanical | $152.8m |
| Electrical | 21/04/26 | 02/02/27 | Electrical | $178.2m |
| Commissioning | 01/08/26 | 02/02/27 | Commissioning | $67m |

R, APR, MAY, JUN, JUL, AUG, SEPT, OCT, NOV, DEC, 2026, JAN, FEB, MAR, AP

EK 10, WEEK 15, WEEK 20, WEEK 25, WEEK 30, WEEK 35, WEEK 40, WEEK 45, WEEK 50, WEEK 55, WEEK 1, WEEK 5, WEEK 10, WE

Procurement

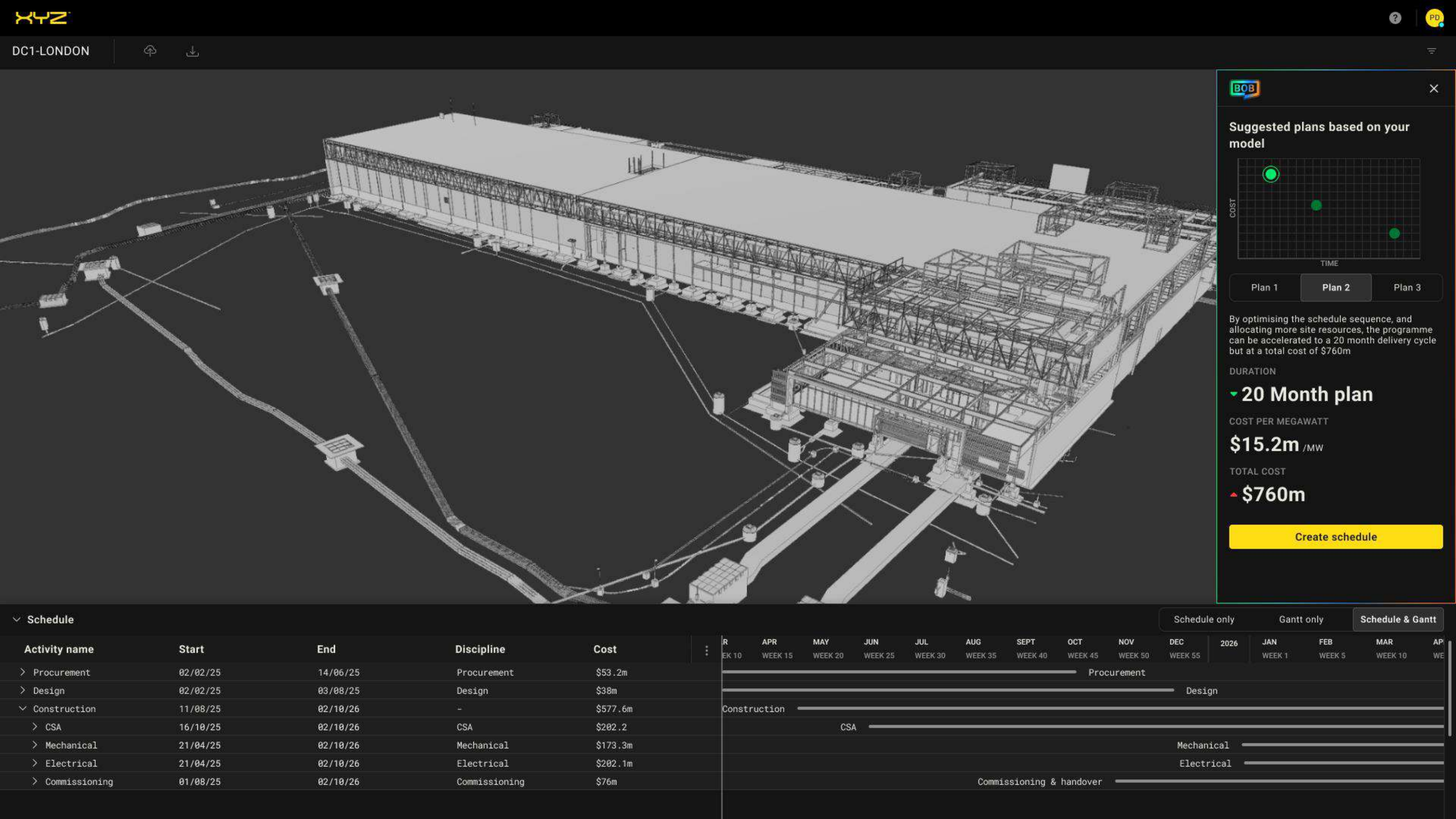
Design

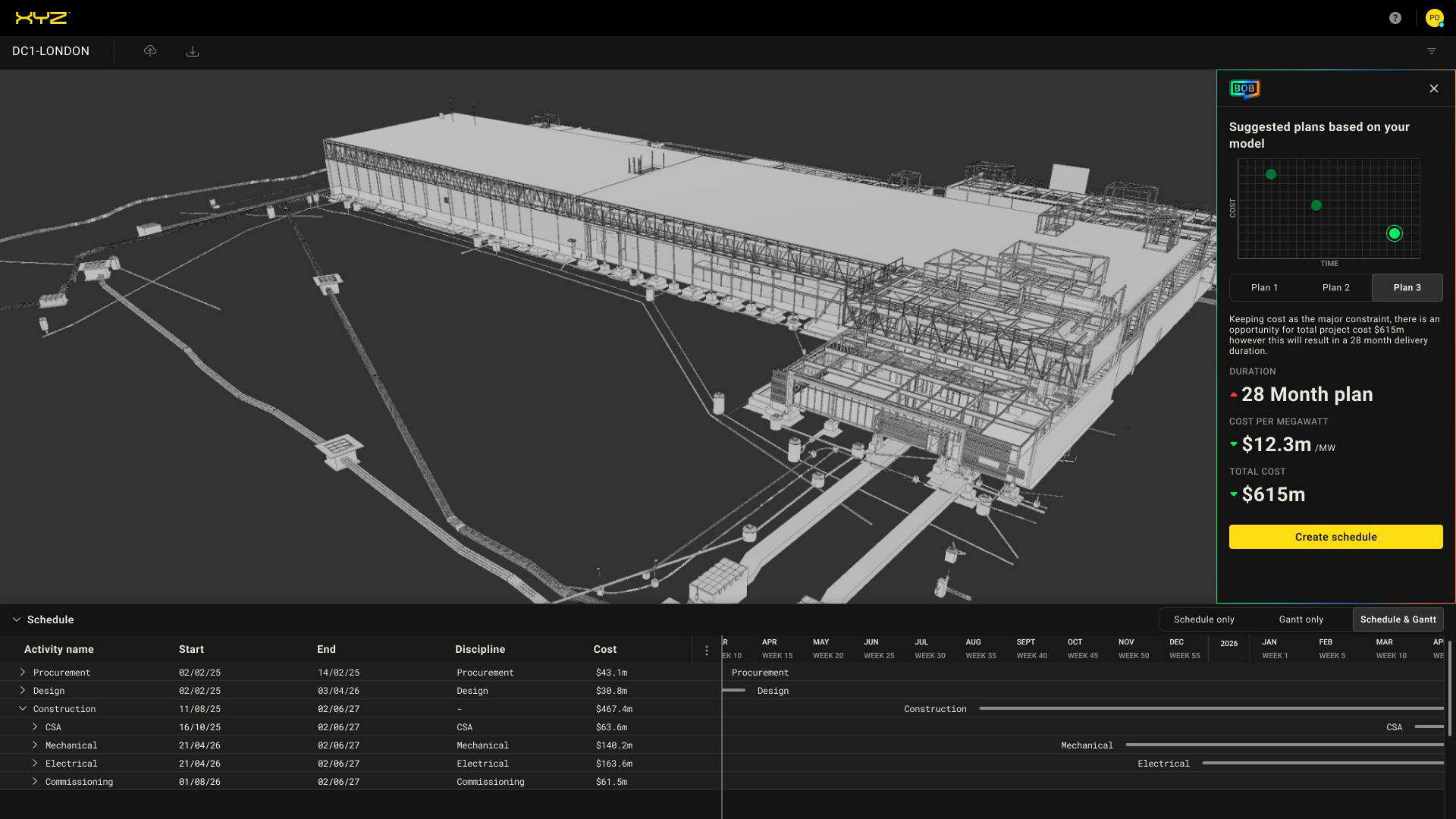
Construction

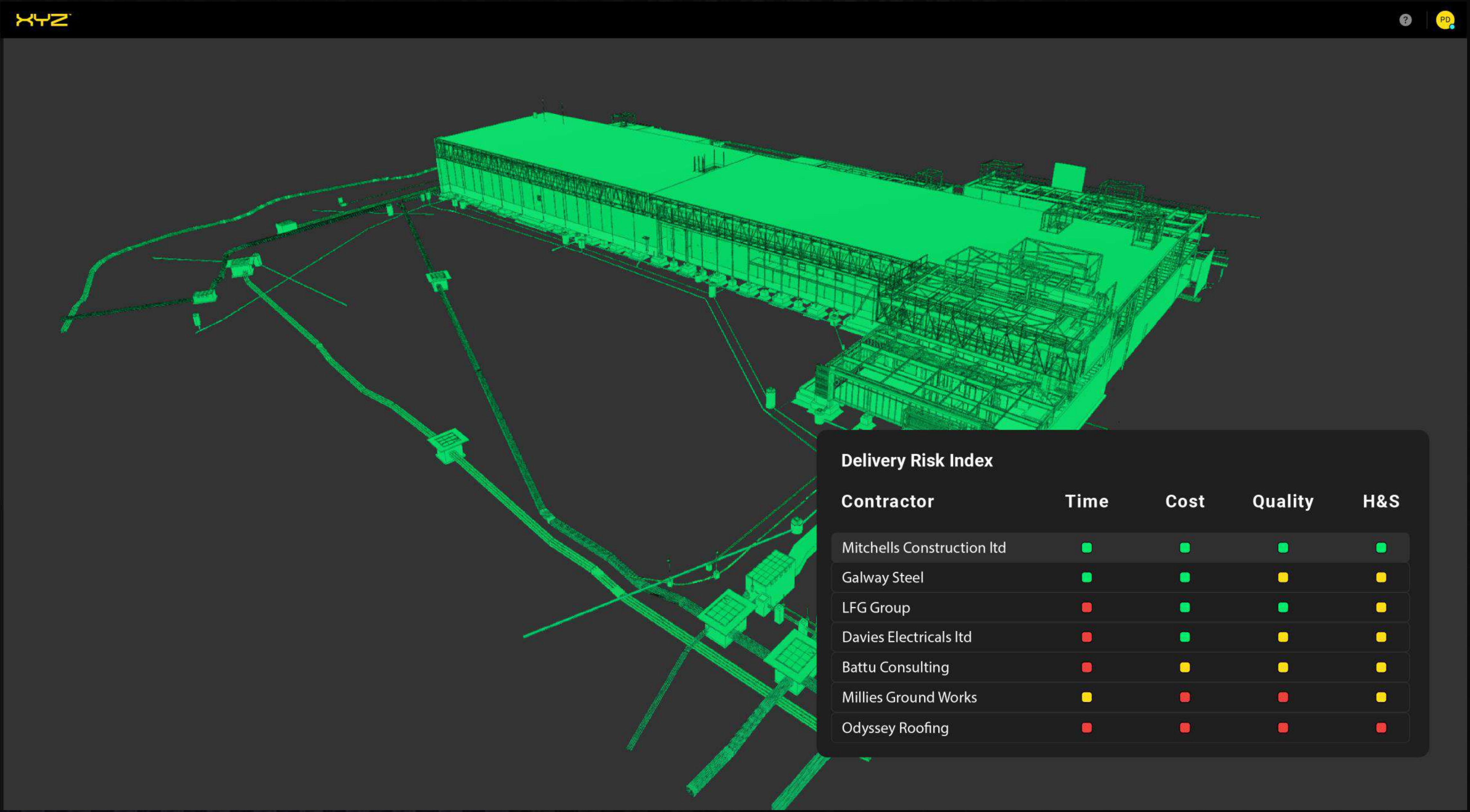
CSA

Mechanical

Electrical


XYZ
DC1-LONDON
BOB
Suggested plans based on your model
COST
TIME
Plan 1
Plan 2
Plan 3
By optimising the schedule sequence, and allocating more site resources, the programme can be accelerated to a 20 month delivery cycle but at a total cost of $760m
DURATION
20 Month plan
COST PER MEGAWATT
$15.2m /MW
TOTAL COST
$760m
Create schedule
Schedule
Schedule only
Gantt only
Schedule & Gantt
Activity name
Start
End
Discipline
Cost
Procurement 02/02/25 14/06/25 Procurement $53.2m
Design 02/02/25 03/08/25 Design $38m
Construction 11/08/25 02/10/26 - $577.6m
CSA 16/10/25 02/10/26 CSA $202.2
Mechanical 21/04/25 02/10/26 Mechanical $173.3m
Electrical 21/04/25 02/10/26 Electrical $202.1m
Commissioning 01/08/25 02/10/26 Commissioning $76m
APR WEEK 15
MAY WEEK 20
JUN WEEK 25
JUL WEEK 30
AUG WEEK 35
SEPT WEEK 40
OCT WEEK 45
NOV WEEK 50
DEC WEEK 55
2026
JAN WEEK 1
FEB WEEK 5
MAR WEEK 10
Procurement
Design
Construction
CSA
Mechanical
Electrical
Commissioning & handover


XYZ
DC1-LONDON
BOB
Suggested plans based on your model
COST
TIME
Plan 1
Plan 2
Plan 3
Keeping cost as the major constraint, there is an opportunity for total project cost $615m however this will result in a 28 month delivery duration.
DURATION
28 Month plan
COST PER MEGAWATT
$12.3m /MW
TOTAL COST
$615m
Create schedule
Schedule
Schedule only
Gantt only
Schedule & Gantt
Activity name
Start
End
Discipline
Cost
Procurement 02/02/25 14/02/25 Procurement $43.1m
Design 02/02/25 03/04/26 Design $30.8m
Construction 11/08/25 02/06/27 - $467.4m
CSA 16/10/25 02/06/27 CSA $63.6m
Mechanical 21/04/26 02/06/27 Mechanical $140.2m
Electrical 21/04/26 02/06/27 Electrical $163.6m
Commissioning 01/08/26 02/06/27 Commissioning $61.5m
APR WEEK 15
MAY WEEK 20
JUN WEEK 25
JUL WEEK 30
AUG WEEK 35
SEPT WEEK 40
OCT WEEK 45
NOV WEEK 50
DEC WEEK 55
2026
JAN WEEK 1
FEB WEEK 5
MAR WEEK 10
Procurement
Design
Construction
CSA
Mechanical
Electrical




**Delivery Risk Index**

| Contractor | Time | Cost | Quality | H&S |
|---|---|---|---|---|
| Mitchells Construction ltd | Green | Green | Green | Green |
| Galway Steel | Green | Green | Yellow | Yellow |
| LFG Group | Red | Green | Green | Yellow |
| Davies Electricals ltd | Red | Green | Yellow | Yellow |
| Battu Consulting | Red | Yellow | Yellow | Yellow |
| Millies Ground Works | Yellow | Red | Red | Yellow |
| Odyssey Roofing | Red | Red | Red | Red |


XYZ


XYZ
XYZ
XYZ


XYZ™
BUILD IT RIGHT, FIRST TIME

# Day 1 Close

# Global-Hive Summit
## September 2024 – Day 2

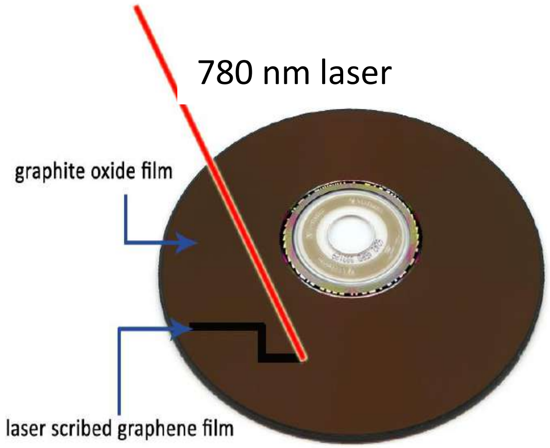
# Welcome & Intro

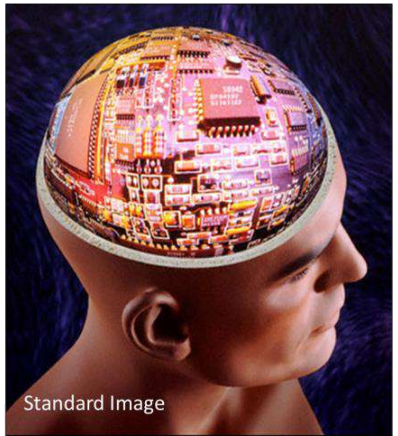
Richard Kaner

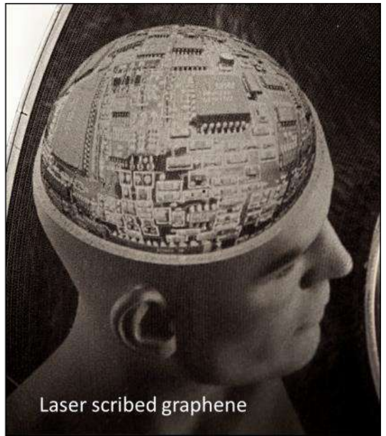
# Graphene for Energy Storage and Other Applications

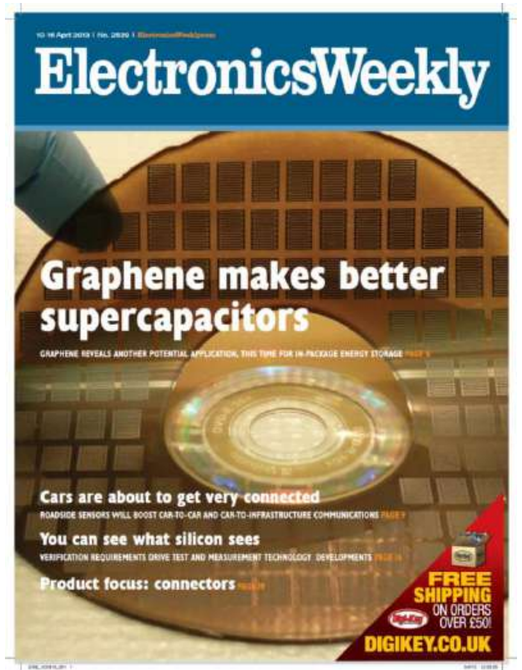

## Richard B. Kaner

Distinguished Professor, Department of Chemistry & Biochemistry
Distinguished Professor, Department of Materials Science & Engineering
Dr. Myung Ki Hong Endowed Chair in Materials Innovation
University of California, Los Angeles (UCLA)

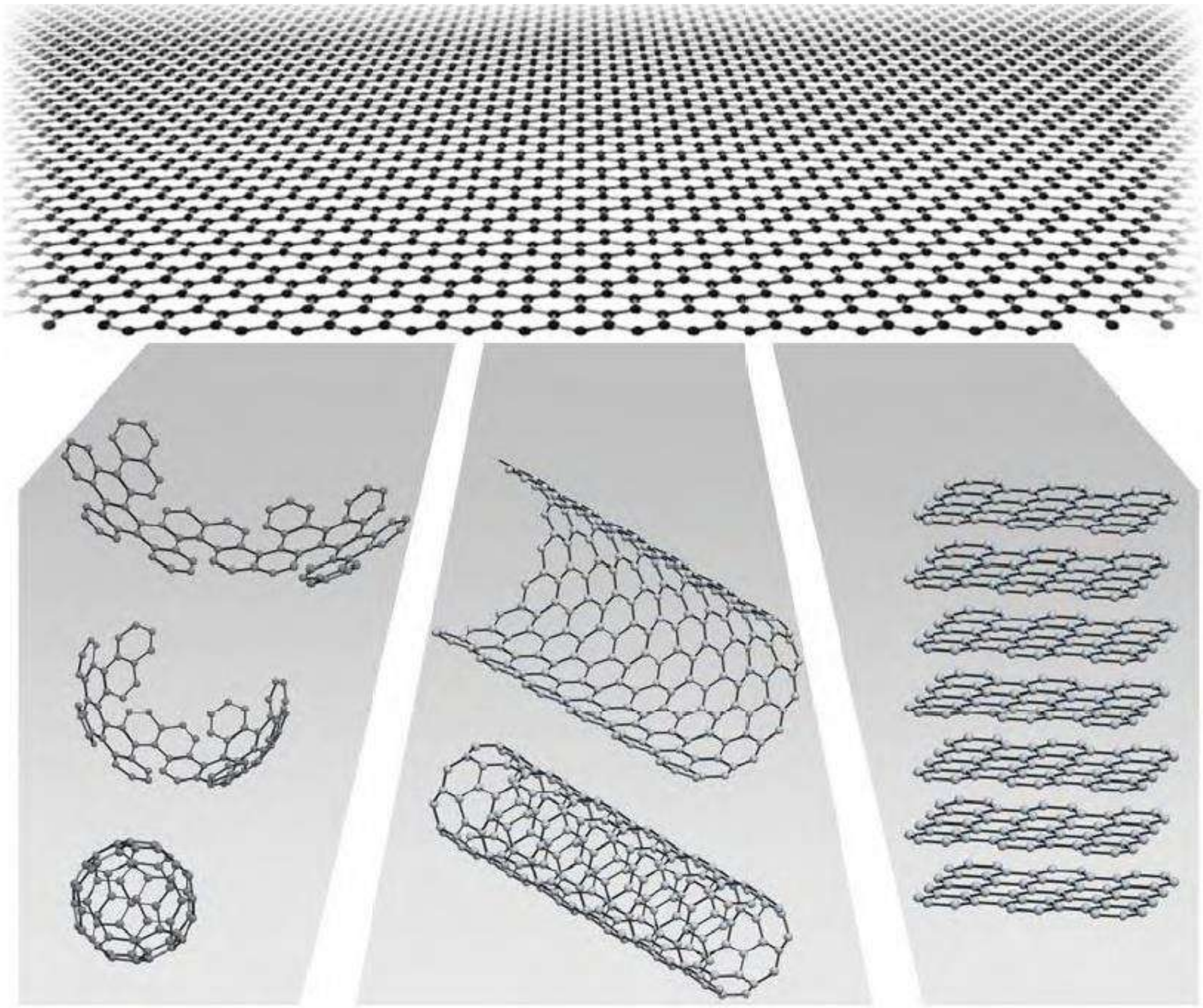





Standard Image


Laser scribed graphene



# Graphene: The Building Block for All Forms of Carbon



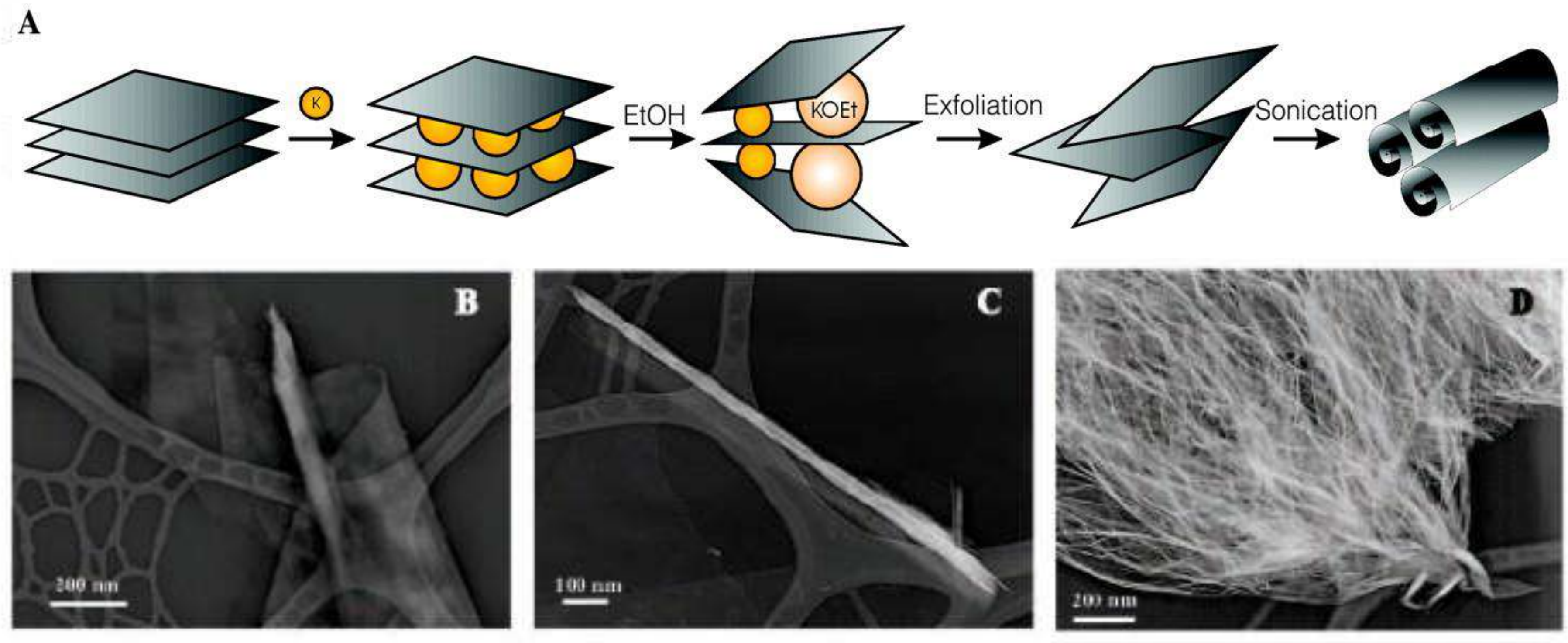
Graphene ➔ 0D fullerenes, 1D carbon nanotubes and 2D graphite.





Geim and Novoselov, *Nature Materials* **6**, 183–191 (2007)

# Intercalation and Exfoliation of HOPG

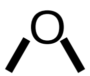


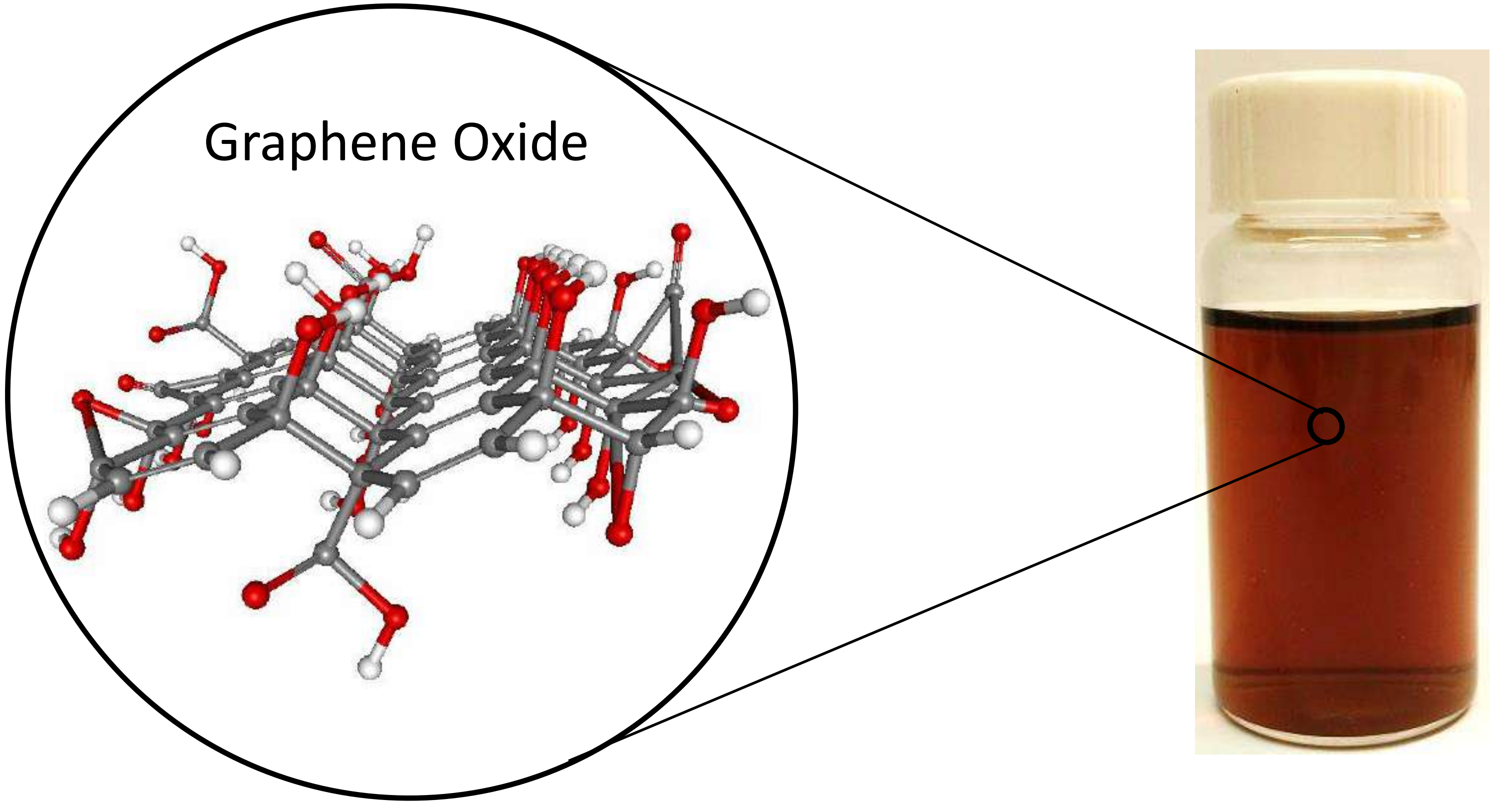

- Produces carbon nanoscrolls comprised of few layer graphene

KANER laboratory UCLA

U.S. Patent #6,872,330 filed May, 2002
Viculis, Mack, Kaner, *Science*, **299**, 1361 (2003)

# Solutions of Graphene Oxide

- Highly oxidized graphite can be prepared with -OH,  , C=O and -COOH functionalities*
- The sheets interact strongly with water and exfoliate



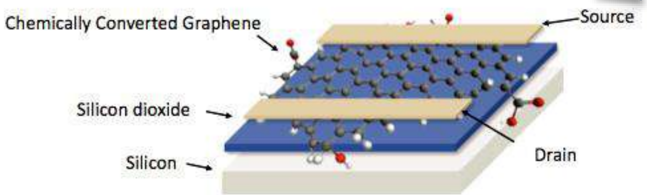

KANER laboratory
UCLA

Brodie, *et al*. *Liebigs Ann. Chem.* **6,** 114 (1860)
*Kovtyukhova, Mallouk, *et al*. *Chem. Mater.* **11**, 3 (1999)

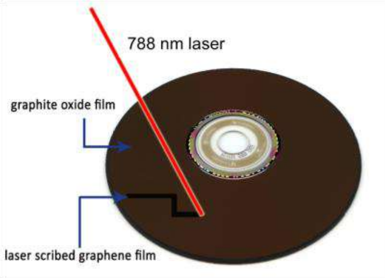
# A Range of Applications Stemming from Graphene Oxide

GRAPHENE PAPER

SUPERCAPACITORS




ELECTRONICS




LIGHT SCRIBE LITHOGRAPHY

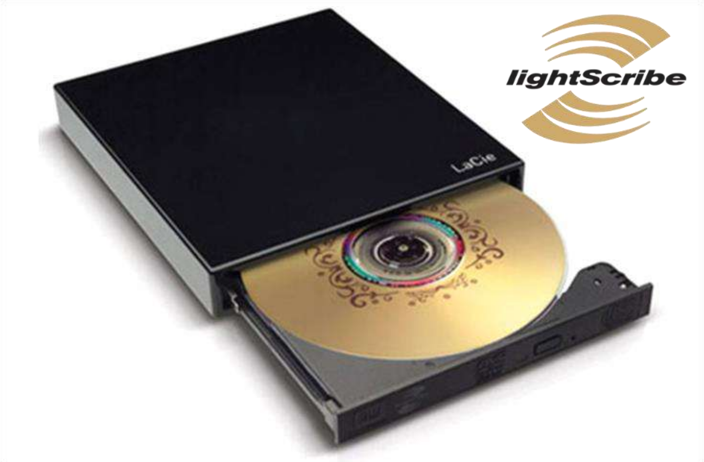
ROBUST CHEMICAL SENSORS

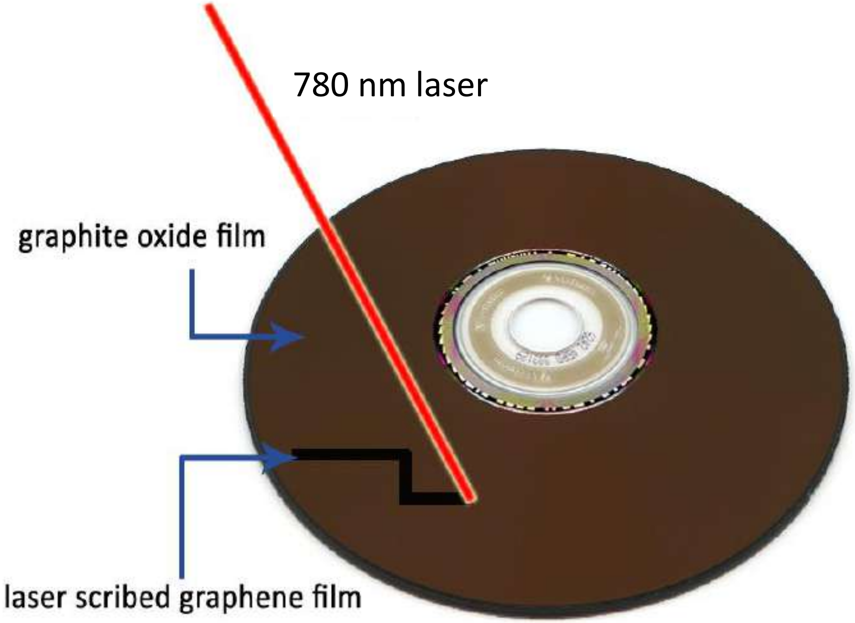
GRAPHENE OXIDE FOAM

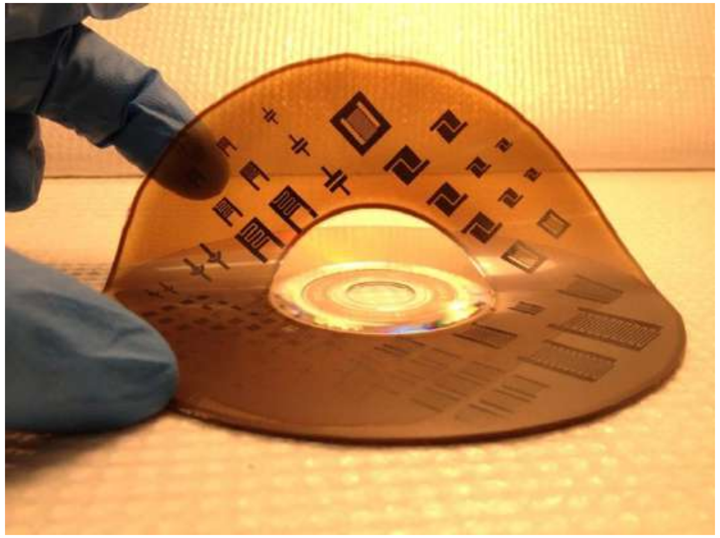
KANER laboratory UCLA

Allen, Tung, Kaner, *Chem. Rev.* **110**, 132 (2010)
Wassei, Kaner, *Accounts of Chemical Research* **46**, 2244 (2013)

# LightScribe: Graphene Electrodes in a DVD Burner

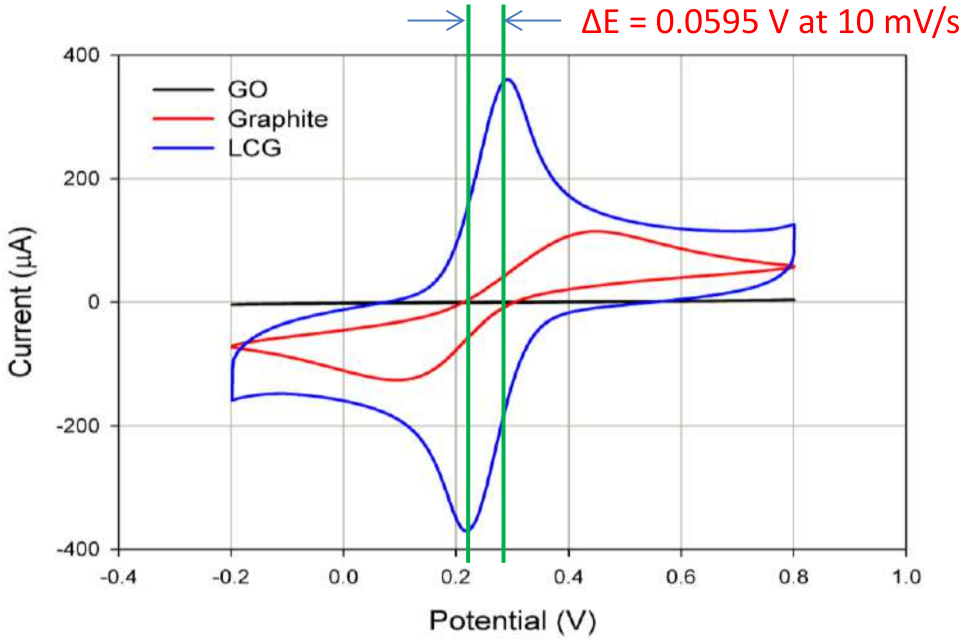



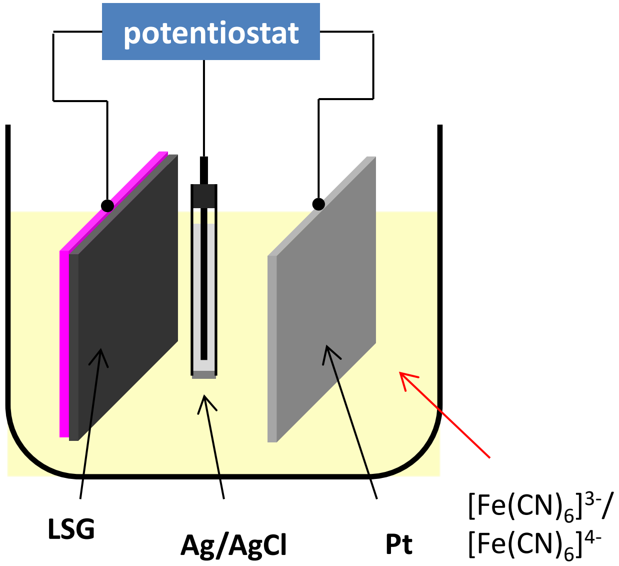



KANER laboratory UCLA

Strong, Dubin, El-Kady, Lech, Wang, Weiller, Kaner, *ACS Nano* **6**, 1395 (2012)

# Electrochemical Applications of Laser Scribed Graphene




Ferro/ferri-cyanide couple as a redox probe

$$Fe(CN)_6^{3-} + e^- \longrightarrow Fe(CN)_6^{4-}$$

$$E = E^0 - \frac{0.05916\ \mathrm{V}}{z} \log_{10} \frac{a_{\mathrm{Red}}}{a_{\mathrm{Ox}}}.$$

| | Graphite | CNT | LSG |
|---|---|---|---|
| $k^o_{obs}$ (cm $s^{-1}$) | $1.26 \times 10^{-4}$ | $8.34 \times 10^{-5}$<br>$3.67 \times 10^{-3}$* | $1.33 \times 10^{-2}$ |
| | | * Chem. Asian J. 2008, 3, 2046–2055. | All-carbon electrode (no current collector) |

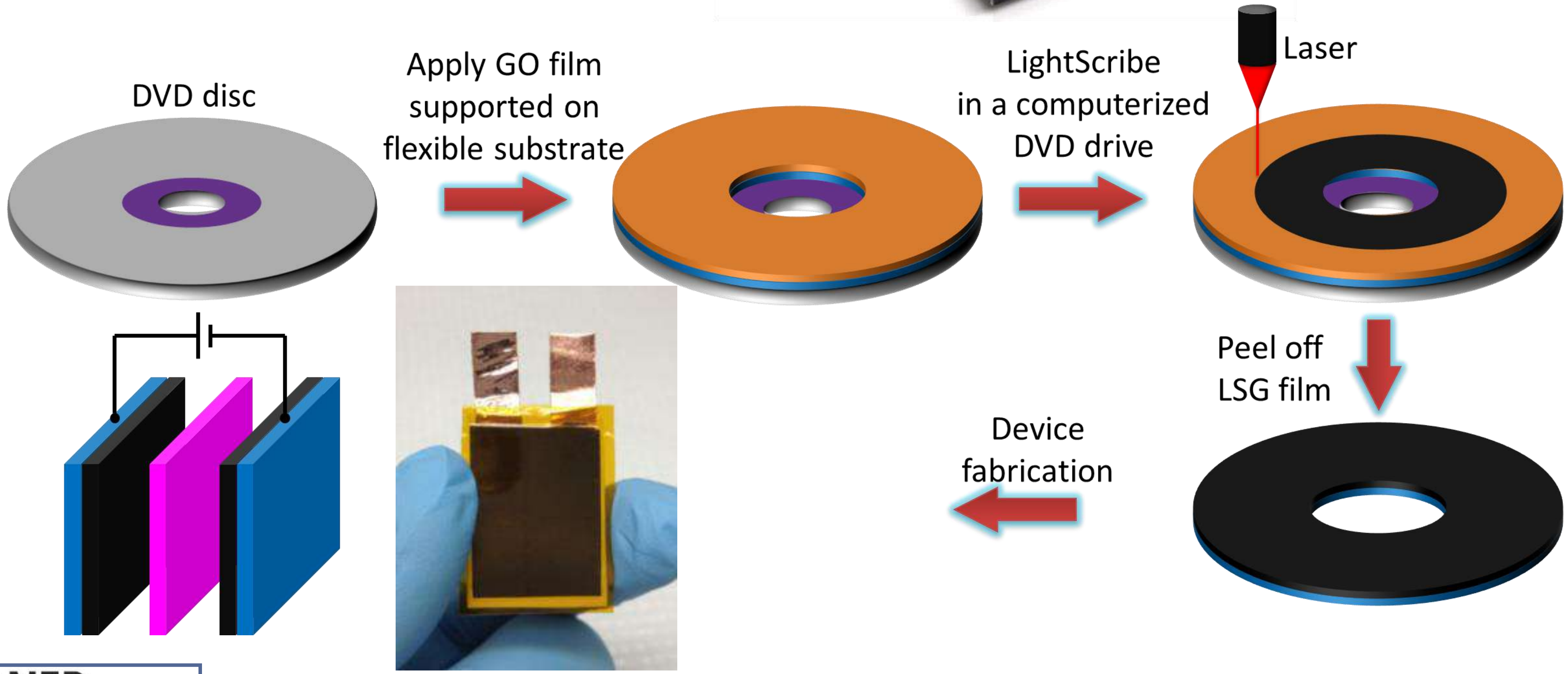
KANER laboratory UCLA



*ACS Nano* **6**, 1395 (2012)

# Making Graphene Supercapacitors in a DVD Burner

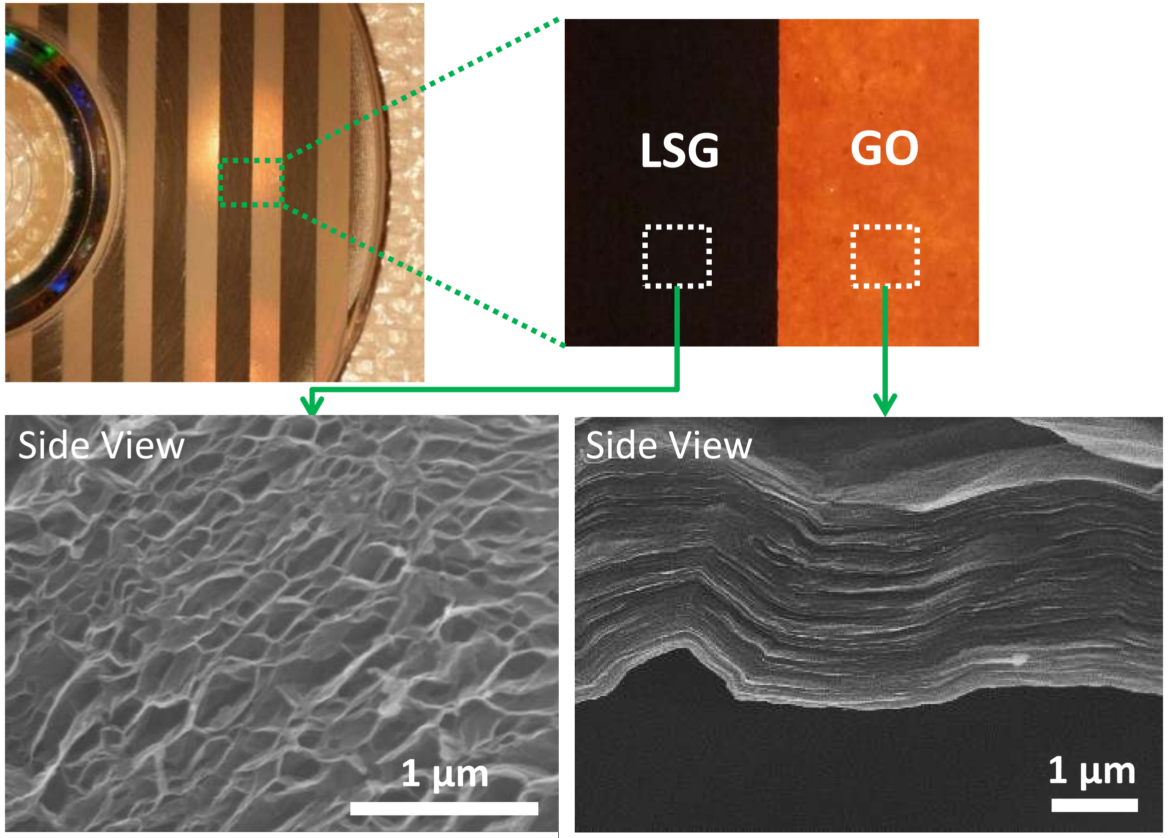
Making graphene supercapacitors
is as easy as burning a DVD




KANER laboratory UCLA

El-Kady, Strong, Dubin, Kaner, *Science* **335**, 1326 (2012)

# High-Performance Laser Scribed Graphene Electrodes (LSG)



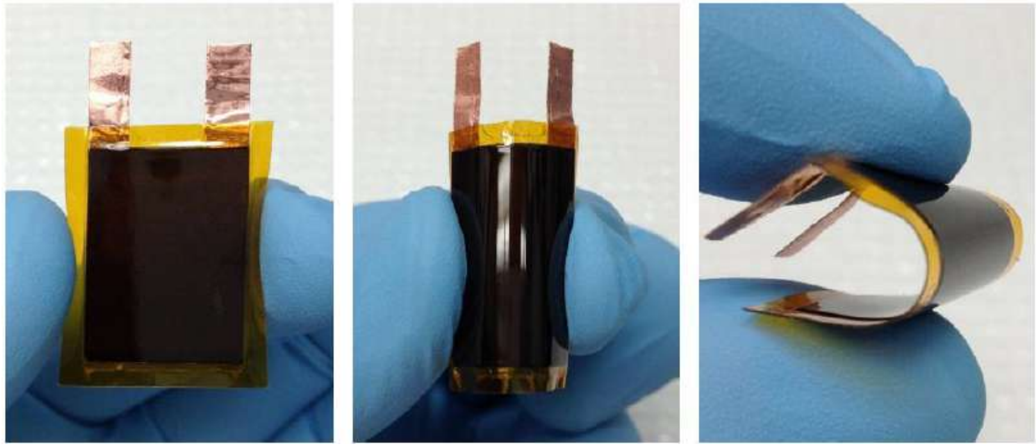


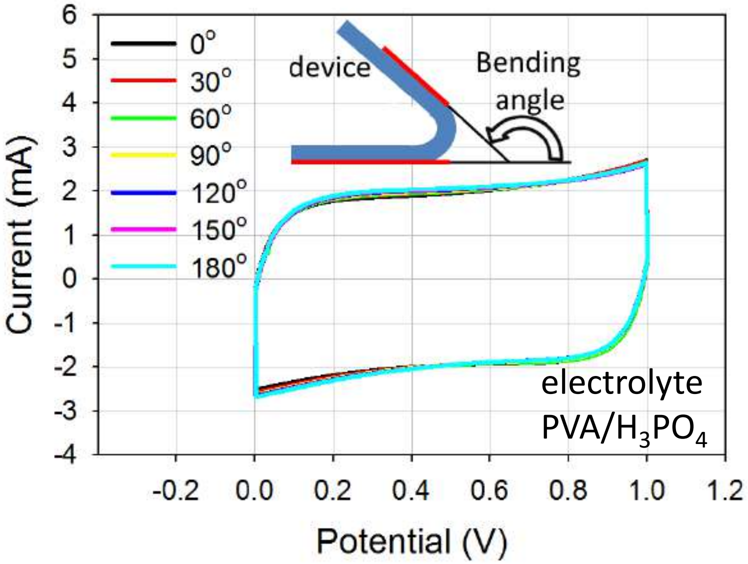
| | Activated Carbon | LSG | Impact |
|---|---|---|---|
| Electrical conductivity (S/m) | 10-100 | 1740 | High power density |
| Surface area ($m^2$/g) | 1000-2000 (micropores) | 1520 (accessible) | High energy density |
| Mechanical properties | Powder | Flexible electrodes | Flexible devices |
| Binders and current collector | Yes | No | Simple fabrication |

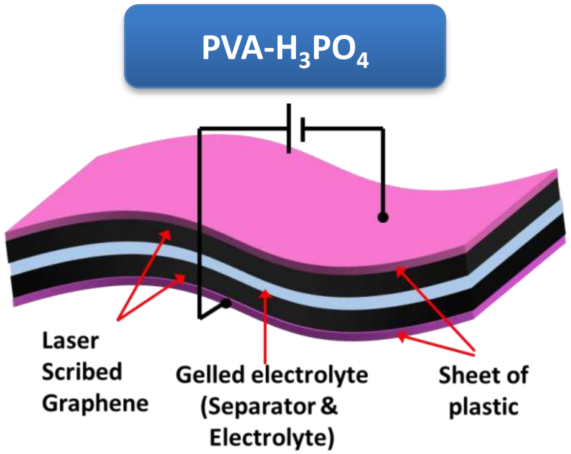
KANER laboratory UCLA

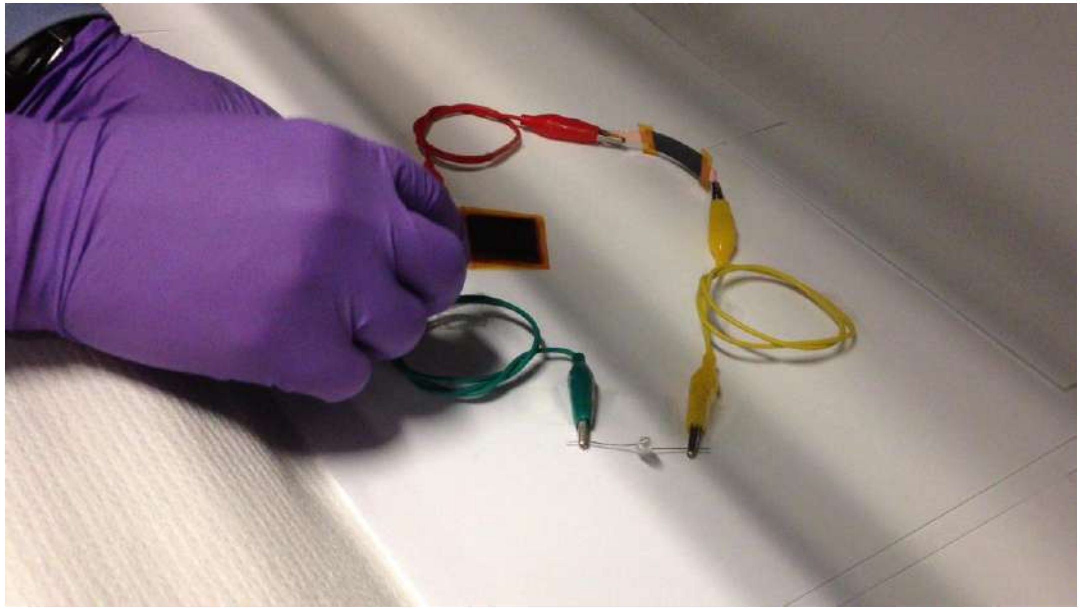
*Science* **335**, 1326 (2012)

# Flexible, All-Solid-State Supercapacitors

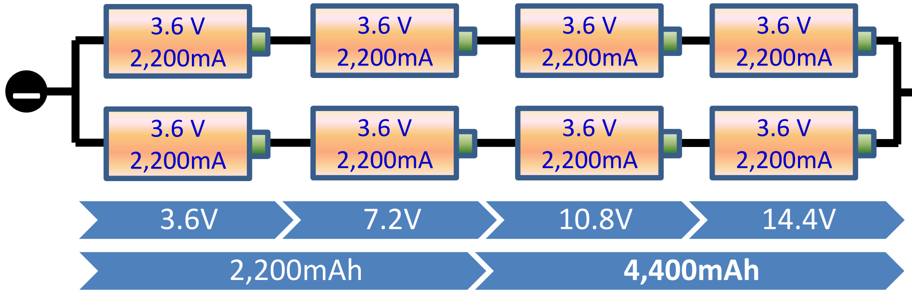




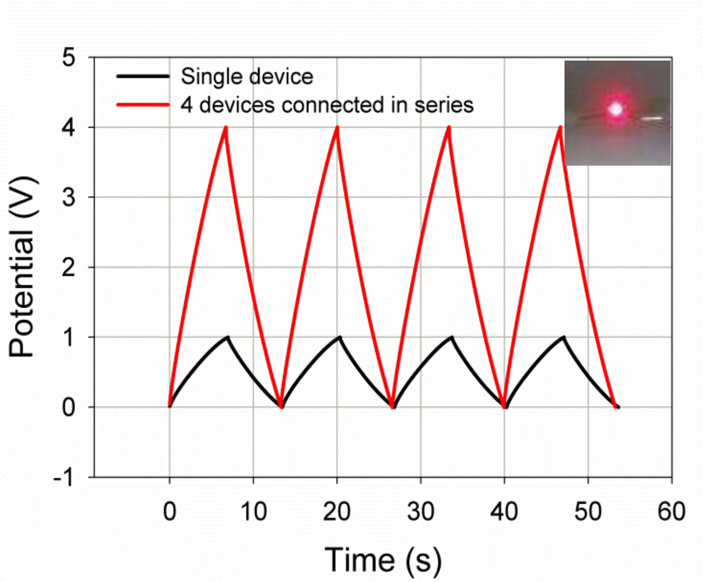



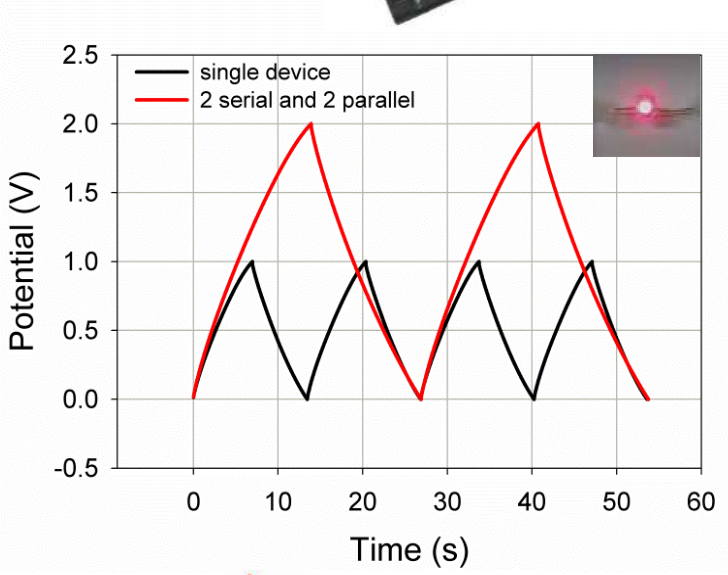
# Tandem Supercapacitors



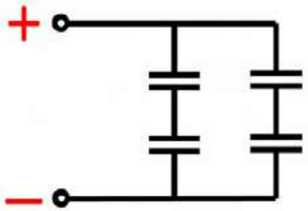


## Tandem supercapacitors

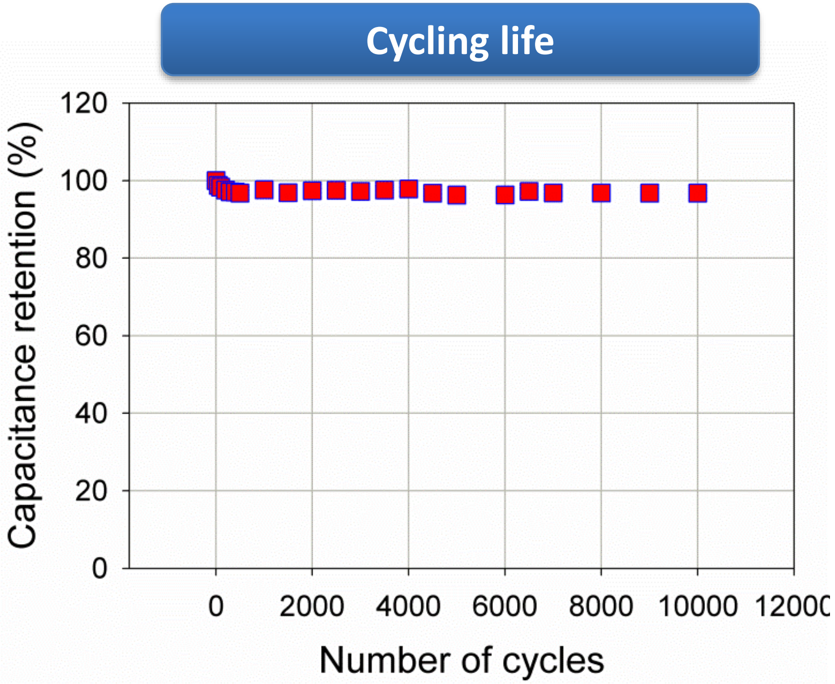


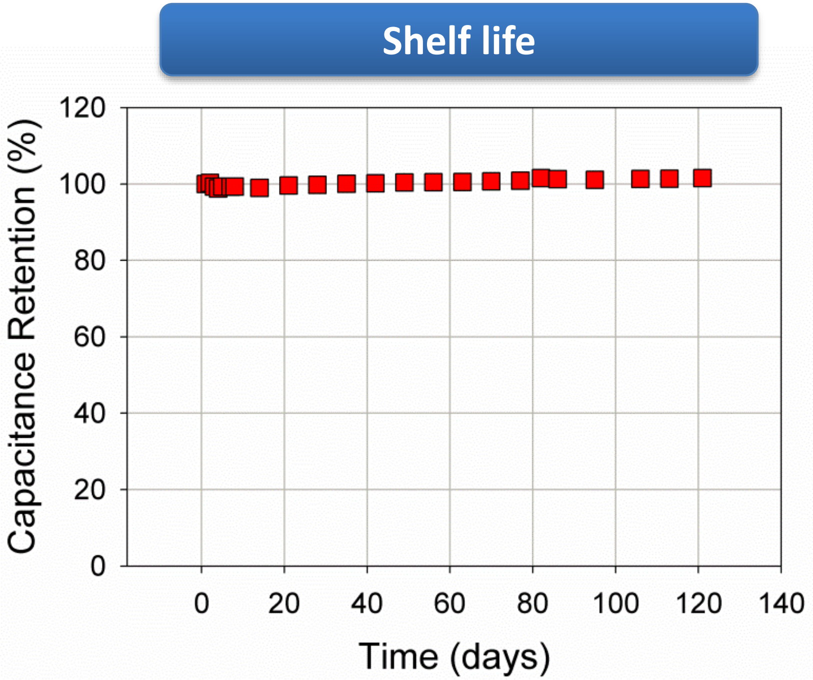





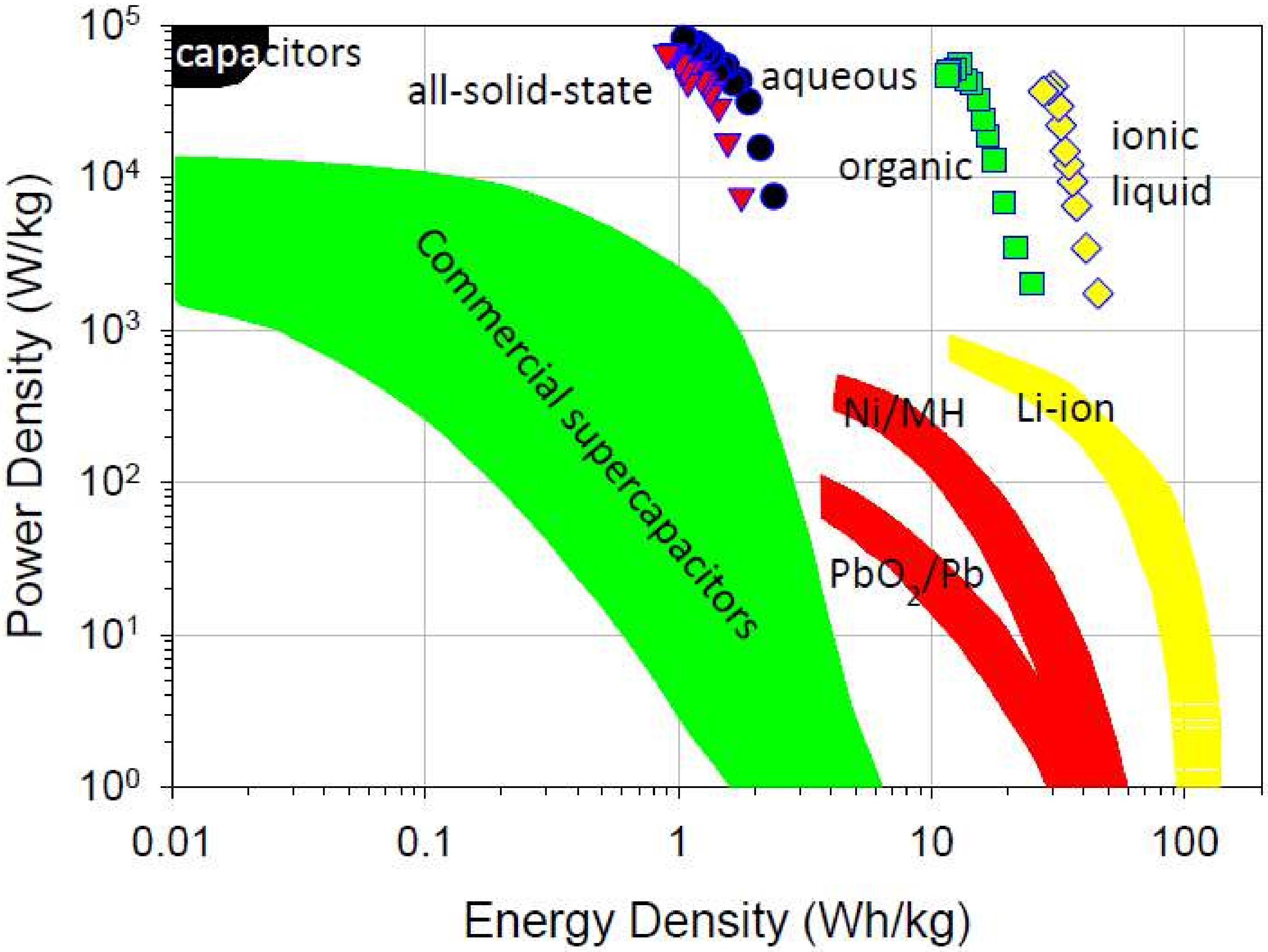


# Cycling and Shelf-Life

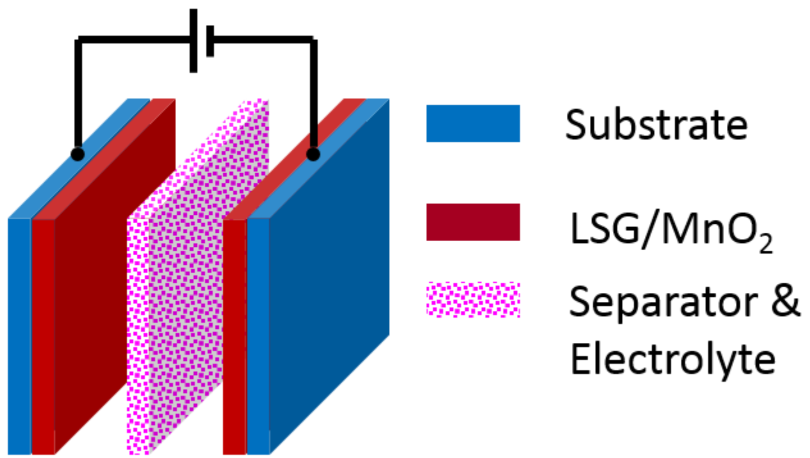


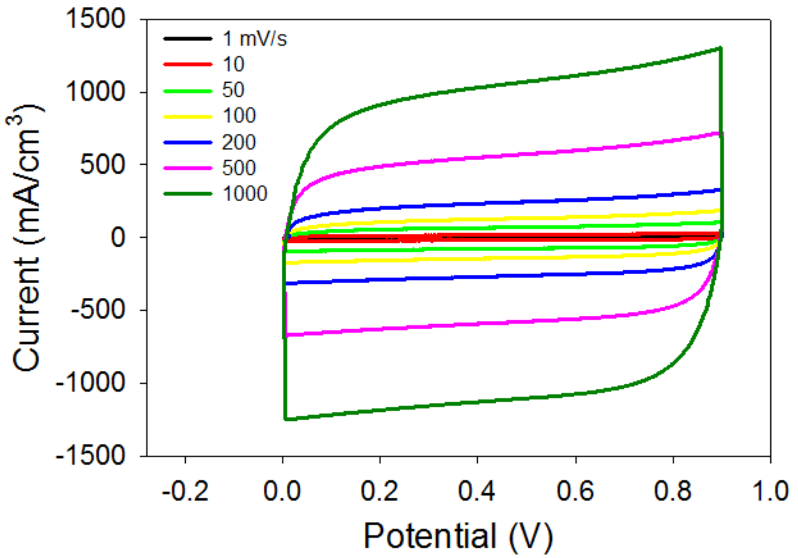



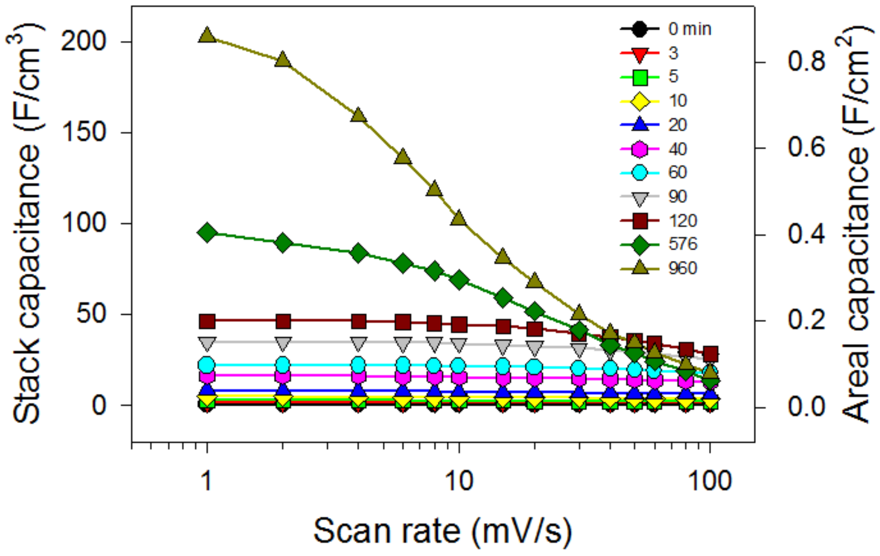
# LSG vs. Commercial Supercapacitors

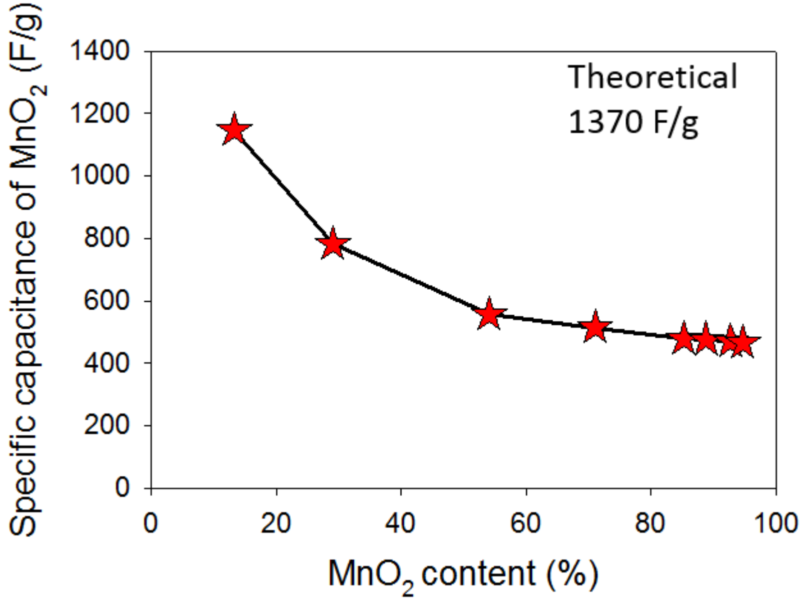


# Symmetric Supercapacitors



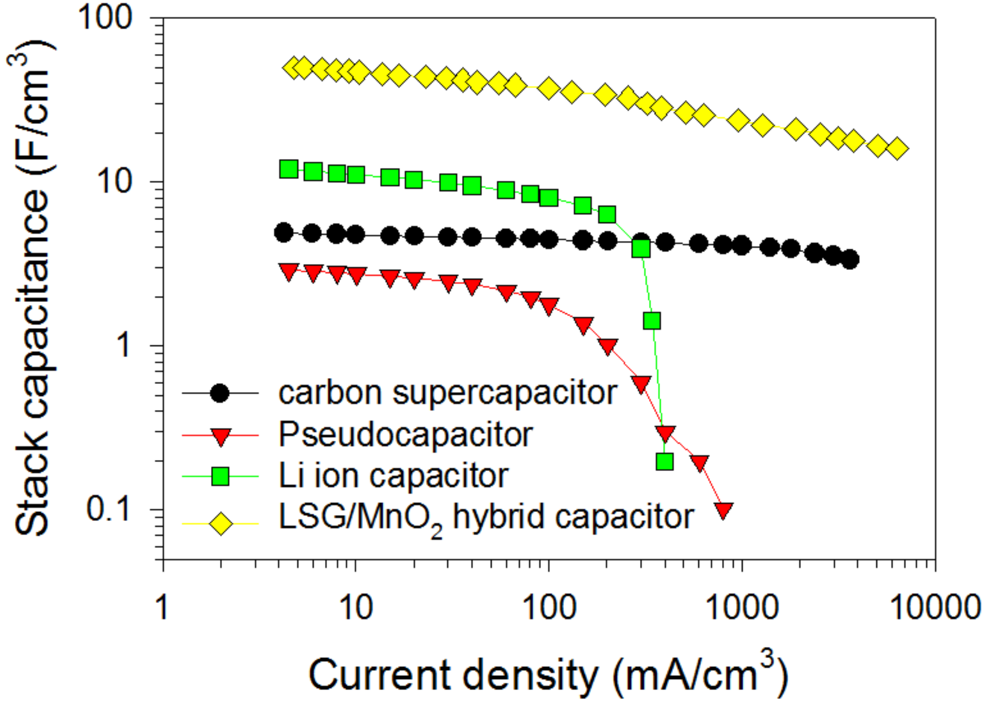






*PNAS* **112**, 4233 (2015)

# Commercially Available Pseudo- and Hybrid-Capacitors




Li ion capacitor

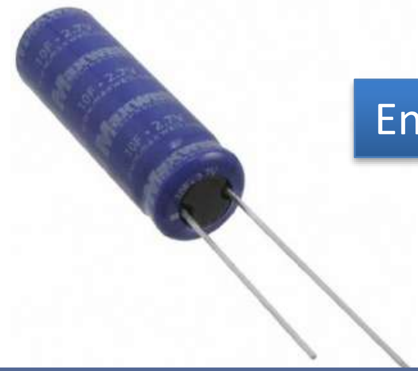
2.3V

Pseudocapacitor

3.3 V

EDLC

2.7 V



Energy Density = ½ $CV^2$

KANER *laboratory* UCLA



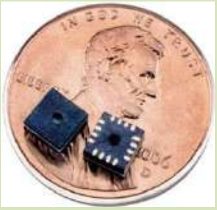
*PNAS* **112**, 4233 (2015)

# Need for Miniaturized Energy Storage

## Miniaturized electronics


Cardiac pacemaker

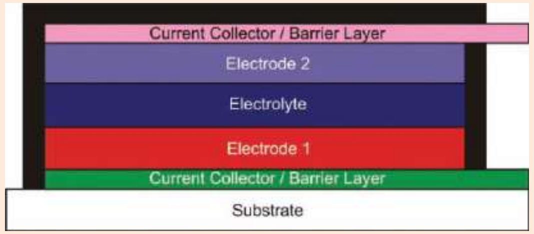
RFID

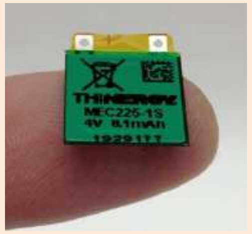


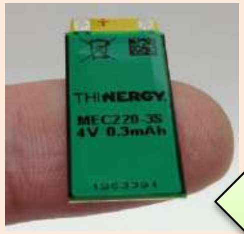
MEMS sensors

Hearing aids

## Micro-batteries

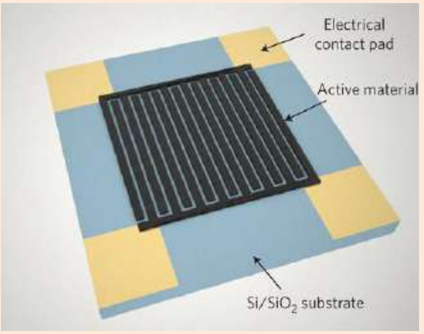


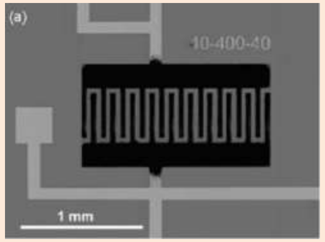



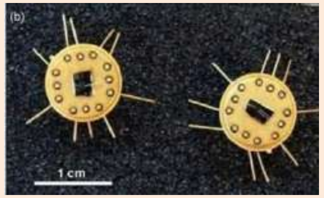




Adv. Energy Mater. 1, 10 (2011)

## Micro-supercapacitors



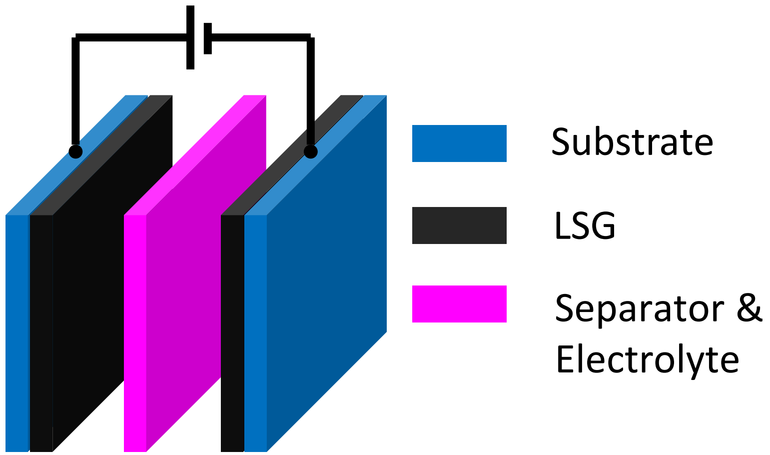



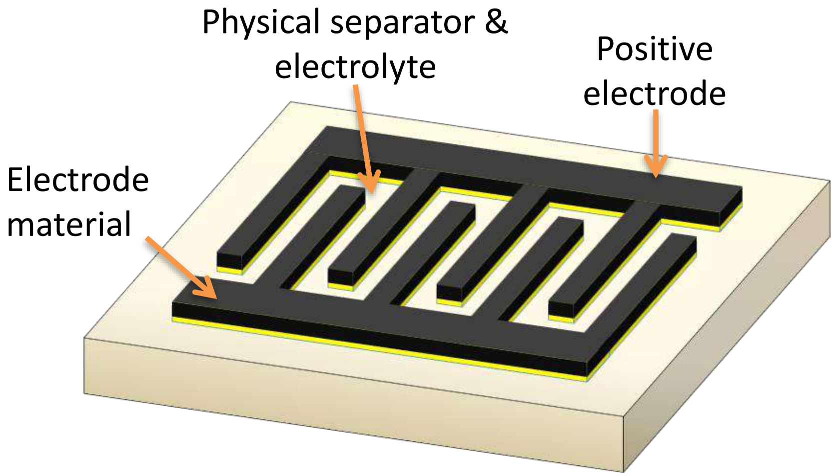




*Jos, Oudenhoven, Adv. Energy Mater.* **1**, 10 (2011)
Simon, Gogotsi *et al., Science* **328**, 480 (2010)
Simon, Gogotsi *et al., J. Power Sources* (2010)
*Nature Nanotechnology* **5**, 651 (2010)

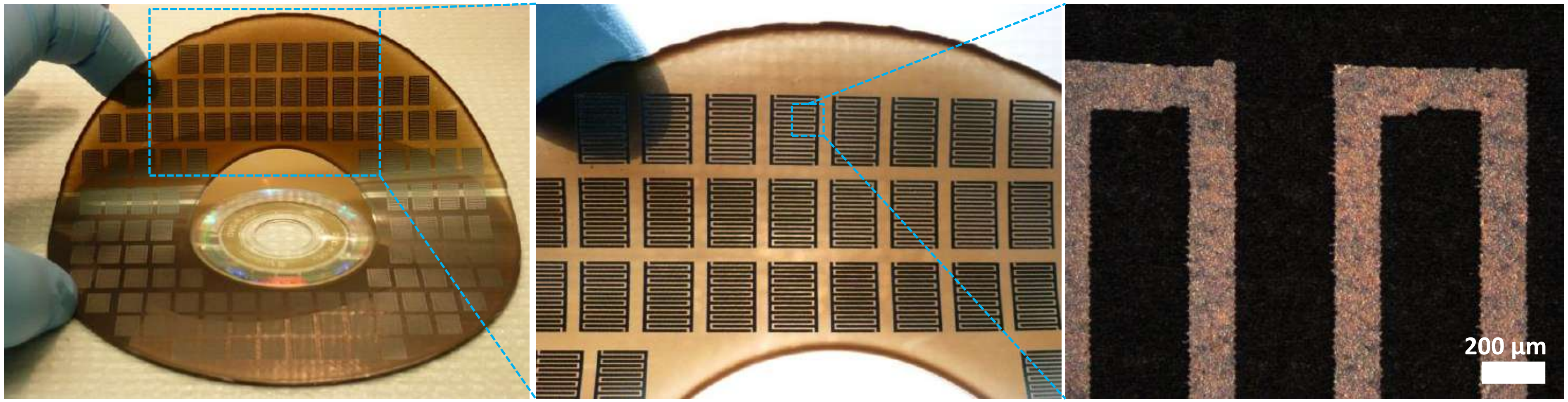
KANER laboratory UCLA

# Scalable Fabrication of Graphene Micro-Supercapacitors

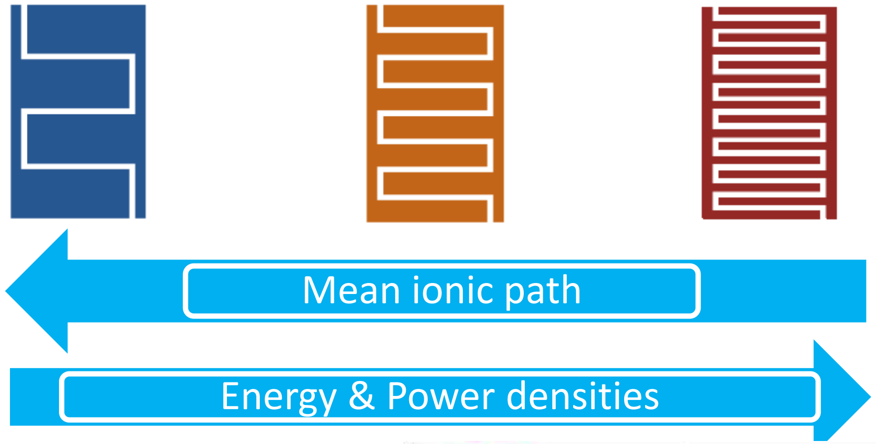


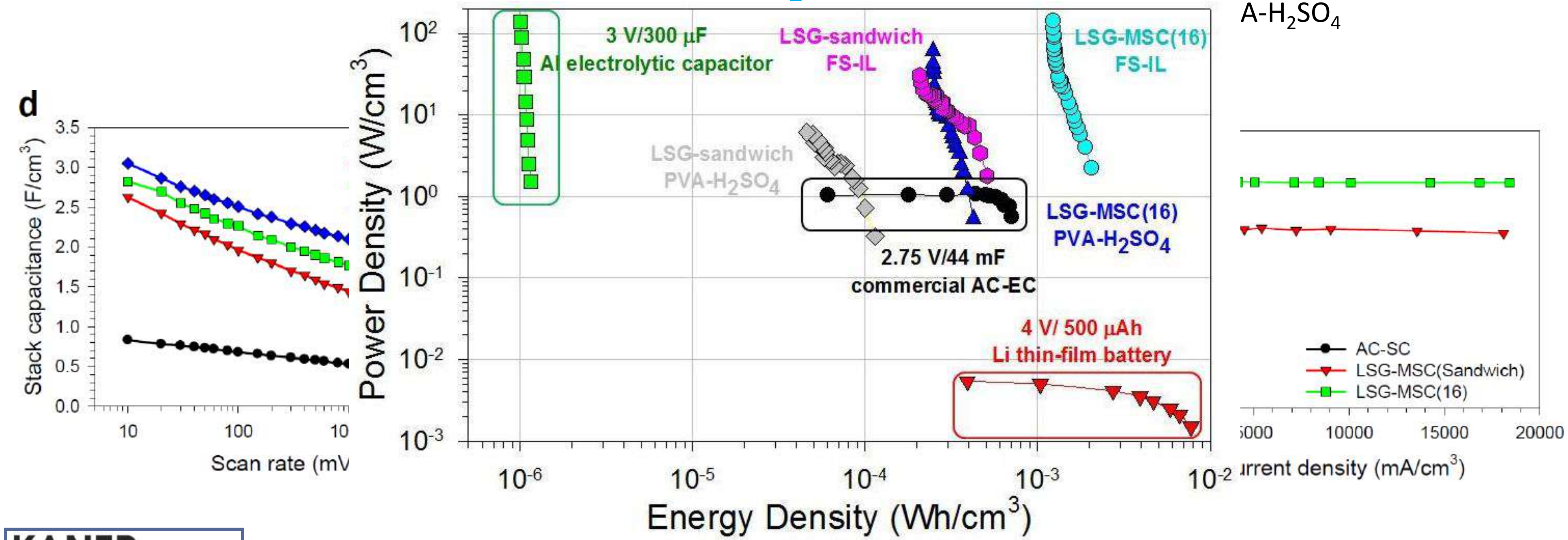

>100 micro-supercapacitors made in <30 minutes



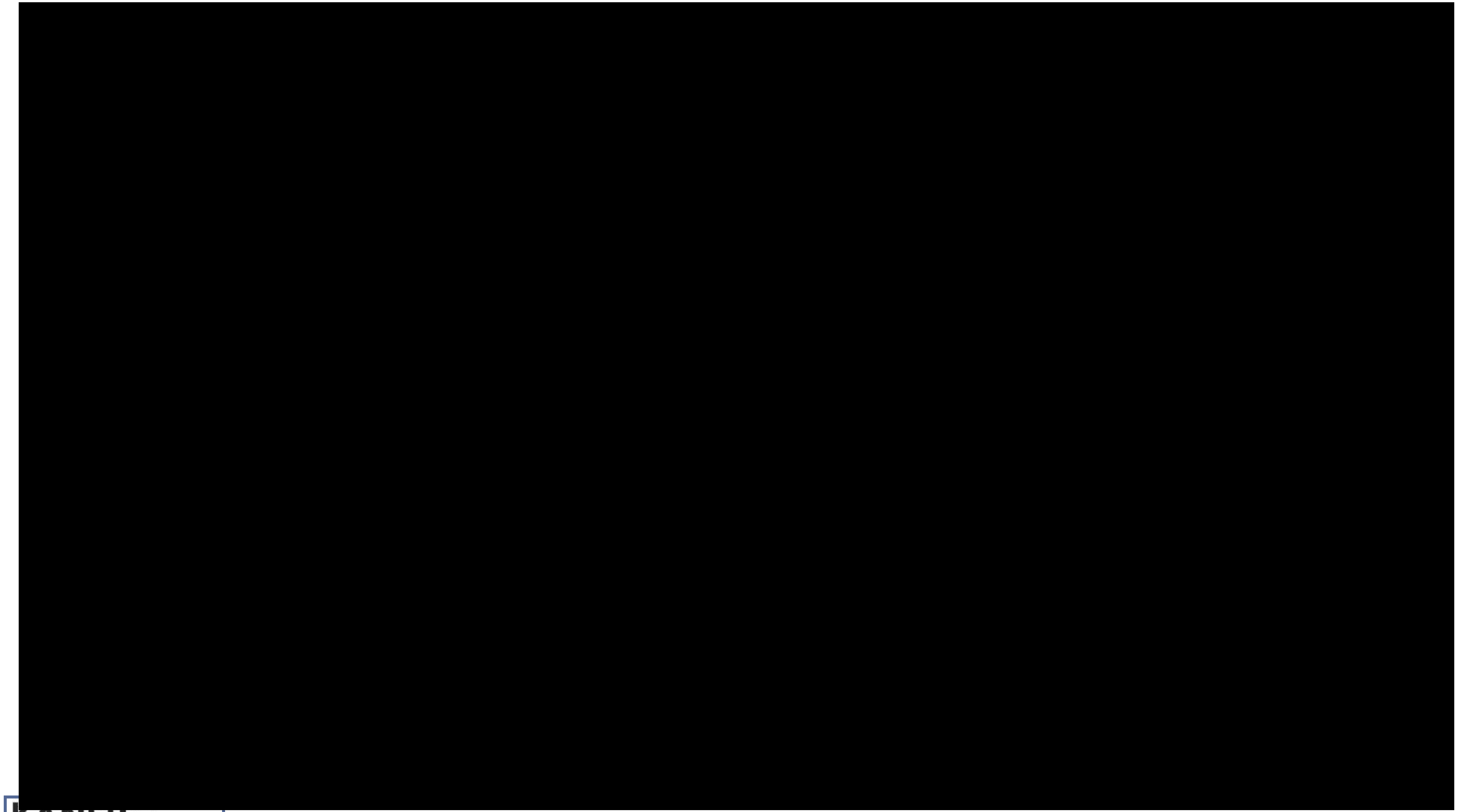
# Miniaturization Results in Increased Energy and Power




A-$H_2SO_4$



# NOVA: Search for the Super Battery



NANOTECH

# Graphene Powered Batteries


→ MAKING MATERIALS MATTER

# Product Offering and Commercial Readiness


## 100% American-Made

- Purchasers are looking to secure domestically manufactured battery alternatives over existing internationally sourced supply chains
- Nanotech's mid-scale production operates in Chico, California and qualifies for both Advanced Manufacturing PTC Credits ($35/kWh) and Electrode Active Materials PTC (10% of active materials costs)

## Already Producing at Scale

- Nanotech has an operational mid-scale manufacturing facility, located in Chico California, capable of producing 150MWh or 1 million batteries per month of 18650 and 21700 cells
- The Company is ready to finance a full-scale manufacturing facility with a high-quality product offering and a growing customer base

## Chemistry Agnostic & Safe Technology Platform

- Nanotech has designed, developed, and commercialized multiple battery formats across LCO, NMC, and LFP chemistries to produce the safest high-performing batteries available today
- Nanotech's IP and trade secrets are chemistry agnostic, allowing the Company to target multiple existing market segments and adapt with the evolution of battery chemistries moving forwards

## Graphene-Powered Cells

- Nanotech is the only company to have industrialized the production of high purity, single-layer graphene
- Graphene improves conductivity, safety, energy density, and cycle life in batteries and has applications across multiple other high-value industries

## Strong Customer Base Following

- Nanotech is in discussion with a number of customers that can take the full production capacity of their full-scale manufacturing line
- $13GWh+ annual sales in active negotiation

BASF
We create chemistry

# Nanotech's Technology and Production Roadmap

From Technology Incubation to Commercialization

**2002**

**WORLD'S FIRST GRAPHENE IP**

Spin out of UCLA with issuance of the first graphene patent

**2014**

**NANOTECH ENERGY FOUNDED**

Nanotech was founded to pursue graphene-based opportunities including a graphene battery

**2016**

**CHICO 1 AND GRAPHENE BATTERY**

R&D facility established and first graphene-based battery developed

**2019**

**NON-FLAMMABLE BATTERY**

Unique Organolyte™ electrolyte technology used to demonstrate first inherently safe, non-flammable li-ion battery

**2021**

**PURE GRAPHENE**

Achieved 95% monolayer graphene independently confirmed by three different institutions in the United States

**2022**

**CHICO 1**

Successfully commissions 3MWh pilot facility that produces flexible low-volume throughput including 18650 and flat cells

**2023**

**100% U.S. MADE BATTERY**

Nanotech launches 100% made in America cells for consumer product applications

**2023**

**CHICO 2**

Medium-scale production facility begins manufacturing cells in Q4

**2026**

**FULL-SCALE MANUFACTURING LINE**

First GWh production line comes online to produce 18650 NMC batteries

NANOTECH

*Technology Incubation Period*

*Company Commercialization*

The integration of graphene into electrodes improves the performance and safety of battery cells

**Improved Energy Density**

Increase the overall energy density of the battery by increasing the reversible capacity of the cathode. Our graphene can be utilized to increase the capacity of LFP by 5-20%

**Longer Cycling Life**

Graphene can increase the cycling life of the battery. Graphene can be uniformly coated on the cathode, which provides good protection for cathode particles against volume expansion or agglomeration

**Increased Power Density**

Increase the power density of the cells by manipulating the electronic and ionic conductivity of the electrodes and electrolytes

**Next Generation Silicon Anodes**

Integrating graphene into silicon anodes provides a conductive, flexible matrix that mitigates large volume changes and instability during use, enhancing conductivity, charge retention, and overall battery life

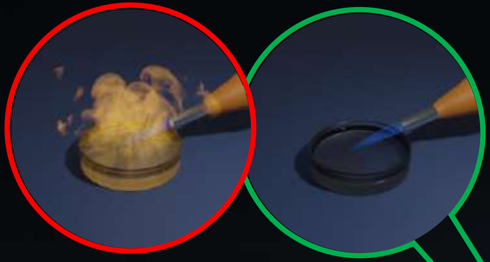
**Reduced Resistance**

The presence of graphene also reduces cell impedance

# Nanotech's Unique Battery Technology

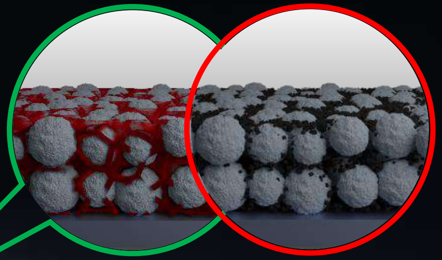
Nanotech's portfolio of protective patents, trade secrets, and industry experience offers a platform that: (i) introduces graphene into the electrodes, (ii) creates a non-flammable electrolyte, and (iii) produces a next generation lithium-ion battery across multiple cell formats

## ELECTROLYTE



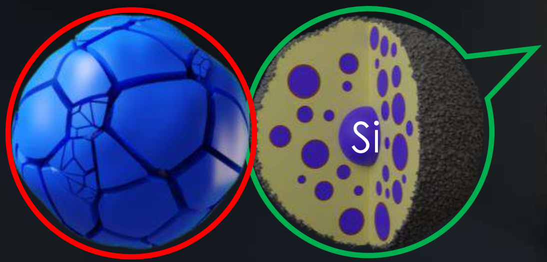
Organolyte™ is a non-flammable electrolyte that offers high energy density and functions across a wide range of operating temperatures without sacrificing safety measures, unlike competitors

## CATHODE



Graphene wraps the cathode particles to improve cycle life, energy density, safety, and conductivity

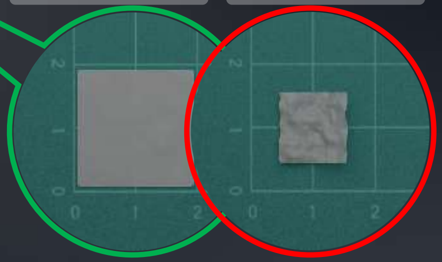

## ADVANCED ANODES




Graphene is enabling the next-generation of anodes such as silicon by improving strength, durability, and life cycle

## CURRENT COLLECTOR & SEPARATOR

150°C for 1h | 150°C for 1h



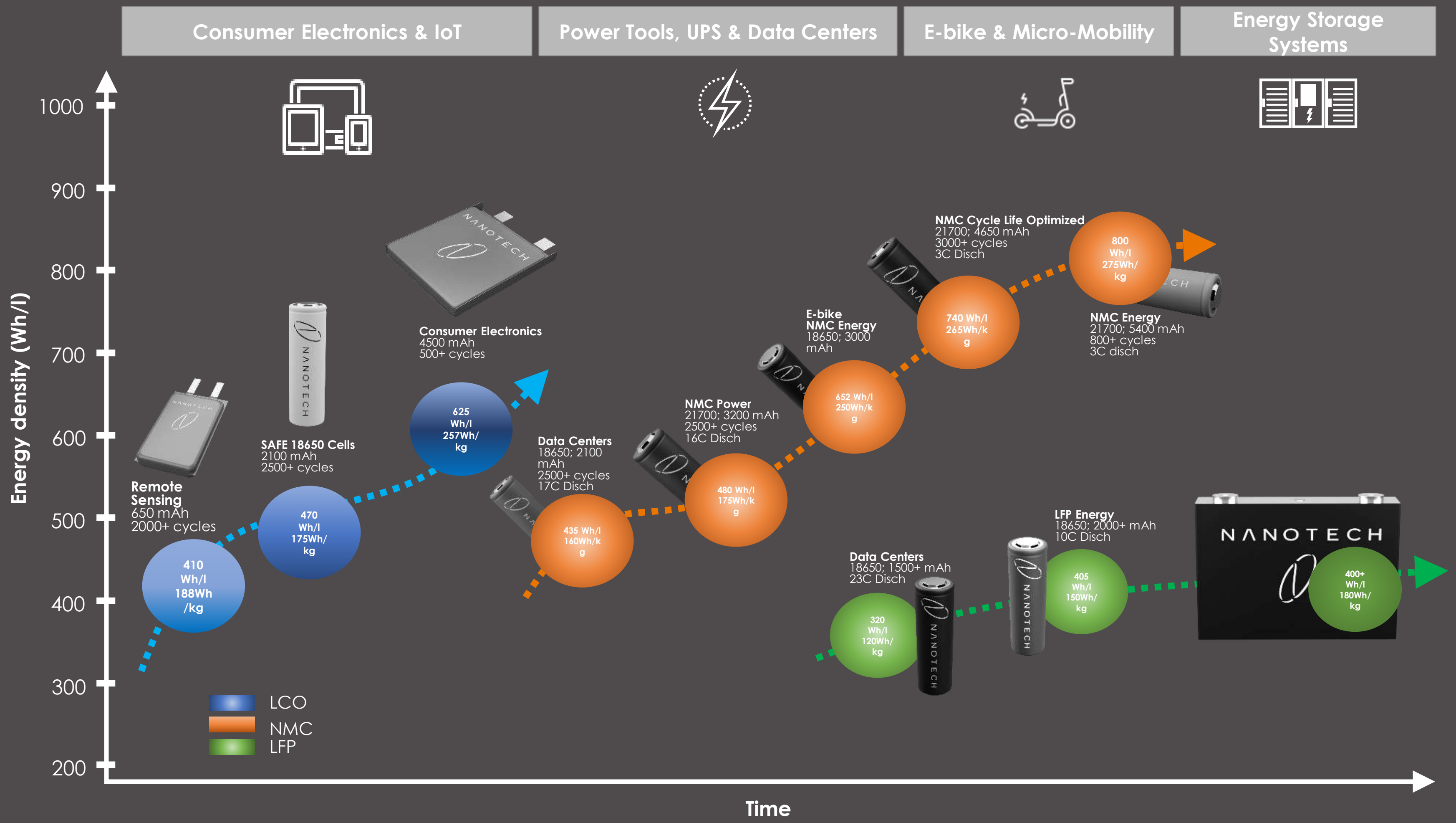
High thermal separators provide additional safety features by functioning at higher temperatures. Also utilizing lighter metalized plastic current collectors can improve the safety and energy density of batteries

Traditional Lithium ion

Nanotech Battery Tech

# Multiple Battery Formats Using Nanotech Technology

On the back of its proprietary graphene breakthrough, Nanotech has designed, developed, and commercialized multiple battery chemistries that are both safe and high-performing

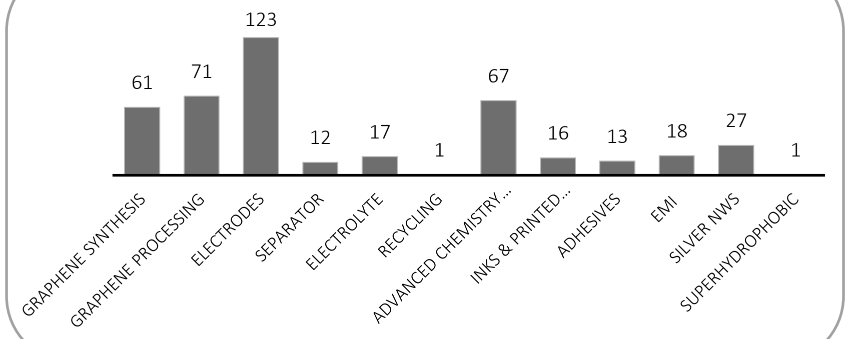


# Nanotech's Patent Portfolio

Nanotech has built a strong global portfolio of over 300 patents around its graphene and battery platforms

- Nanotech has the very first graphene patent ever submitted and issued
- The Company continues to be the only company producing non-restacking single layer graphene sheets on a commercial scale.
- The Company has over 300 patents filed covering all aspects from graphene synthesis, processing to applications in batteries, supercapacitors, inks, adhesives, EMI Shielding, printed electronics, its non-flammable Organolyte™ electrolyte technology, Li-S, Si anode, separators, and silver nanoparticles / nanowires

Patent Portfolio by Product




| Flag | Country | Patents Issued | Patents Pending | Total |
|---|---|---|---|---|
| | U.S. | 54 | 25 | 79 |
| | Europe | 12 | 17 | 29 |
| | China | 11 | 16 | 27 |
| | Japan | 17 | 10 | 27 |
| | South Korea | 14 | 11 | 25 |
| | Canada | 8 | 17 | 25 |
| | Australia | 16 | 6 | 21 |
| | India | 6 | 15 | 21 |

| Flag | Country | Patents Issued | Patents Pending | Total |
|---|---|---|---|---|
| | Taiwan | 14 | 4 | 18 |
| | Israel | 11 | 3 | 14 |
| | Mexico | 4 | 7 | 11 |
| | Brazil | 7 | 1 | 8 |
| | Hong Kong | 1 | 3 | 4 |
| | Vietnam | 2 | 1 | 3 |
| | Eurasia | 1 | 0 | 1 |
| | Indonesia | 1 | 0 | 1 |

| Flag | Country | Patents Issued | Patents Pending | Total |
|---|---|---|---|---|
| | Germany | 1 | 0 | 1 |
| | France | 1 | 0 | 1 |
| | Italy | 1 | 0 | 1 |
| | Turkey | 1 | 0 | 1 |
| | UK | 1 | 0 | 1 |
| | PCT | 1 | 0 | 1 |
| | **Total** | **185** | **145** | **330** |

# Nanotech's Cell Offering



NANOTI
phens
21
9

## Faster Charging

- Nanotech's LFP cells can withstand higher current when compared to market alternatives
- This is an important characteristic for electric vehicle applications as it can better cope with fast charging scenarios

## Higher Energy Density

- Nanotech's LFP Cells have 30% Higher Energy Density
- Commercial 18650 LFP cells offering ~1200mAh, whereas Nanotech's LFP power cell delivers up to 1600 mAh

## Improved Safety

- Nanotech's LFP Cells have a better safety rating than existing state of the art LFP cells

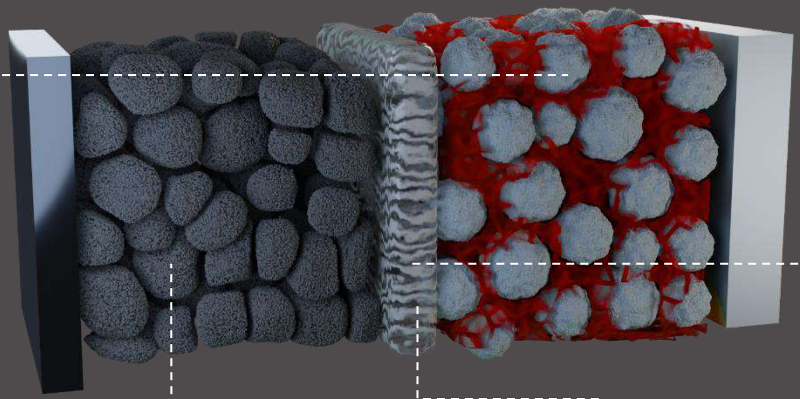
## Larger Usable Capacity

- Nanotech's LFP can fully discharge at extremely high currents (up to 30A), while maintaining a reasonable temperature of <70oC
- Unlike traditional NMC cells, where you often need to limit the depth of discharge to around 70-80%, Nanotech LFP power cells can be fully discharged without concerns of excessive overheating

## Long Term Cycling

- The introduction of graphene into the cathode significantly improves cycling stability to over 6,000 cycles under ideal conditions

Nanotech's portfolio of protective patents, trade secrets, and industry experience offers a platform that: (i) introduces graphene into the electrodes, (ii) creates a non-flammable electrolyte, and (iii) produces a next generation lithium-ion battery across multiple cell formats



**A Cathode**

Graphene wraps the cathode particles to improve cycle life, energy density, safety, and conductivity

**B Anode**

Graphene is enabling the next-generation of anodes such as silicon by improving strength, durability, and life cycle

**C Electrolyte**

Organolyte™ is a non-flammable electrolyte that offers high energy density and functions across a wide range of operating temperatures without sacrificing safety measures, unlike competitors

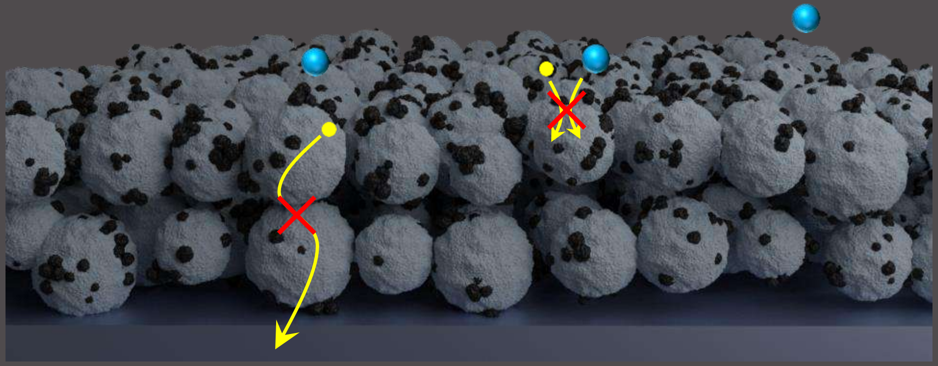
**D Separator**

High thermal separators provide additional safety features by functioning at higher temperatures

# A How Does Graphene Optimize the Cathode?

Graphene enables an “expressway” to facilitate electron transfer

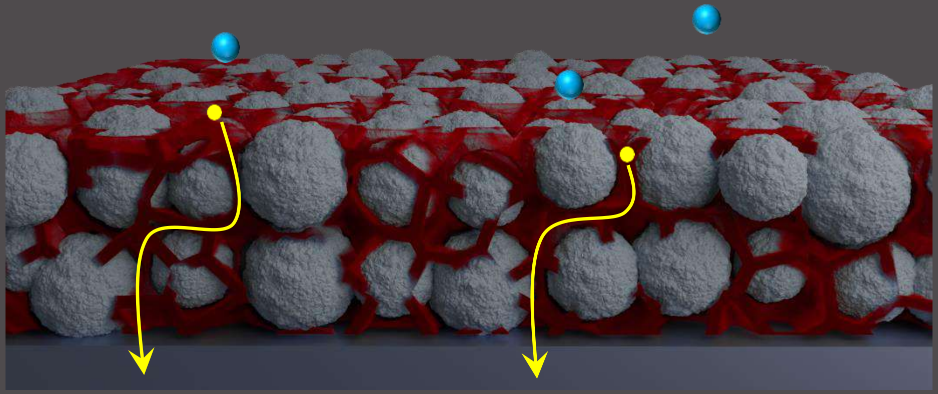
## Traditional Approach



### Point-to-Point Contact

In traditional electrodes, poor distribution of carbon black causes slow ion insertion and interparticle resistance, compromising the overall power density of the cell

## Nanotech Approach



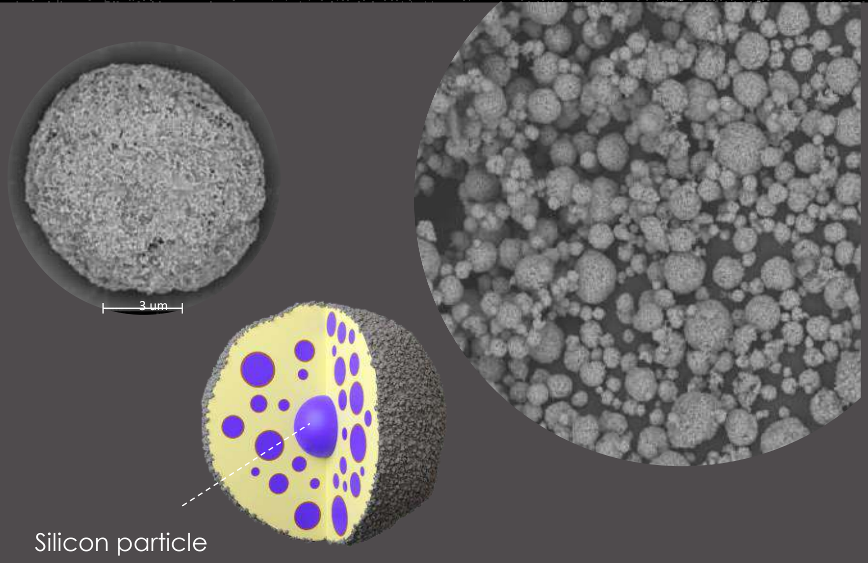
### Plane-to-plane Contact

Graphene provides 3D network, acting as an ideal electronic and mechanical support to increase the reversible capacity, power and cycling stability of standard cathodes

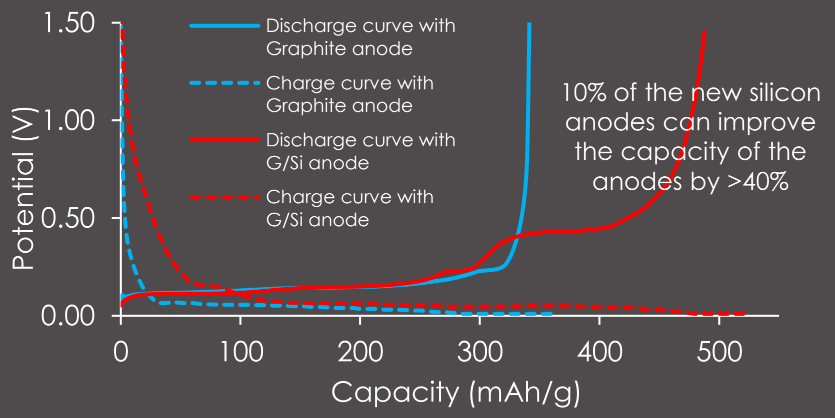
# B Graphene Allows for High Capacity and Stability in Next-Gen Silicon Anodes

## Nanotech's Silicon Anode Solution

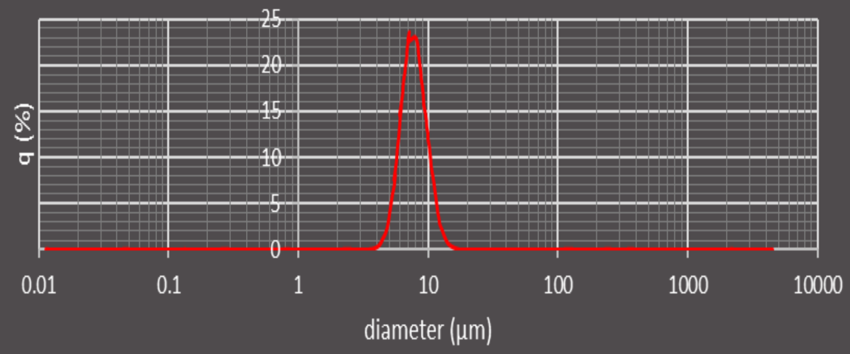
- Nanotech currently utilizes graphite for its anodes, but continues to develop and integrate its high-purity graphene into silicon anodes for next generation cells
- In a conventional graphite anode, it takes six carbon atoms to hold one lithium ion. In a silicon anode, each silicon atom can hold four!
- Silicon can store up to 10 times more lithium compared to graphite which enables batteries to have much greater energy
- Unfortunately, silicon anodes experience huge volume change (up to 300%) during charge and discharge and eventually leading the anode to disintegrate
- Graphene is a promising host for silicon nanoparticles for the design of high-capacity anodes
- The particle size distribution measurements show the powder with D50=8um, which is ideal for battery applications




## Silicon Anodes Improve Capacity




## Particle size distribution for silicon

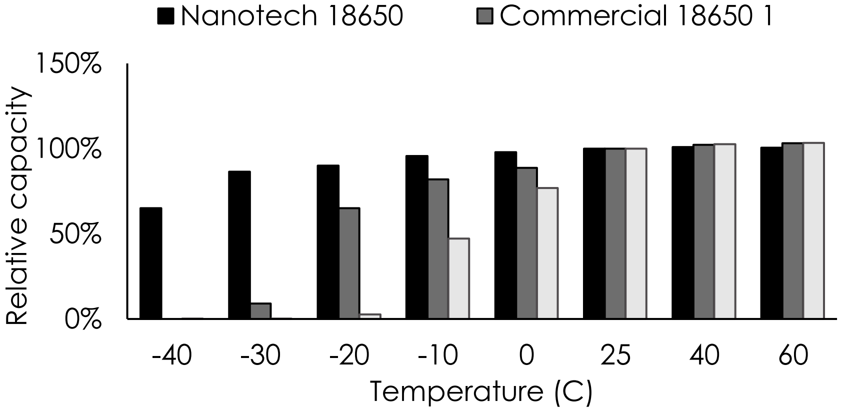


# C Nanotech's Proprietary Electrolyte

## Overview

- Nanotech's proprietary electrolyte technology, Organolyte™, enhances the safety rating of cells by utilizing patented high flashpoint / non-flammable electrolytes
- Organolyte™ reveals a wider operation temperature range
- The electrolyte not only expands a battery's operating temperature rage, but also improves its low temperature performance as displayed in the graph on the right
- Organolyte™ is a liquid-based electrolyte made from solvents readily available in the market, which are controlled and manufacturer in their Chico 1 facility
- Nanotech has developed over 100 Organolyte™ formulations tailored to various chemistries, cell designs, and applications

## Temperature Dependence of Discharge Capacity





# Manufacturing Roadmap to Fulfill Customer Orders

Nanotech is commissioning its Chico 2 facility, which will be running at full capacity by Q2 2025

## Chico 1

*Best-in-Class R&D Center*

- Pilot facility operating since 2016
- Flexible low-volume throughput for sample cells
- Key R&D center for developing next-gen battery cells
- Produces ~100 battery per day
- Graphene production capabilities of up to 3 tones per year

## Chico 2

*Mid-Scale Production Facility*

- Started commissioning in Q4 2023 and continues to ramp up production through 2024
- Capacity of 150MWh or 1 million batteries per month (20 cells per min)
- Semi-automated production line manufacturing18650 and 21700 cells
- Capable of producing LCO, NMC, and LFP cells
- 22.3 million cells committed, representing ~$150 million in revenue

## Gigafactory

*Full-Scale Production Facility*

- 500,000 square foot facility with multiple production lines for various battery chemistries
- Full design complete and set to be operational in Q1 2026
- Capability to scale up to 6GWh or 600 million batteries per year
- Facility includes a scale up of graphene production
- Over 13GWh under contract

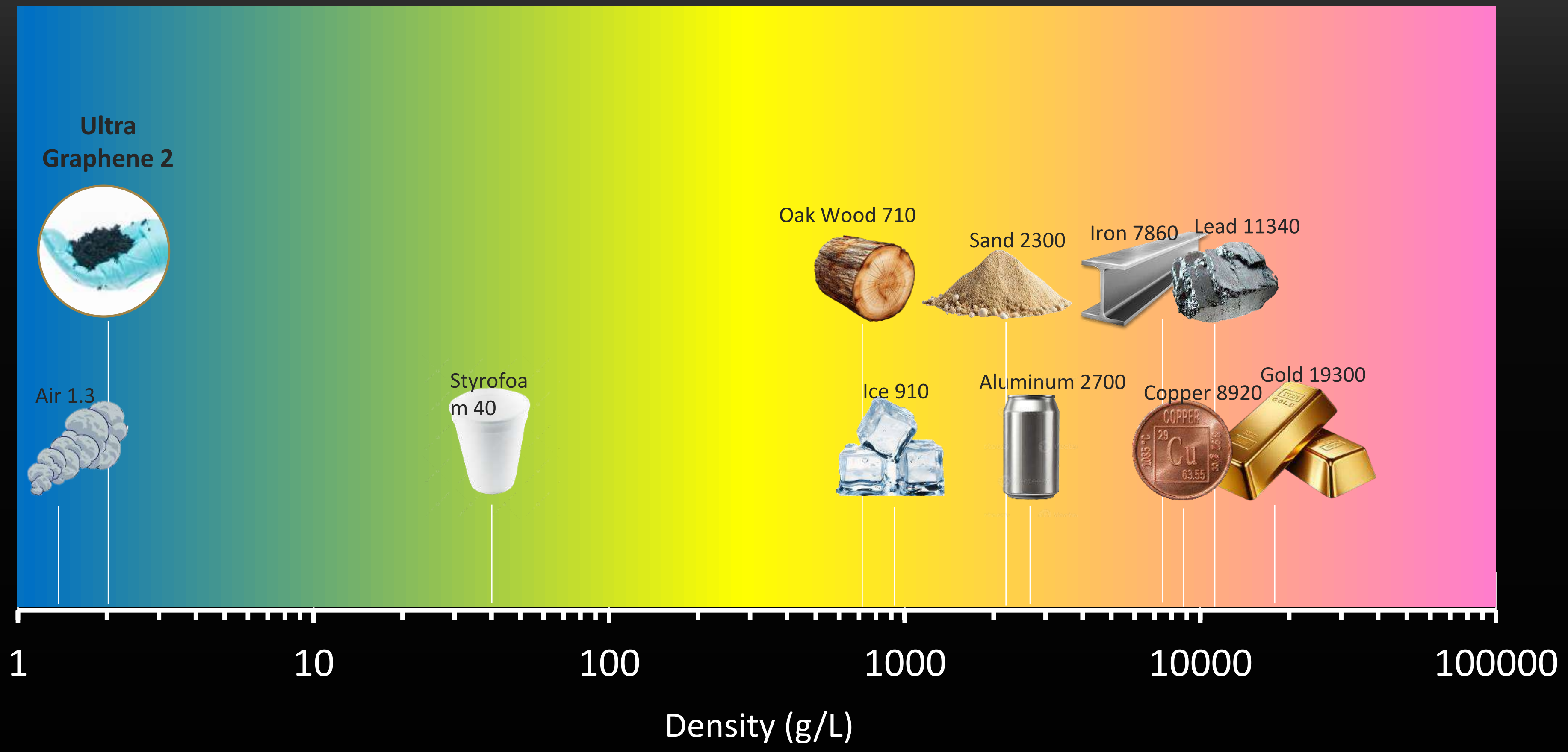
2016 → **Today** → 2026

# LIGHTEST AND STRONGEST MATERIAL ON EARTH


Just 2 grams of graphene can fill a 1-liter bottle, showcasing its extreme lightness. In comparison, the same weight of graphite powder is shown, with graphene being 550 times lighter.

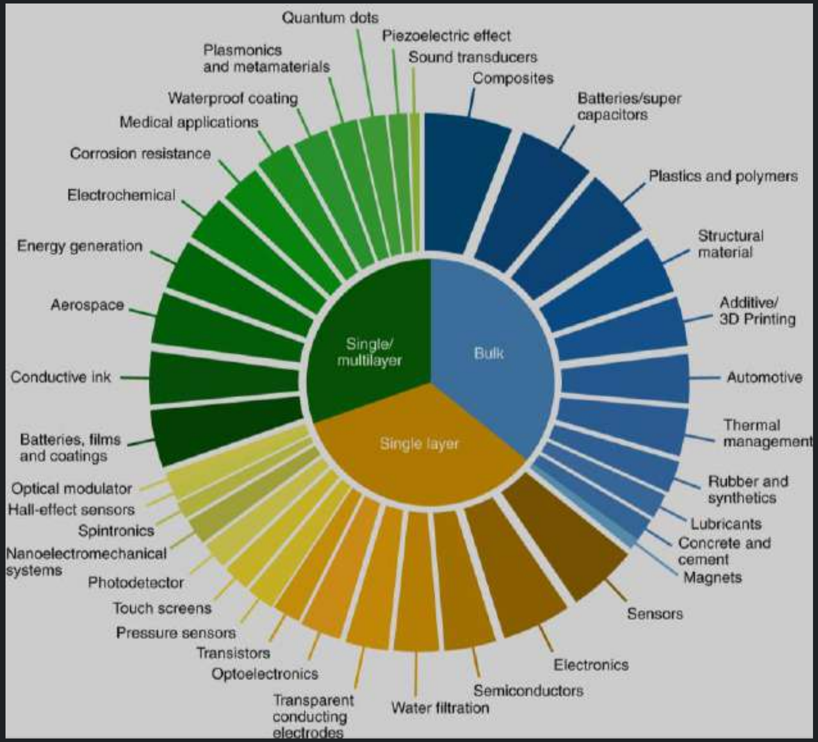
# LIGHTEST AND STRONGEST MATERIAL ON EARTH

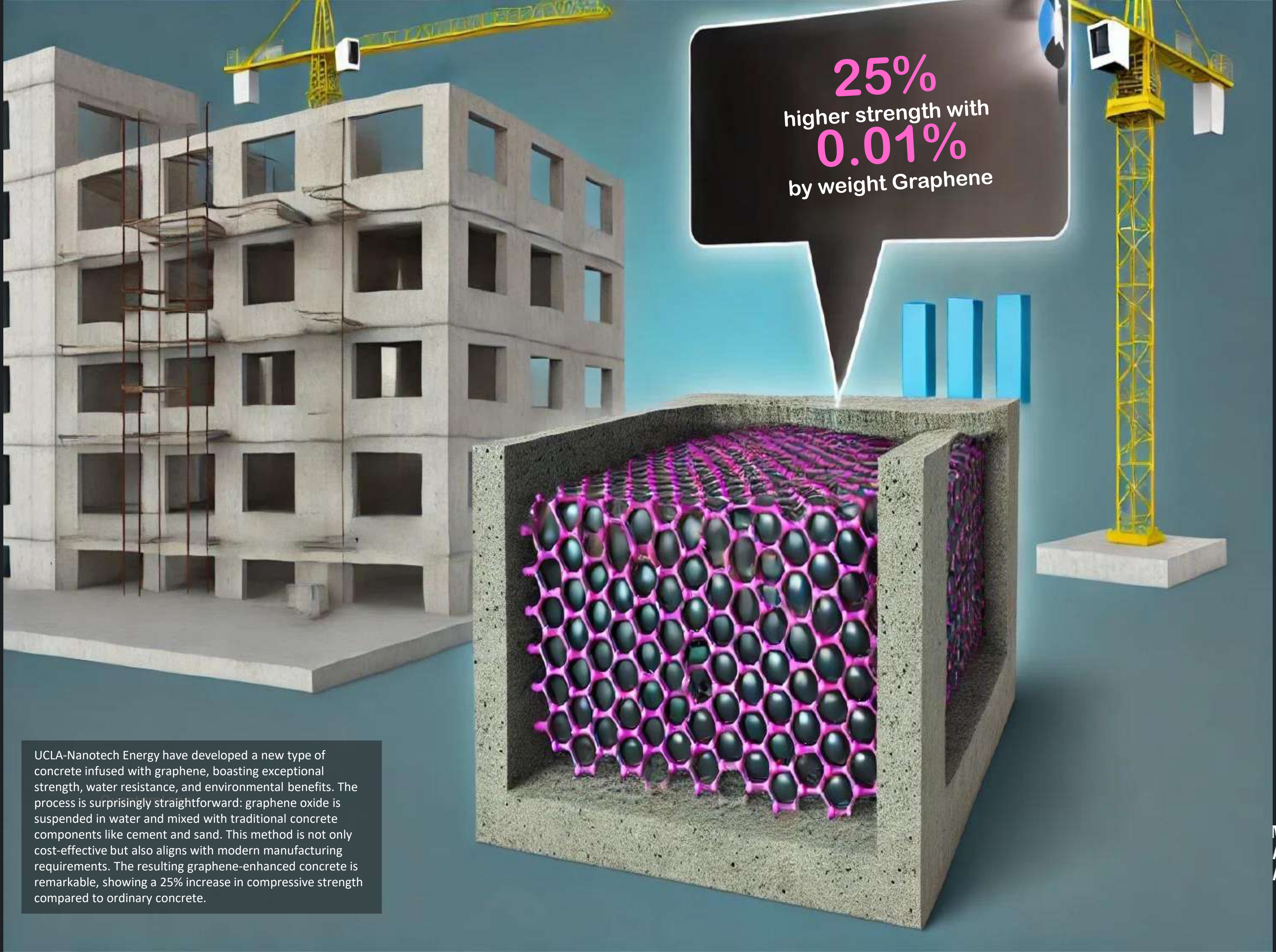
With a density of just 2 g/L, our graphene is one of the lightest materials known—comparable to air at 1.3 g/L. Despite its lightness, graphene is 4000 times lighter than steel yet 200 times stronger, having the potential to revolutionize the material industry.



# GRAPHENE MANUFACTURE AND APPLICATIONS

- We can produce enough to meet the demands for Chico 2 battery production with 150+ MWh and planning for 2.5GWh
- Actively collaborating with the supply chain to explore opportunities for domestic supply and implement strategies to reduce manufacturing costs.
- Collaborating with customers to explore potential applications in the following areas:
  - **Construction:** Enhancing the electrical and/or mechanical properties of mortar and cement.
  - **Recycling:** Strengthening recycled polymers for improved mechanical performance.
  - **Energy Storage:** Enhancing the surface conductivity of silicon anodes for more efficient energy storage.
  - **Material Dispersions:** Improving the dispersibility of graphene in polar solvents and polymers for various applications.
  - **Advanced Coatings:** Developing superhydrophobic spray paints for ultradry surface applications.

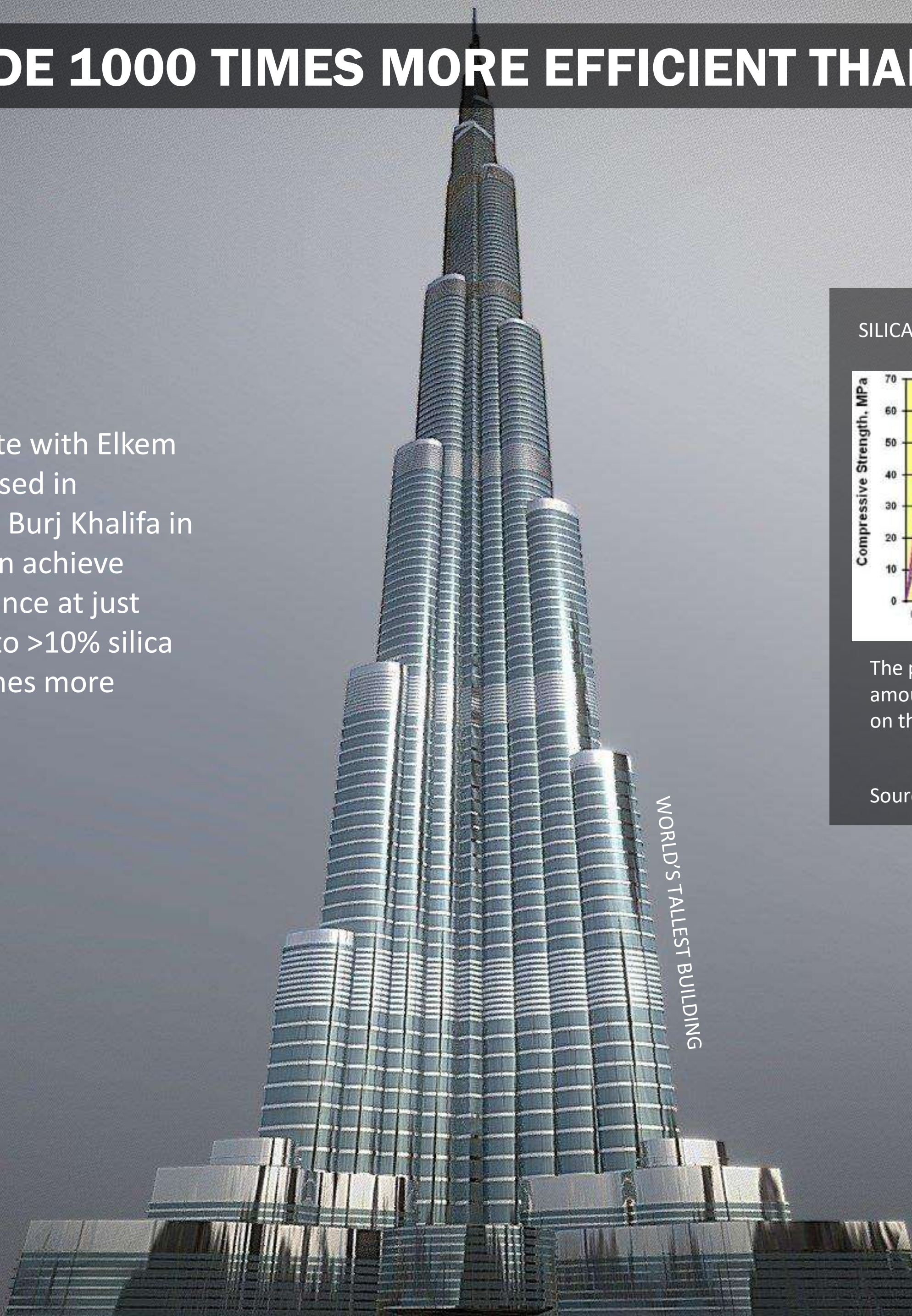





UCLA-Nanotech Energy have developed a new type of concrete infused with graphene, boasting exceptional strength, water resistance, and environmental benefits. The process is surprisingly straightforward: graphene oxide is suspended in water and mixed with traditional concrete components like cement and sand. This method is not only cost-effective but also aligns with modern manufacturing requirements. The resulting graphene-enhanced concrete is remarkable, showing a 25% increase in compressive strength compared to ordinary concrete.

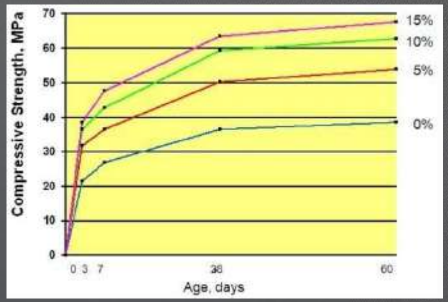
# GRAPHENE OXIDE 1000 TIMES MORE EFFICIENT THAN SILICA FUME!!

High-performance concrete with Elkem MICROSILICA® has been used in landmark projects like the Burj Khalifa in Dubai. Remarkably, GO can achieve similar or better performance at just 0.01% loading compared to >10% silica used, making GO 1000 times more efficient!



WORLD'S TALLEST BUILDING

SILICA FUME CONCRETE

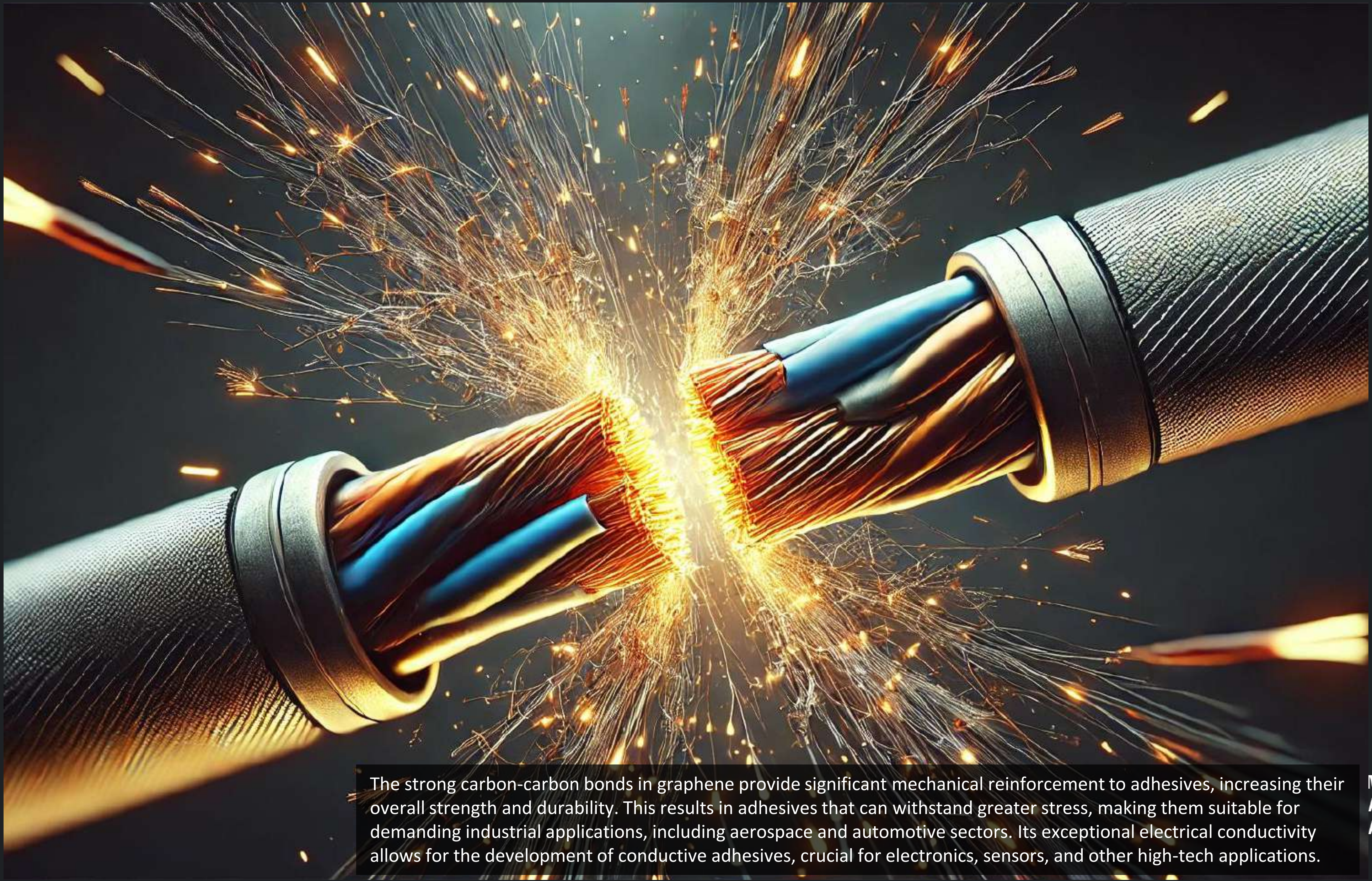



The plot shows influence of variable amounts of fume silica (from 5 to 15%) on the compressive strength of concrete

Source: The constructor.org [link]

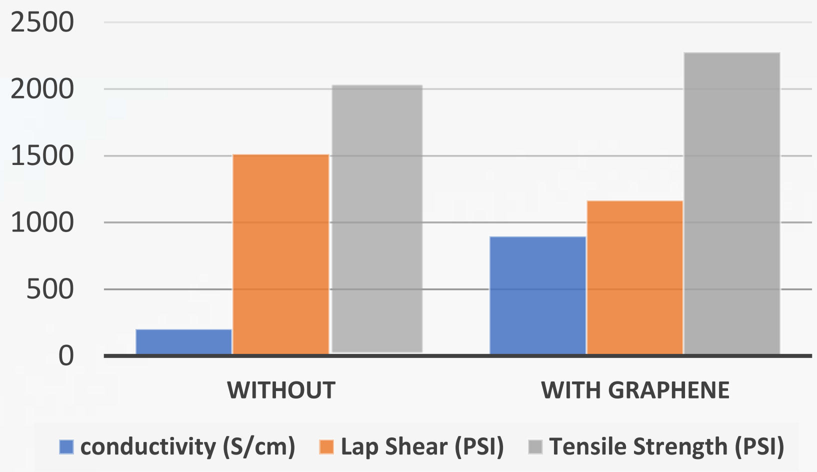
Source: Elkem [link]

# GRAPHENE FOR STRONGER AND CONDUCTIVE ADHESIVES



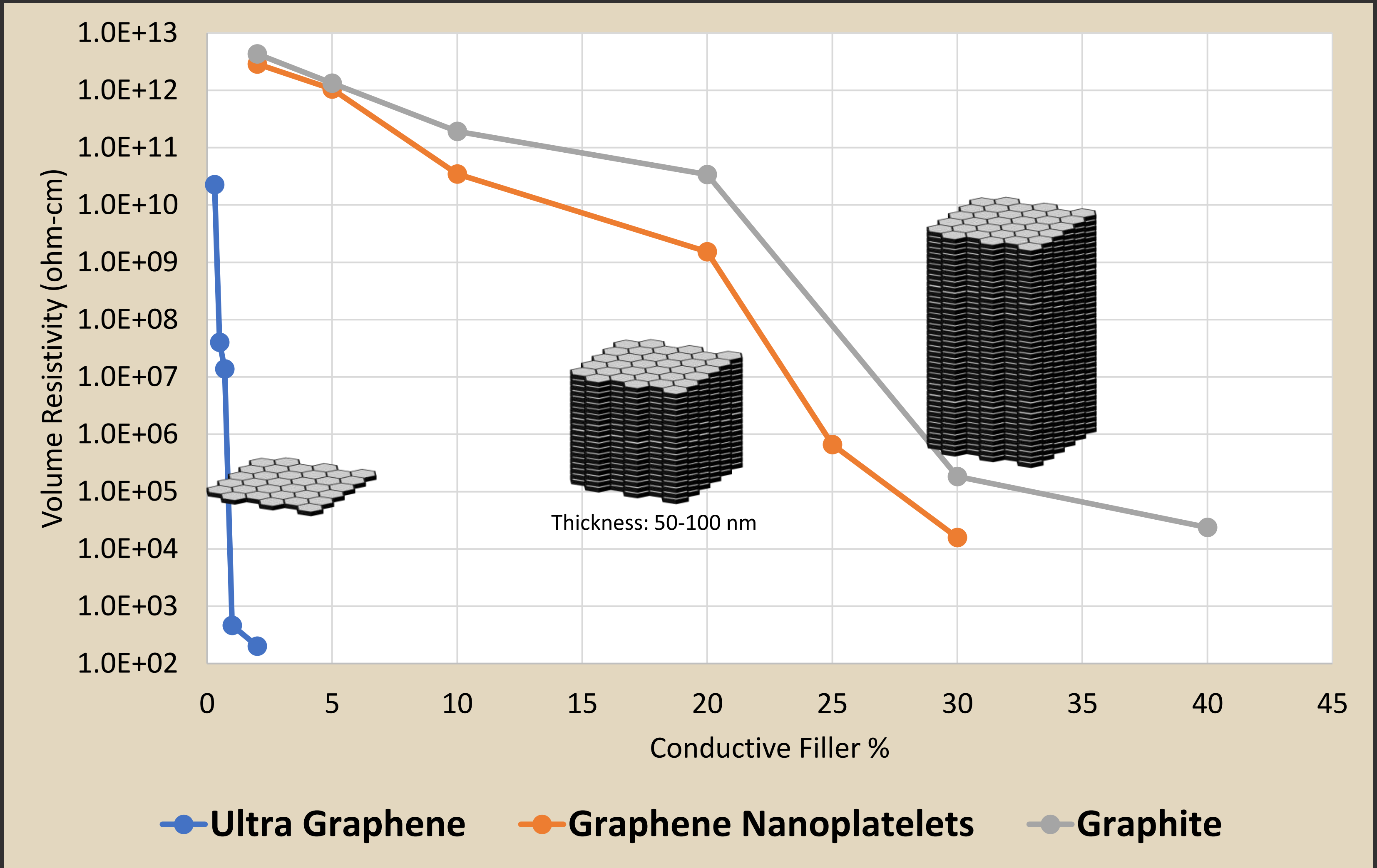
The strong carbon-carbon bonds in graphene provide significant mechanical reinforcement to adhesives, increasing their overall strength and durability. This results in adhesives that can withstand greater stress, making them suitable for demanding industrial applications, including aerospace and automotive sectors. Its exceptional electrical conductivity allows for the development of conductive adhesives, crucial for electronics, sensors, and other high-tech applications.

# GRAPHENE FOR STRONGER AND CONDUCTIVE ADHESIVES




The incorporation of graphene into silver epoxy significantly enhances both electrical and thermal conductivity while maintaining or even improving mechanical strength. This makes it ideal for use in high-performance applications like aerospace, automotive, and advanced electronics, where reliable conductive adhesives are essential.

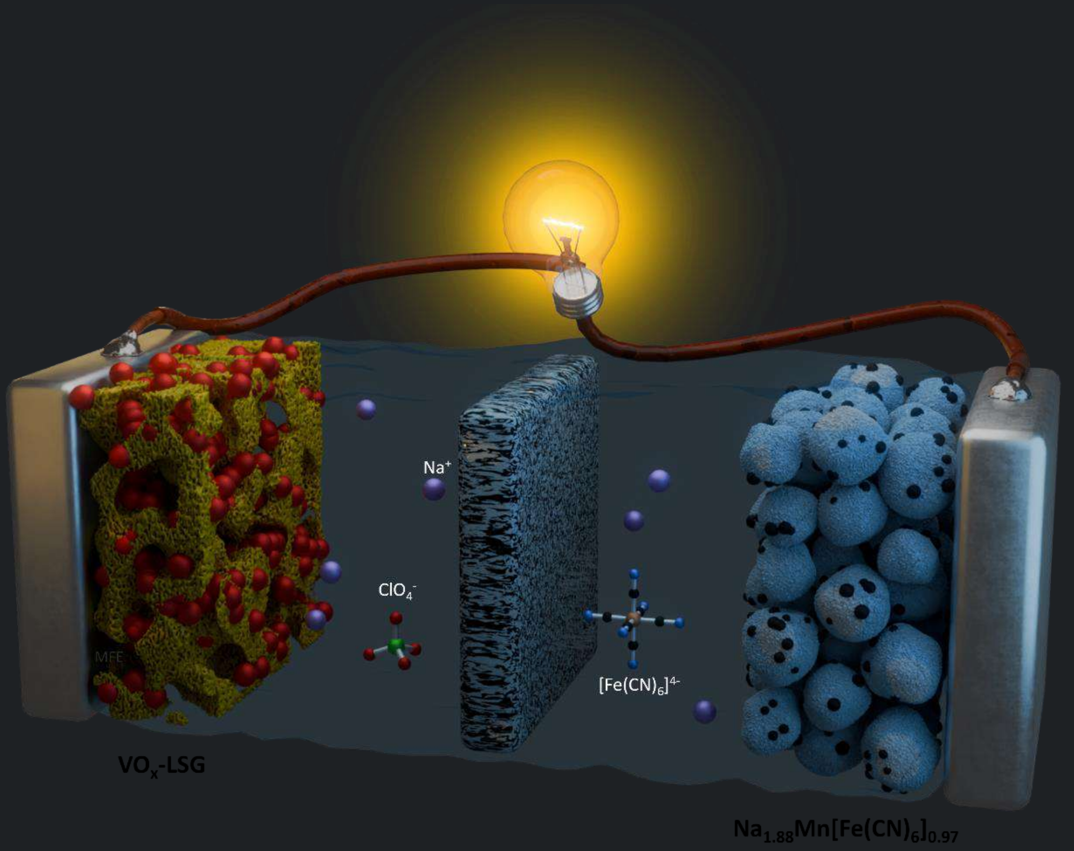
# COMPARING NANOTECH GRAPHENE WITH MARKET: SUPPLIER #1




- Nanotech graphene reaches percolation at <1%, whereas other forms of competitor graphene reaches the same with 25%+ loading
- Lower filler loadings results in better mechanical properties

→ MAKING MATERIALS MATTER

# GRAPHENE FOR ULTRAFAST SODIUM ION BATTERIES




**Advancing Sodium-Ion Battery Technology:**

- **High-Capacity Anodes**: Our research at UCLA leverages graphene in designing high-capacity anodes. The combination of graphene with vanadium oxide results in faster performance compared to conventional hard carbon anodes. Graphene's high surface area and excellent conductivity facilitate rapid charge transfer, leading to improved battery efficiency and cycle life .
- **Superior Cathodes**: We are also developing graphene-based cathodes that significantly outperform the widely used Prussian Blue analogues. Graphene enhances the structural integrity and conductivity of cathode materials, resulting in better overall battery performance .

**Why Graphene Matters:**

- **Enhanced Conductivity**: Graphene's superior electrical conductivity accelerates charge/discharge cycles, making it ideal for ultrafast applications .
- **Structural Stability**: Its mechanical strength supports stable electrode structures, which is critical for the longevity of sodium-ion batteries .


Lu, Yong, Yanying Lu, Zhiqiang Niu, and Jun Chen. "Graphene-Based Nanomaterials for Sodium-Ion Batteries." *Advanced Energy Materials* 8, no. 17 (2018): 1702469.
Zhang, Yan, Xinhui Xia, Bo Liu, Shengjue Deng, Dong Xie, Qi Liu, Yadong Wang, Jianbo Wu, Xiuli Wang, and Jiangping Tu. "Multiscale graphene-based materials for applications in sodium ion batteries." *Advanced Energy Materials* 9, no. 8 (2019): 1803342.

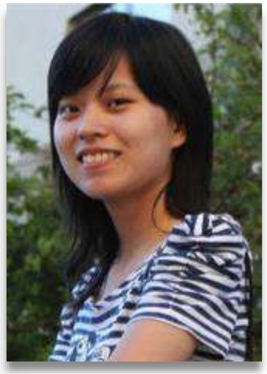
Dr. Maher El-Kady
Nanotech Energy

Dr. Volker Strauss
Max Plank Institute

Dr. Lisa Wang
Lam Research

Dr. Jee Youn Hwang
Hyundai

Dr. Sergey Dubin
Z-Power



Dr. Mengping Li
Lam Research

Dr. Veronica Strong
Intel

Dr. Jonathan Wassei
Rolith Inc.

Dr. Scott Gilje
Northrop-Grumman

Dr. Matthew Allen
McKenzie & Co.

Dr. Vincent Tung
KAUST

Dr. Yuanlong Shao
Soochow Univ.

NSF | the UC Discovery Grant | NORTHROP GRUMMAN AEROSPACE | MITSUBISHI CHEMICAL | FENA | NE Nanotech Energy | Maxwell TECHNOLOGIES Enabling Energy's Future™ | FCRP

# Group Discussion
# AI Infrastructure

# Members Lunch

# Group Discussion

Energy / Power Shortages around the world ad how to solve them

# Comfort Break

Navjot Sawhney

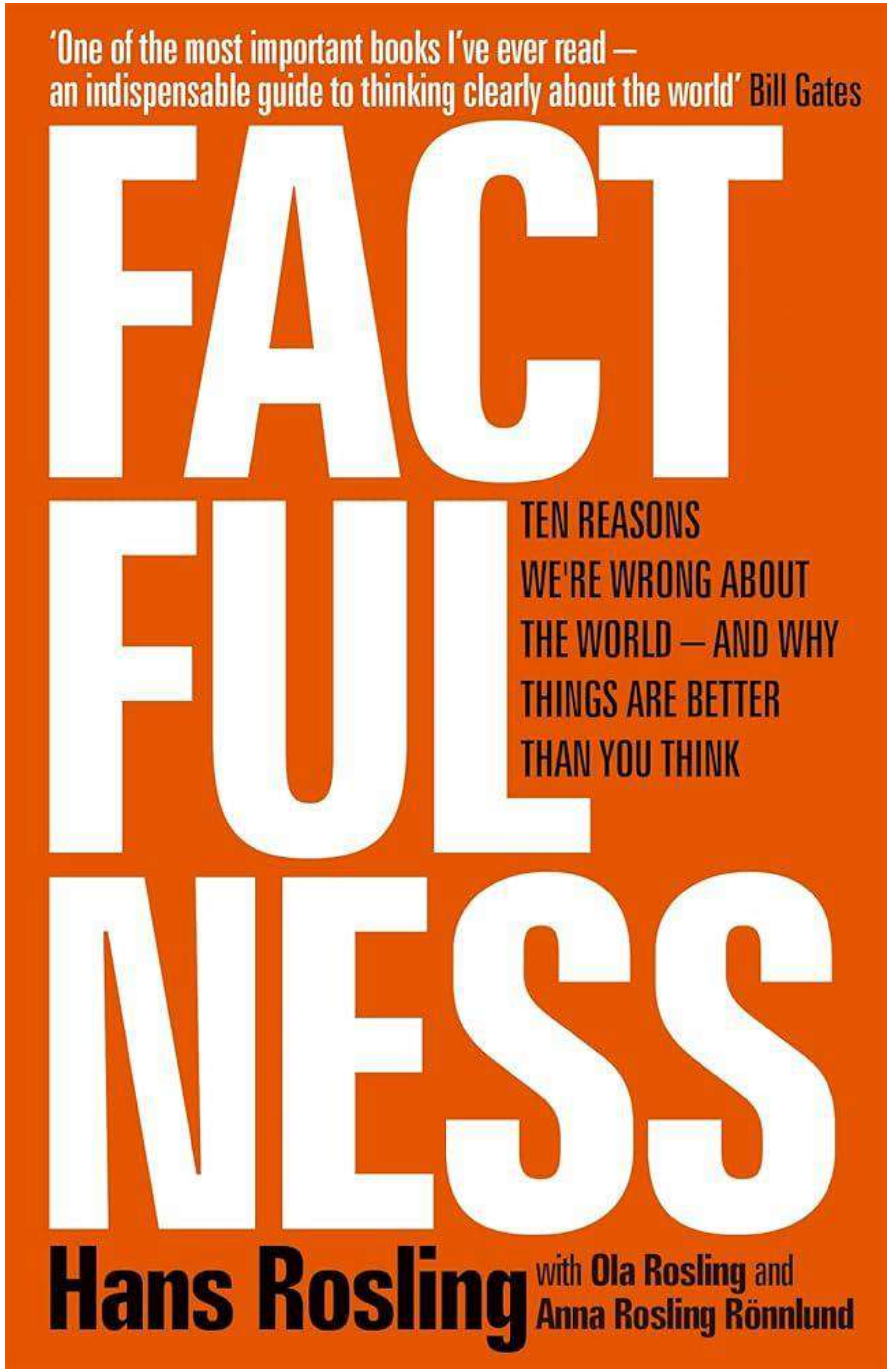
# What would you do with an extra 15 hours a week?

the washing machine project

supported by

Whirlpool FOUNDATION

# Prize


'One of the most important books I've ever read –
an indispensable guide to thinking clearly about the world' Bill Gates
FACT
FUL
NESS
TEN REASONS
WE'RE WRONG ABOUT
THE WORLD – AND WHY
THINGS ARE BETTER
THAN YOU THINK
Hans Rosling
with Ola Rosling and
Anna Rosling Rönnlund

# Questions

**1. In all low-income countries across the world today, how many girls finish primary school?**

- 20%
- 40%
- 60%

**2. Where does the majority of the world population live?**

- Low-income countries
- Middle-income countries
- High-income countries

Prev Next

**3. In the last 20 years, the proportion of the world population living in extreme poverty has . . .**

- Almost doubled
- Remained more or less the same
- Almost halved

**4. What is the life expectancy of the world today?**

- 50 years
- 60 years
- 70 years

**10. Worldwide, 30-year-old men have spent 10 years in school, on average. How many years have women of the same age spent in school?**

- 9 years
- 6 years
- 3 years

# Answers

1. In all low-income countries across the world today, how many girls finish primary school?

- 20%
- 40%
- 60% ✓

## 2. Where does the majority of the world population live?

- Low-income countries
- Middle-income countries ✔
- High-income countries

3. In the last 20 years, the proportion of the world population living in extreme poverty has . . .

- Almost doubled
- Remained more or less the same
- Almost halved ✔

**4. What is the life expectancy of the world today?**

- 50 years
- 60 years
- 70 years ✓

**10. Worldwide, 30-year-old men have spent 10 years in school, on average. How many years have women of the same age spent in school?**

- 9 years ✔
- 6 years
- 3 years

# The story so far…


Welcome to Terminal 5
Heathrow
Welcome to the home of BRITISH AIRWAYS
Help

the washing machine project

# The Problem


the washing machine project
supported by Whirlpool
Reclaiming time, improving lives.

Currently

1,000,000,000

families do not have access to an electric washing machine.

The burden of hand washing clothes falls on women and children, preventing opportunities to work, study or rest.

Innovative **research and development** understanding user needs and behaviors

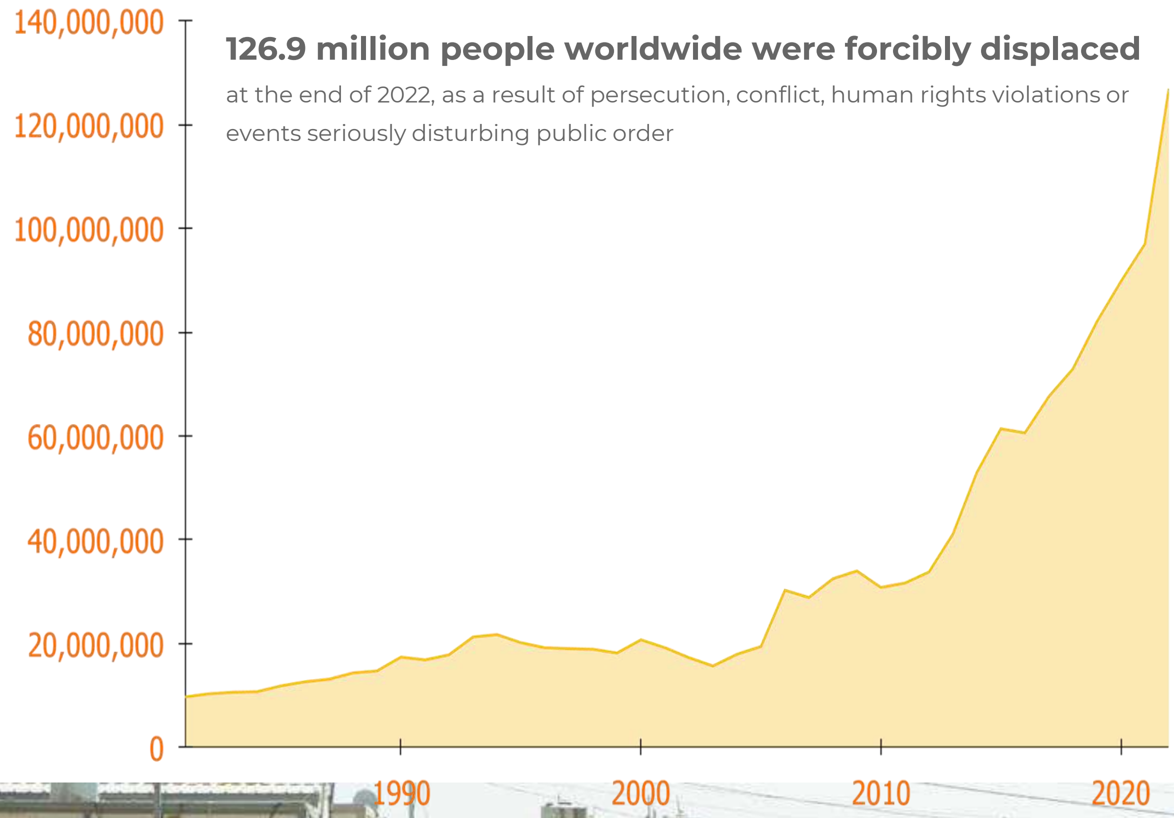
**Programmes** that put academic collaboration, monitoring and evaluation at the core

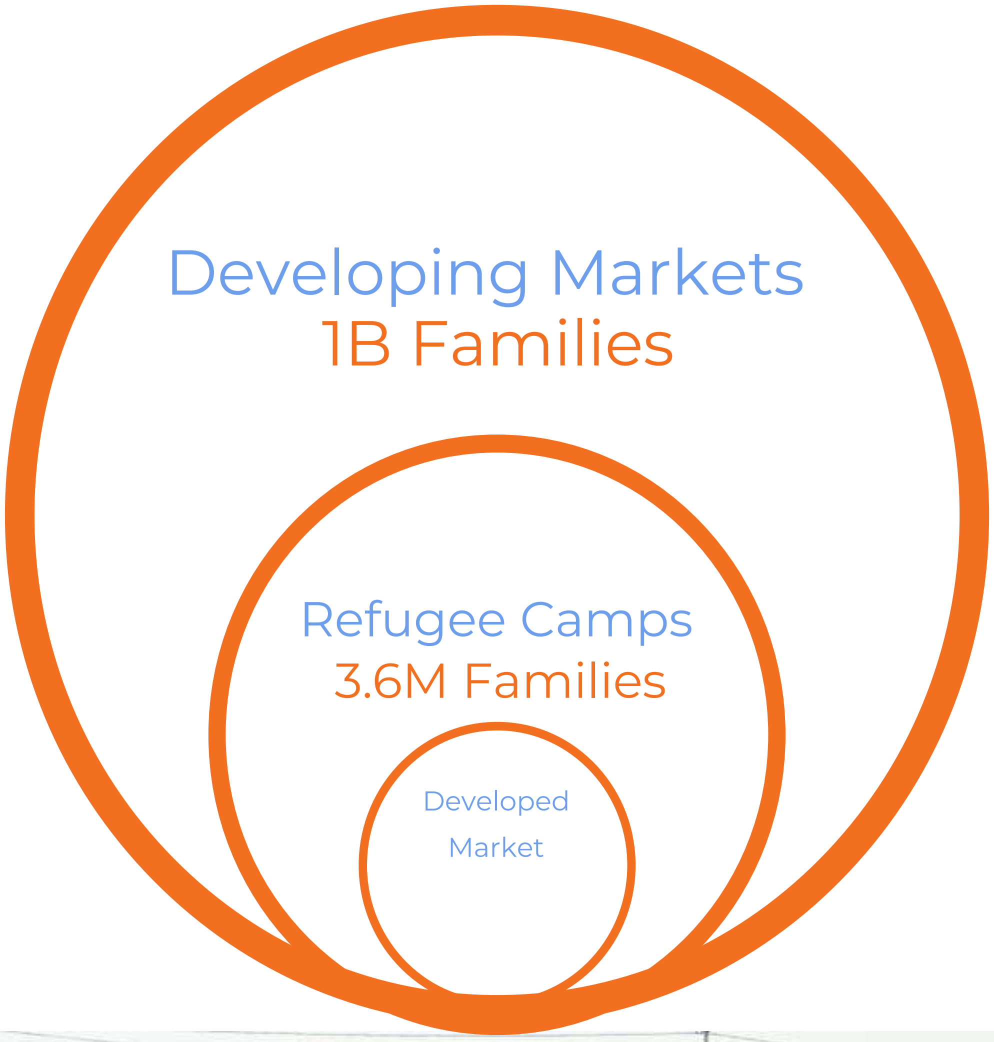
**Sustainable products and operations** building products and services that last

the washing machine project

Sources: Gapminder

# Market Need





TWMP, September 2021, Mamrasham Refugee Camp Iraq, Refugee Homes
Sources: OECD, 2011; Duffin, 2019; TWMP, 2019; UNHCR, 2023

## 60% of the world's population hand wash clothes.

That's over 5 billion people.

**This issue predominantly affects women and girls.**

Spending up to 20 hours per week, those who hand wash clothes are prevented opportunities to rest, play, access education and generate an income.

**When washing clothes at a water source, women and girls are at increased risk of gender-based violence and other forms of violence.**

It is much safer to wash clothes at home, however for many users this is not possible.

the washing machine project


## Physical Burden

Hand washing clothes takes a **physical toll on users**.

Sustained periods hand washing clothes can lead to back pain, skin irritation, as well as physical issues in later life.

Constant exposure to water and detergents can cause hand injuries, skin ailments, and respiratory problems.

According to UNICEF, there are more than **100 million people in the world using untreated surface water.** In these places, children are especially vulnerable to infectious diseases from using unsanitary water.

# Laundry takes time

Up to 20 hours or 2.5 working days each week is spent hand washing clothes globally.

With up to 2.5 days/week saved, **women and girls could dedicate an entire school year's worth of hours (1,000 hours) to education.**

**The time taken annually equals the hours of a part-time job.**

Giving this time back unlocks potential for income generation or professional development, **enhancing female livelihoods** and community prosperity.

the washing machine project

# Our Solution:
# The Divya Washing Machine

# Salad Spinner

# Divya 1.0

# Divya 1.55


the washing machine project
care


the washing machine project
care


the washing machine project
care


TWMP Iraq Pilot Build
2C16
-C2

# The Divya Washing Machine

# Divya

## Key features

1. Horizontal axis, rotational hand crank
2. Metal construction, no welding, tooling free, flat pack
3. Completely disassemblable design

## Key benefits

1. Scope for rapid design iterations based on user feedback
2. Sustainable & fully recyclable
3. Robust and repairable


the washing machine project

# The World's First Flat Packable Washing Machine


TWMP, UNHCR unloading 100 machines ready for distribution to Republic of Congo, 2024

the washing machine project
supported by Whirlpool
Reclaiming time, improving lives.

## Scope for rapid design iterations based on user feedback

## Sustainable & fully recyclable

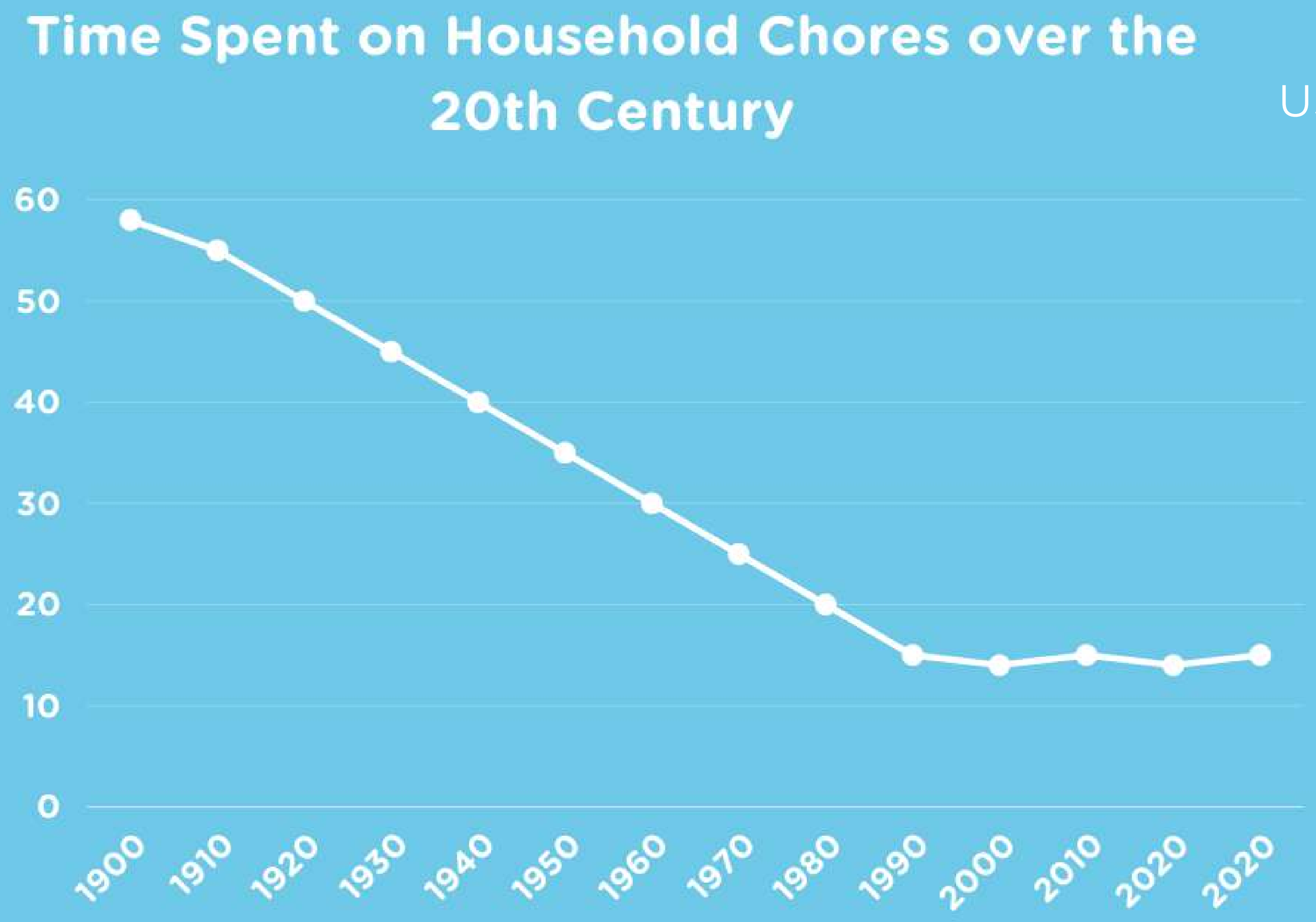
## Robust and repairable

TWMP, Anjali household fixing machine, Kuilapalayam, South India 2024

# The Global Washing Divide

US Households

Hours per week



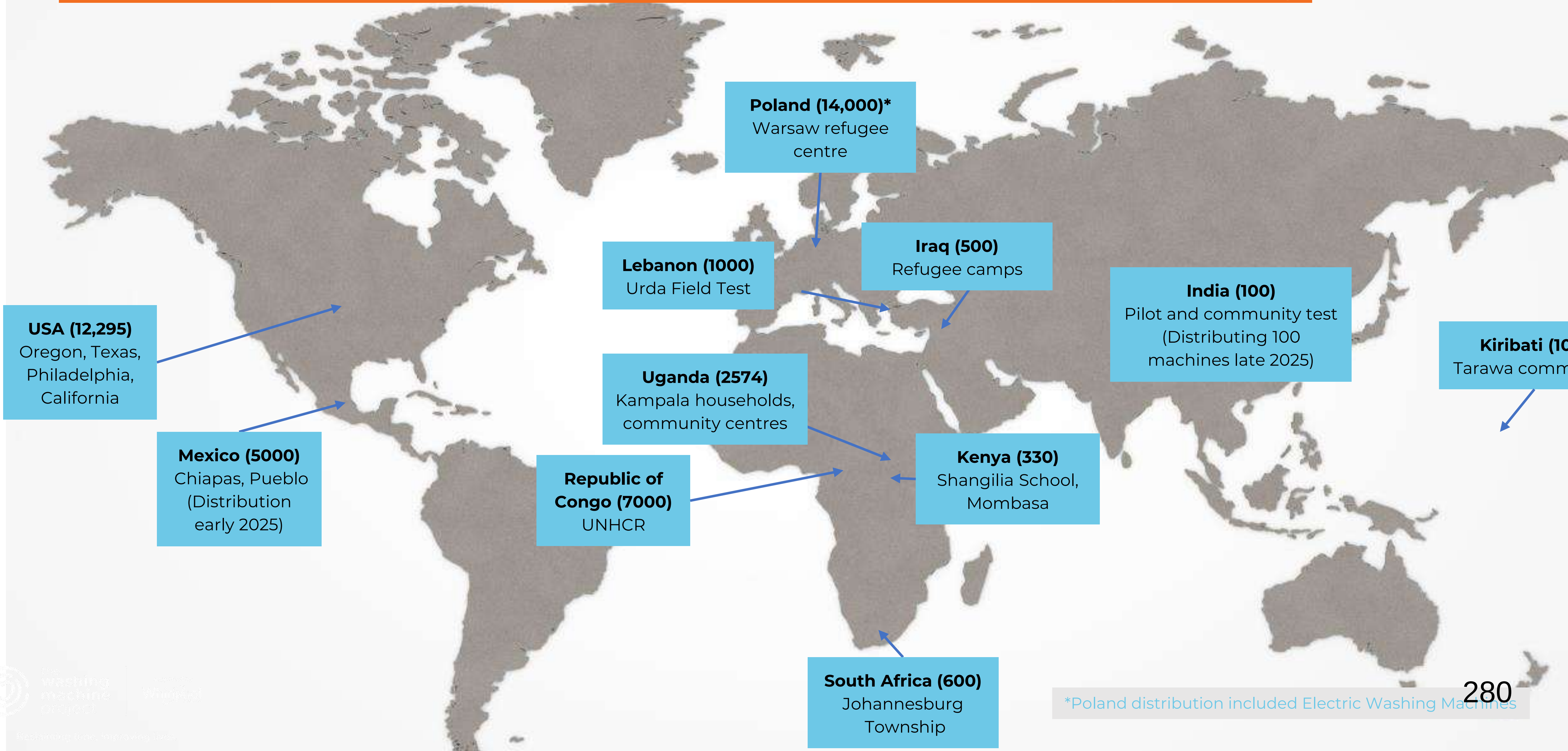

the washing machine project
supported by Whirlpool
Reclaiming time, improving lives.

Effrosyni Adamopoulou, Jeremy Greenwood & Nezih Guner, (March ‘24) - The Household Equipment Revolution

# The Greatest Invention Of The Industrial Revolution?

TWMP, Women and girls washing clothes on riverbank, Betou District, Republic of Congo, 2023

# TWMP has improved over 31,599 lives globally




*Poland distribution included Electric Washing Machines

# Our Users

# Anjali, Tamil Nadu

# Sylvia, Uganda


africell
the washing machine project
RS
MW
the washing machine project
supported by Whirlpool
Reclaiming time, improving lives.
My name is Namaganda Sylvia

# Collaboration and Community

# Supporters

## Agencies

We work with NGOs, INGOs and local agencies in our programming, using their local knowledge to carry out needs assessments of end users, monitoring and evaluation, obtaining government support and distributing Divya washing machines.

## Universities

Collaborating with academic institutes provides us with research and engineering support, alongside monitoring and evaluation expertise.

## Companies

Corporate partners support us through funding, facilities, employee volunteering to build machines, sharing knowledge and expertise and promoting TWMP to their audience.

OXFAM

UNHCR The UN Refugee Agency

care

PLAN INTERNATIONAL

World Vision

Save the Children

UNIVERSITY OF BATH

University of BRISTOL

UNIVERSITY OF CAMBRIDGE

THE UNIVERSITY of EDINBURGH

Whirlpool FOUNDATION

RS Group

JLR

MW MEAN WELL

# Employee Engagement & Builds


the washing machine project

The Washing Machine Project has a vision to create a world leading organisation, which brings together *Innovation, Research and Development* to solve some of the world's most pressing humanitarian and development challenges.

1,000,000 impacted by 2029 (0.1% of 5.6 billion)

the washing machine project

# The Promise


2017

# Three call to actions for you

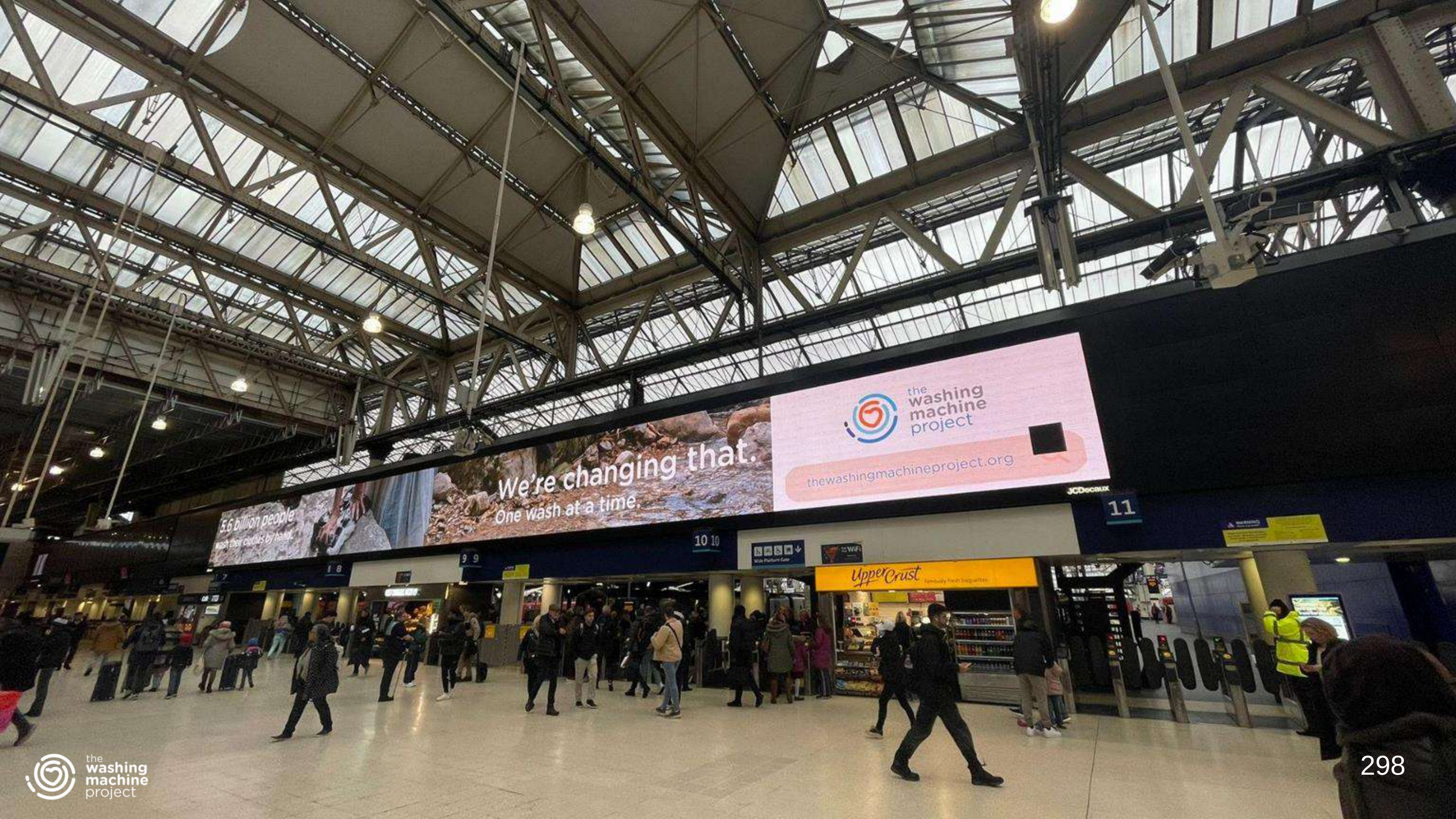
Create a Global Hive Programme to distribute 75 machines and 10,000 people impacted

$100k for 75 machines in Uganda

$2k-$5k each

# Tailored CSR and ESG partnership and collaboration opportunities with your organisations

# Strategic direction and amplification of The Washing Machine Project through thought leadership and talks




the washing machine project

What would you do with an extra 15 hours a week?

# Questions

the washing machine project

supported by

Whirlpool FOUNDATION

# Day 2 Close