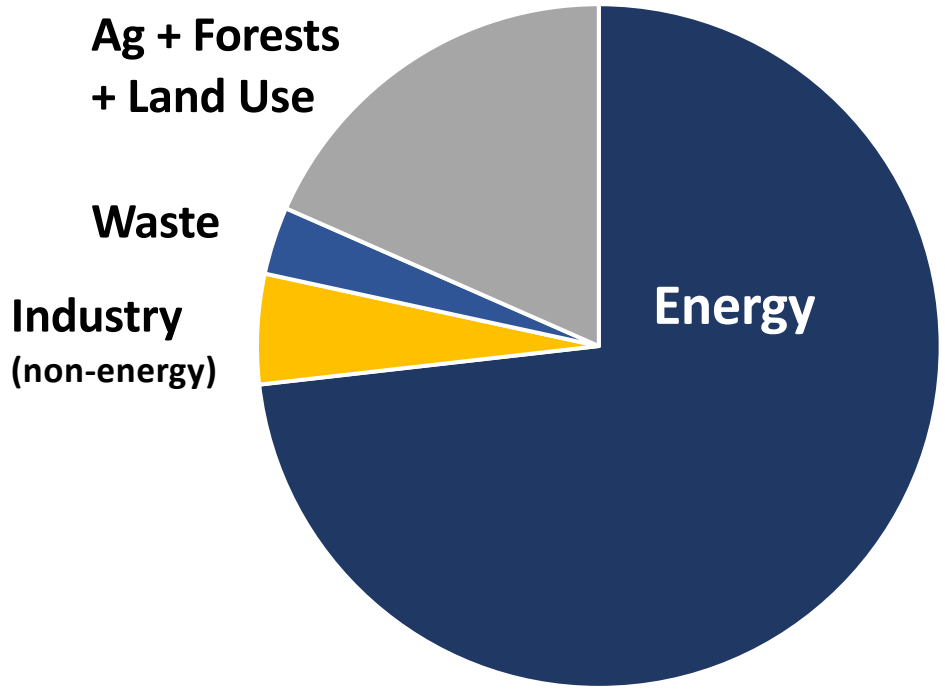

UN environment programme
finance initiative
PRI
Principles for Responsible Investment
NET-ZERO ASSET OWNER ALLIANCE
Carbon Removal Technologies - Carbon Direct webinar
13/06/22
WWF
GLOBAL OPTIMISM

The core arithmetic of net-zero is harsh and unforgiving:

We are failing & We're out of time

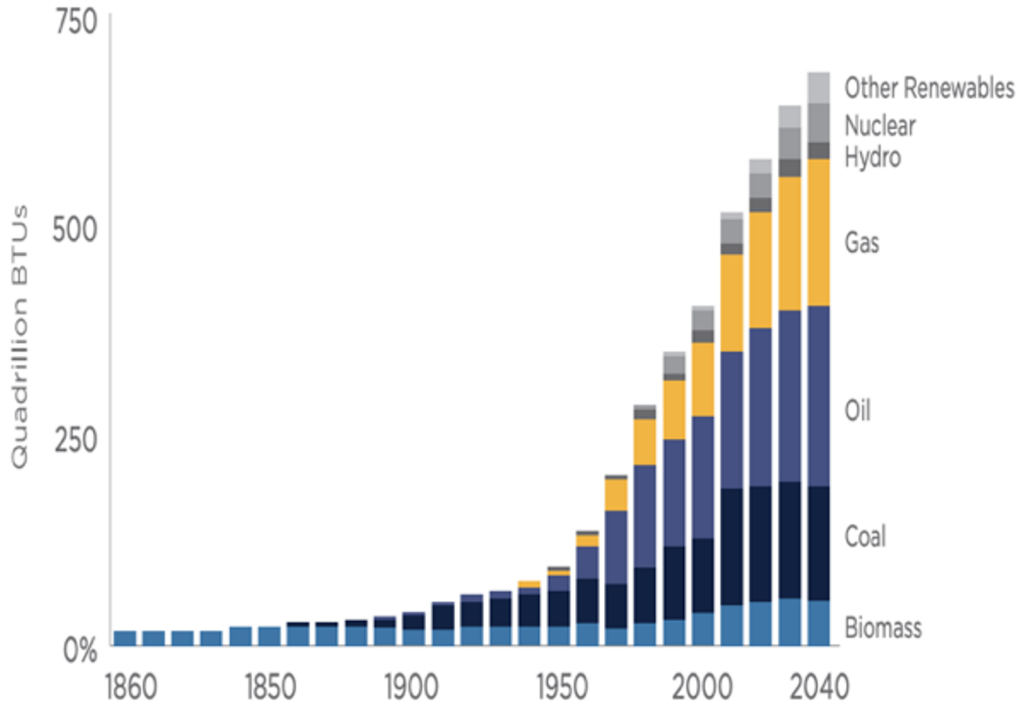
51 billion tons -> 0 in 30 years is really, really hard

Energy is most of the challenge, and we've never used less energy every



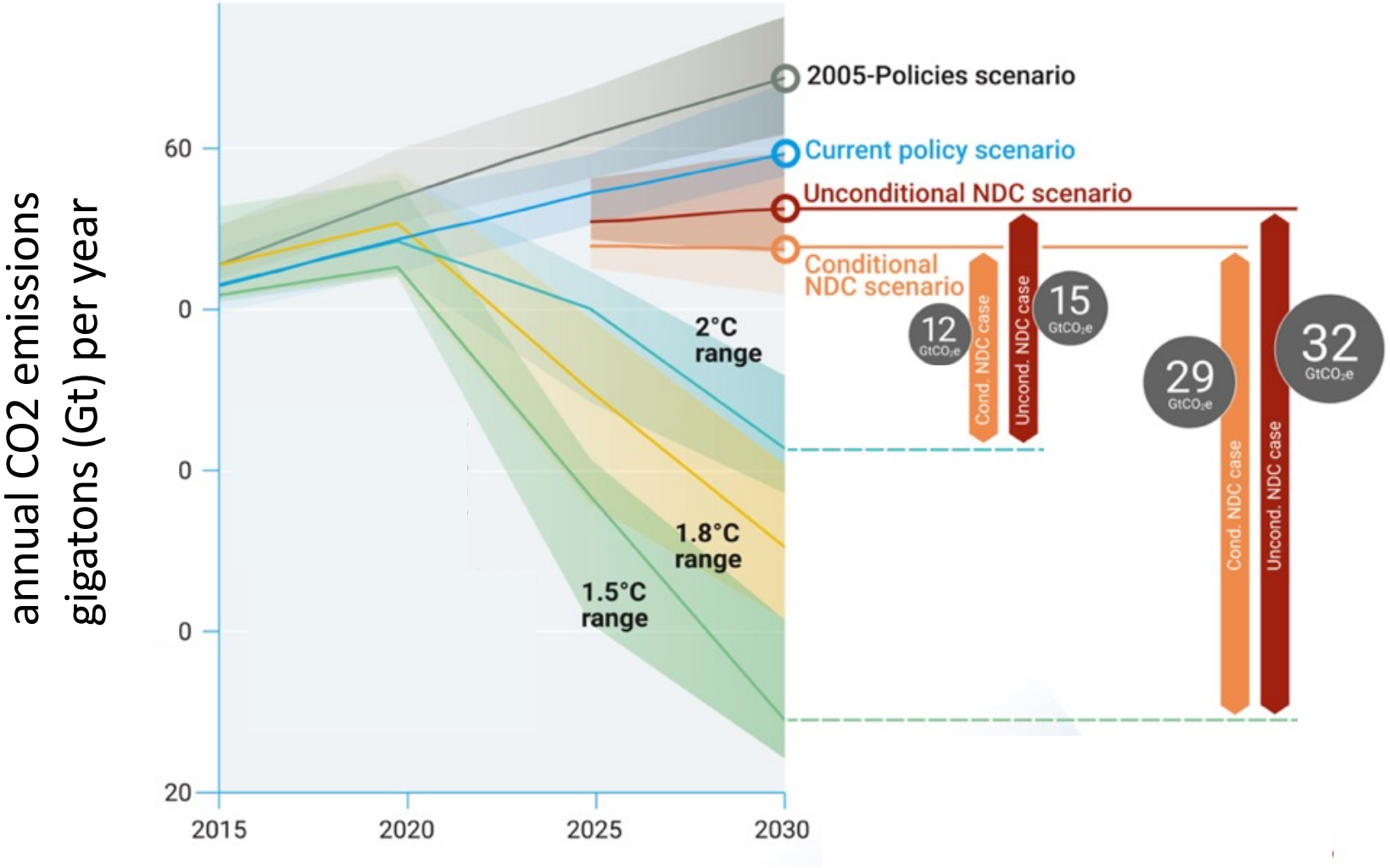
75% of emissions are outside power sector

Global mix of fuels, quadrillion BTUs (quads)



Source: Center on Global Energy Policy; Smil, Energy Transitions; ExxonMobil Energy Outlook 2018

For 1.5 ℃, the math is 50% reduction in 10 years



Source: UN Environmental Program 2019

The core arithmetic of net-zero is clarifying:

All sectors
All approaches

Only one way to stabilize climate: net-zero everywhere

- Any emissions anywhere add to atmospheric CO2 concentration
- Every year of delay makes problem worse
- We don't have solutions for about 50% of the portfolio

For net zero: CO_2emissions - CO_2removals = 0

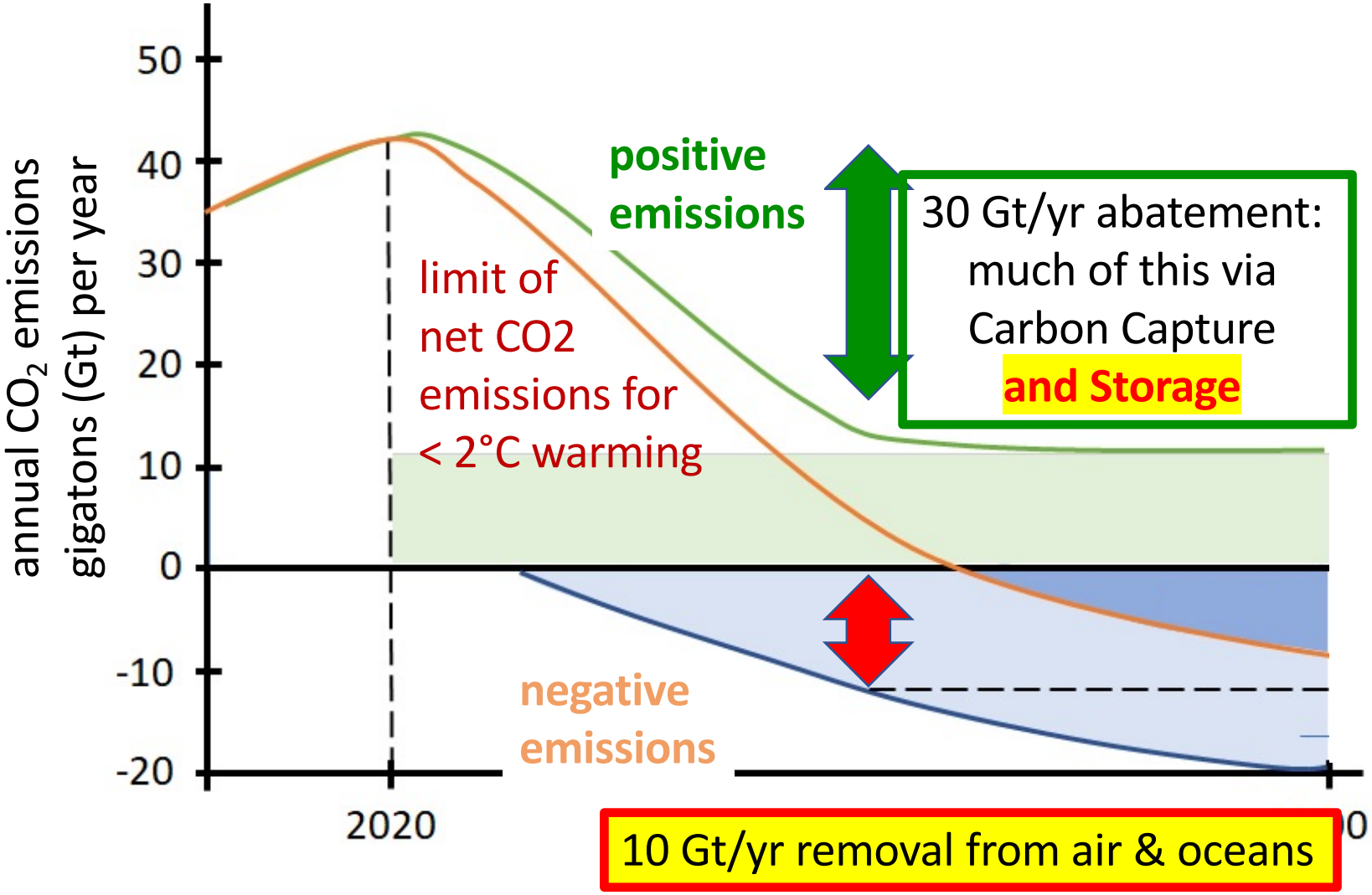
- Any residual emissions must be balanced by removal
- Likely need 10 Gt/y CO2 removal by 2050
- Any delay or failure requires more CO_2 removal

Carbon from the earth must be returned to the earth

- Natural systems must return to balance
- Biosphere has limited capacity
- Risk of return is getting worse

CO_2 return to the geosphere anchors the net-zero global economy

Required CO_2 storage & removal from air by ~ 2060



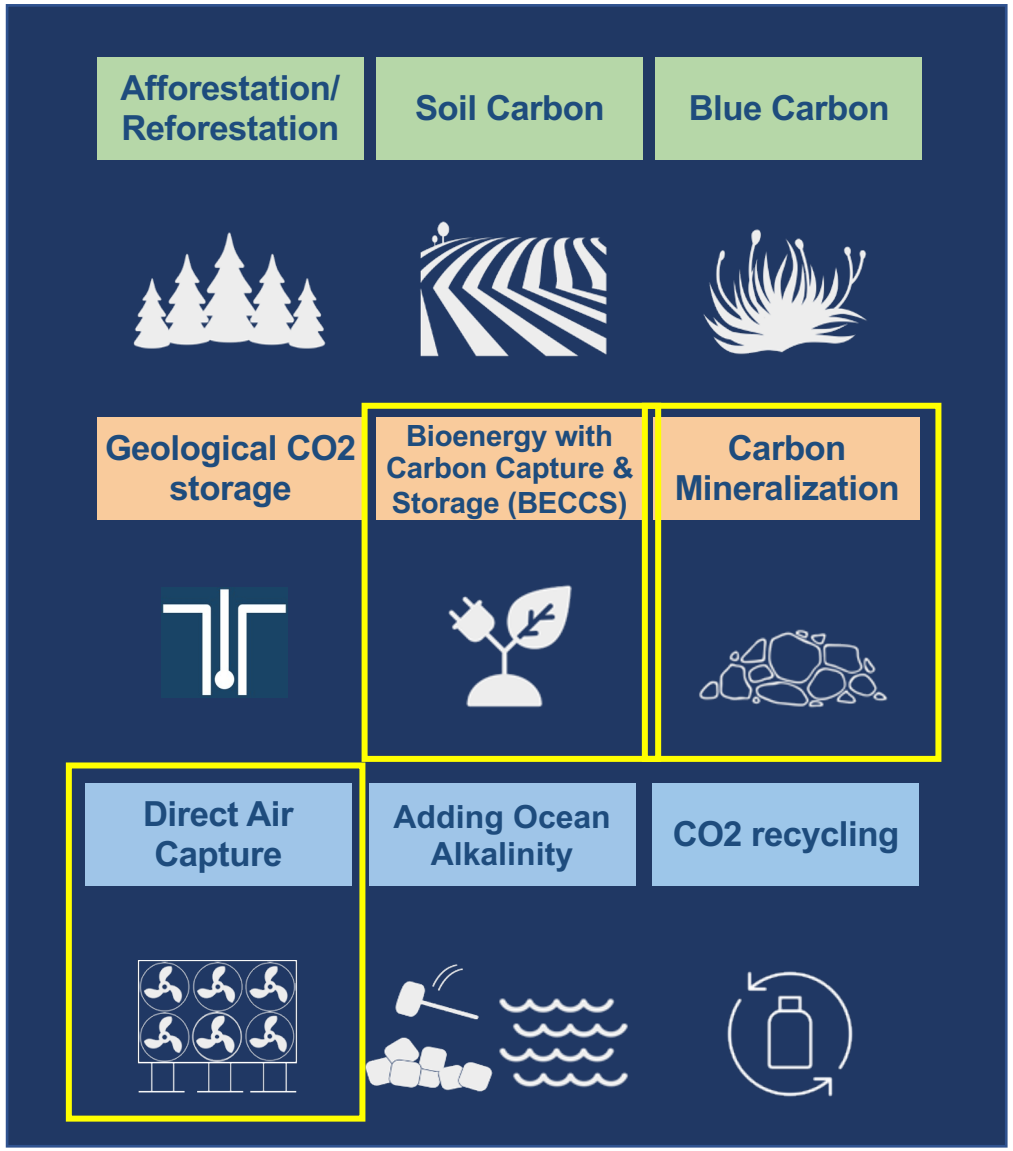
Source: CDR Primer (Wilcox et al., 2021, after UNEP 2017)

Carbon Management: Pillar of the Net-Zero Economy

CARBONDIRECT

Dr. S. Julio Friedmann
Chief Scientist & Chief Carbon Wrangler
Temple Shir Shalom, Sonoma, June 2022

Many forms of CO_2 removal – some issues remain



Different degrees of sureness (science)

Different technical readiness & maturity

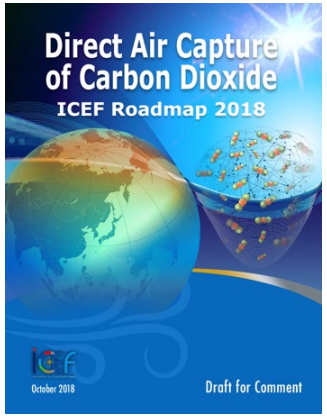
Different risks (additionality, reversal)

Different duration

Different cost

A mixed portfolio will perform best on cost, risk, and performance

All CO_2 removal approaches have benefits & challenges

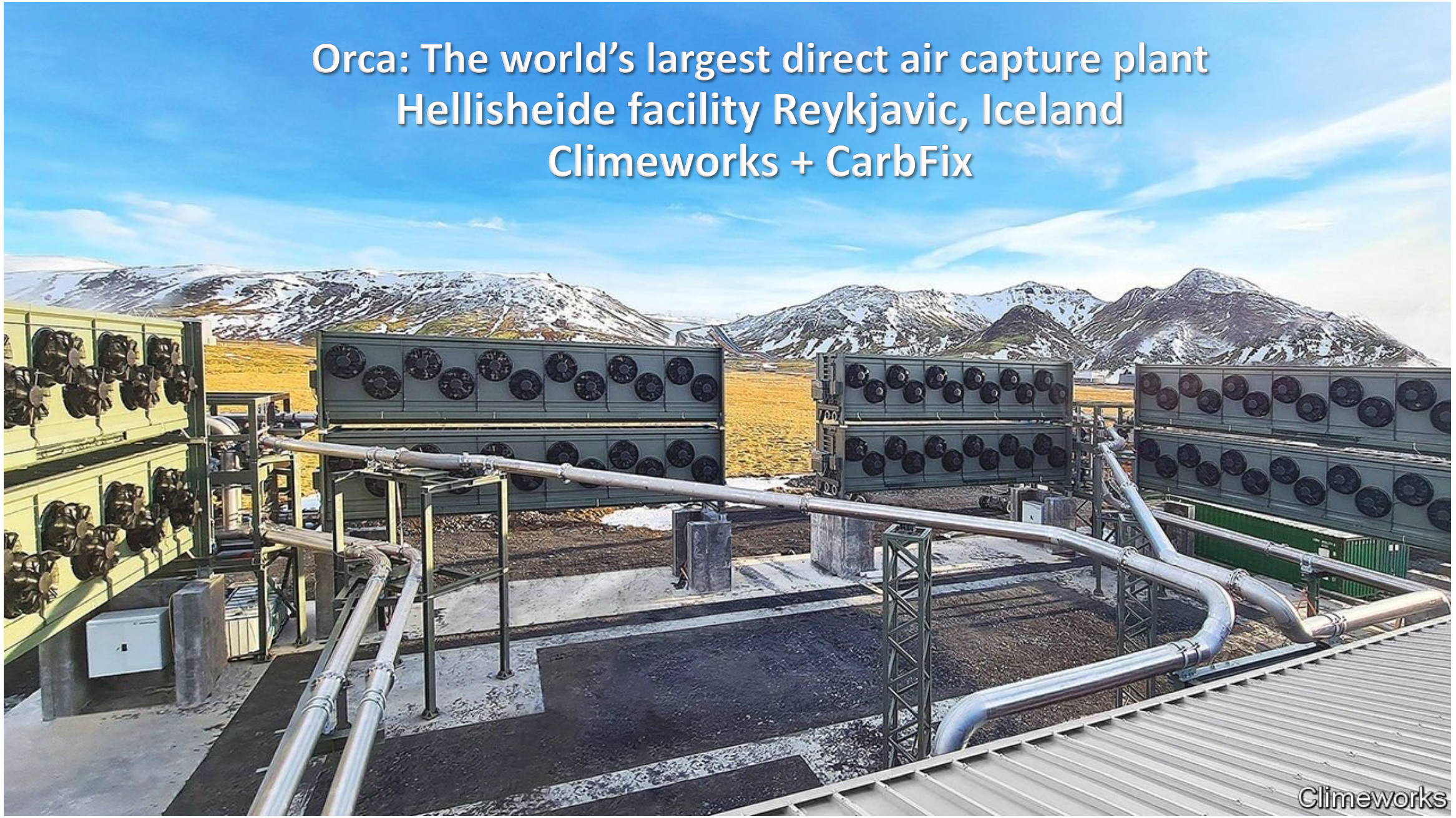


		Cost	Energy Requirements	Land Use	Water Consumption	Risk of Reversal	Verifiability	Implement. Readiness
NATURAL	Reforestation & Enhanced Forest Management	🟢	🟢	🟠	🟠	🟠	🟢	🟢
	Wetland & Coastal Restoration	🟢	🟢	🟢	🟢	🟠	🟠	🟢
	Soil Carbon Restoration	🟢	🟢	🟢	🟢	🟠	🔴	🟠
TECHNOLOGICAL	DACS	🔴	🟠	🟢	🟢	🟢	🟢	🟠
	Terrestrial Enhanced Weathering	🟠	🟠	🟢	🟠	🟢	🟢	🟠
	Ocean Alkalinity Modification	🟠	🟠	🟢	🟢	🟢	🟠	🔴
HYBRID	Hybrid Bioenergy with CCS (BECCS)	🟠	🟢	🟠🟢	🟠	🟢	🟠	🟢
	Bioenergy with Biochar Sequestration (BEBCS)	🟠	🟢	🔴	🟠	🟠	🔴	🟢

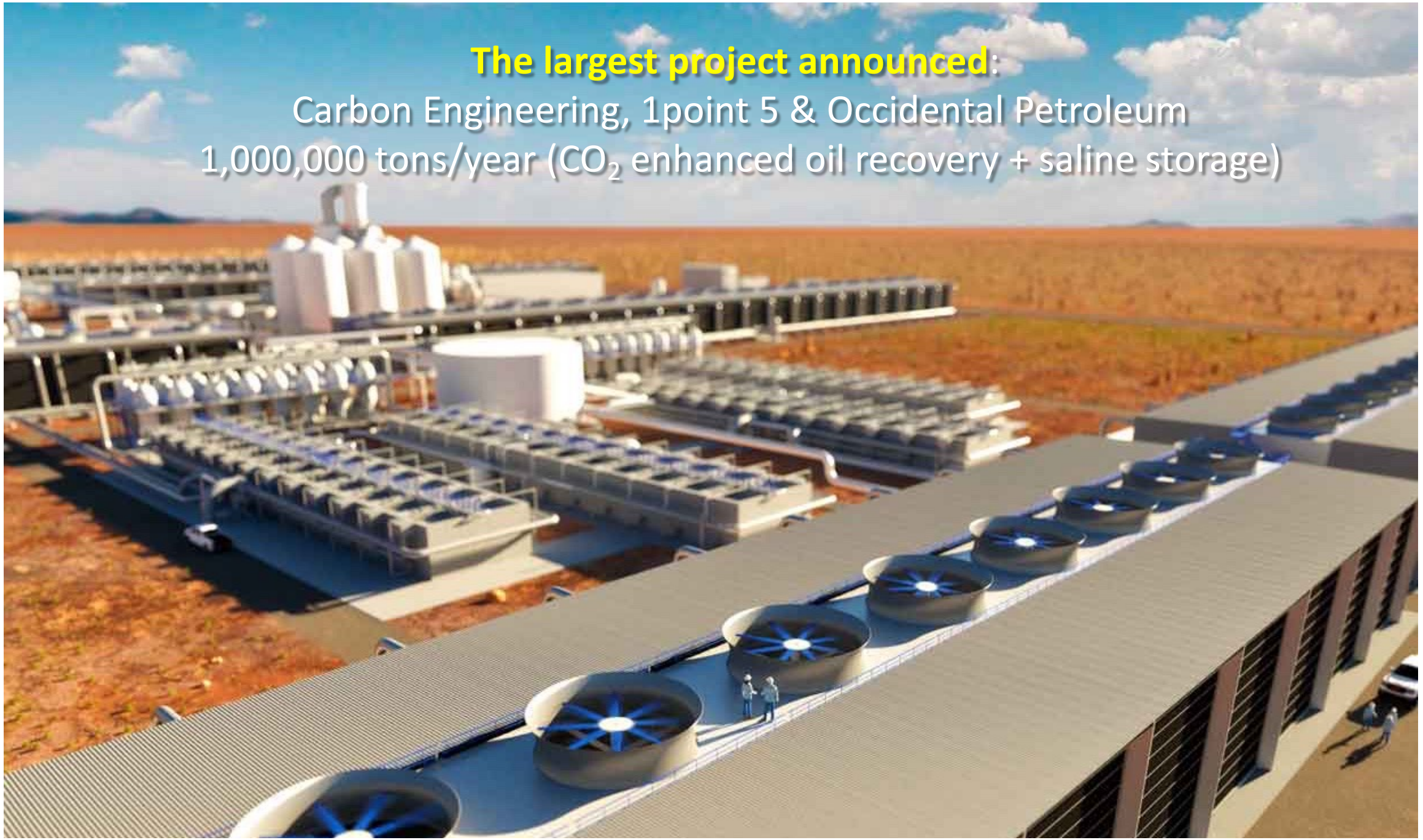
LEGEND: 🟢 Generally Acceptable/ Available; 🟠 Exercise Caution; 🔴 Potentially Unacceptable/ Unavailable

https://www.icef-forum.org/roadmap/

Orca: The world's largest direct air capture plant
Hellisheide facility Reykjavic, Iceland
Climeworks + CarbFix

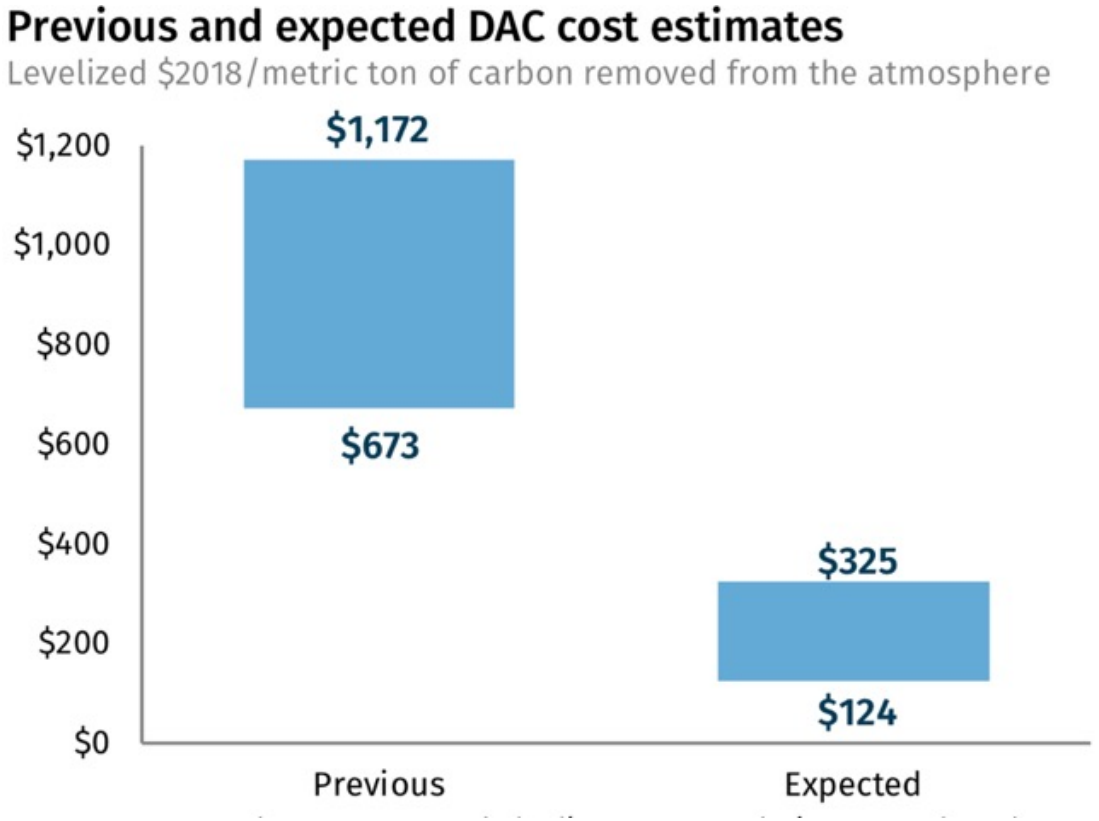


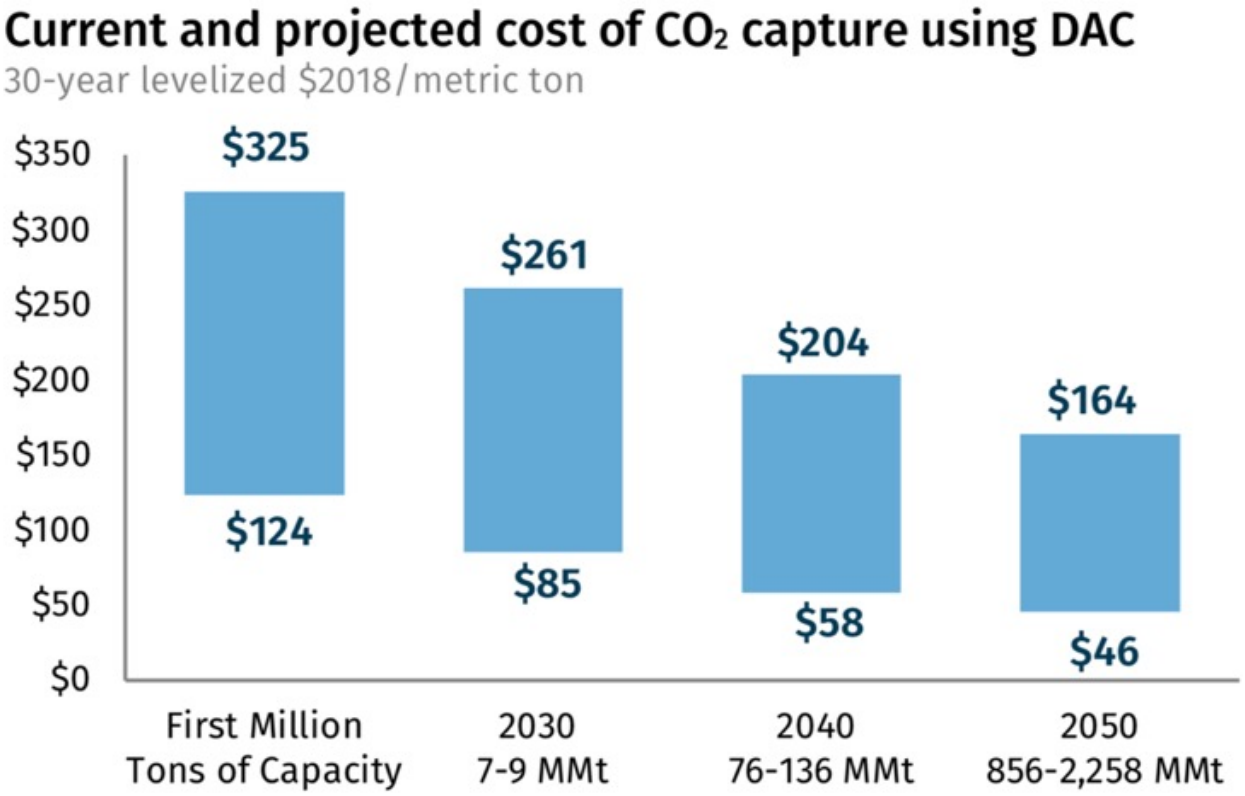

The world’s largest direct air capture plant
Does the CO_2 work of 200,000 trees with 0.1% of the land


The largest project announced:
Carbon Engineering, 1point 5 & Occidental Petroleum
1,000,000 tons/year (CO_2 enhanced oil recovery + saline storage)

DACCS has no resource constraint and “uniform” costs for application

Cost curve is flat, so cost should vary chiefly as a function of deployment





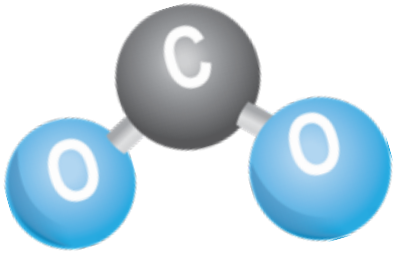
Rhodium Group, 2019

Carbon mineralization turns CO_2 to stone

- Natural process in which CO_2 becomes bound in rocks as a solid mineral.
- Happens naturally at a slow rate as certain rocks are exposed to carbon dioxide, permanently removing roughly 0.3 Gt of CO_2 from the atmosphere each year

Rocks rich in calcium or magnesium

+



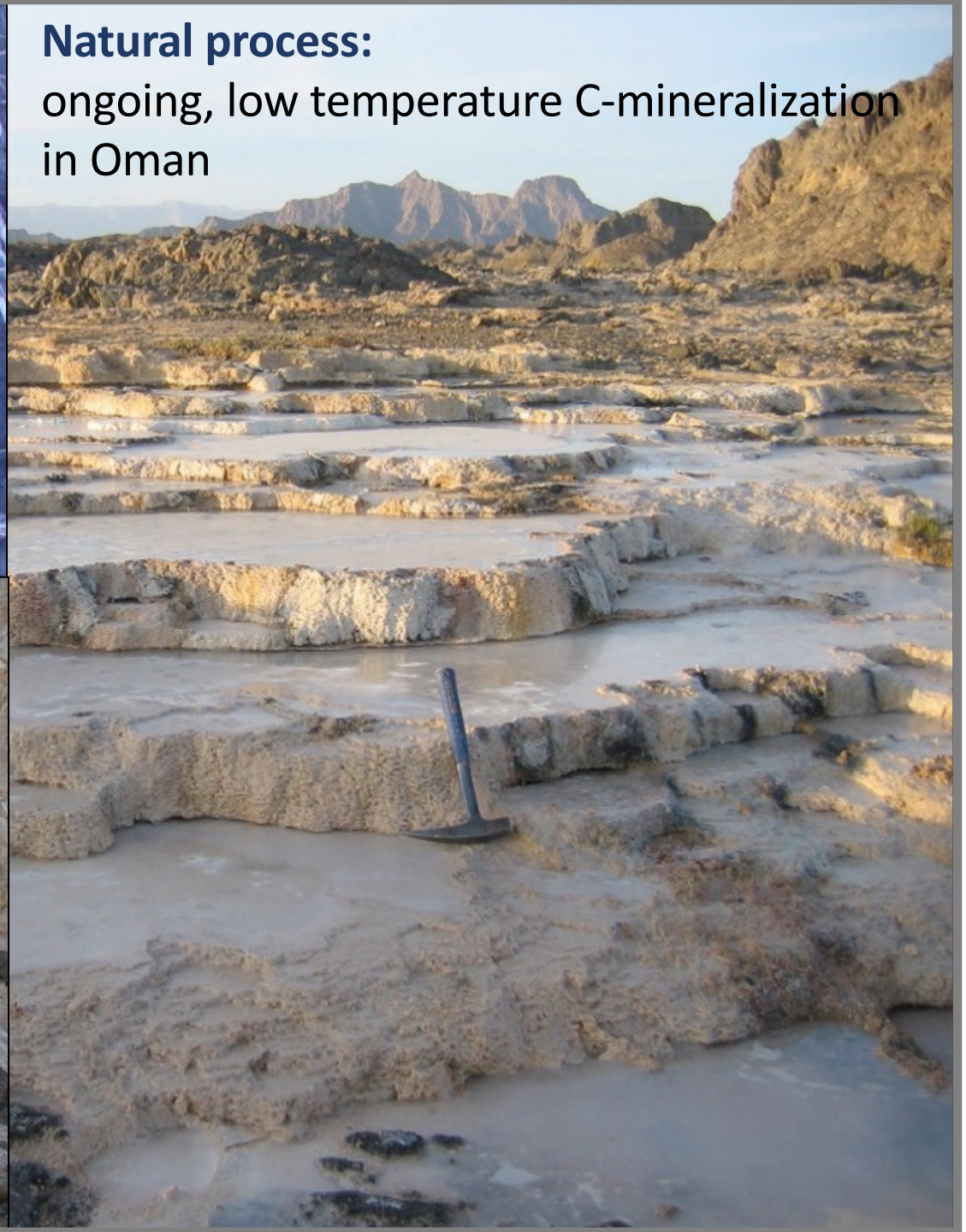
Carbon dioxide

=

Carbonate minerals

Natural process:

ongoing, low temperature C-mineralization in Oman

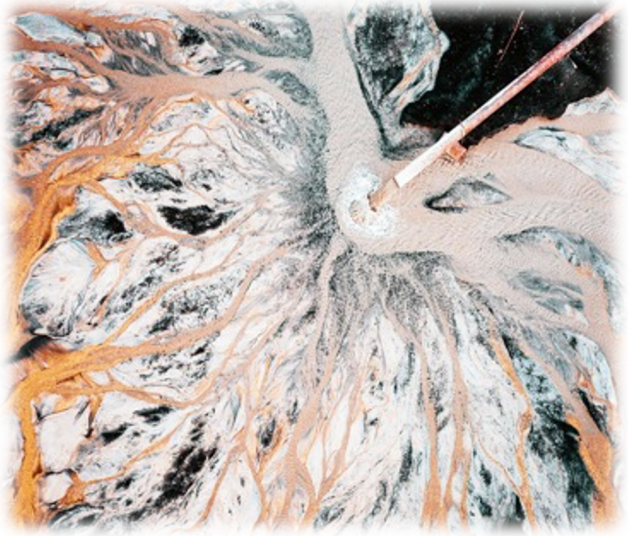


Carbon mineralization is an important pathway for CO_2 removal

Many gigatons/y of CO_2 removal potential

Two broad approaches:

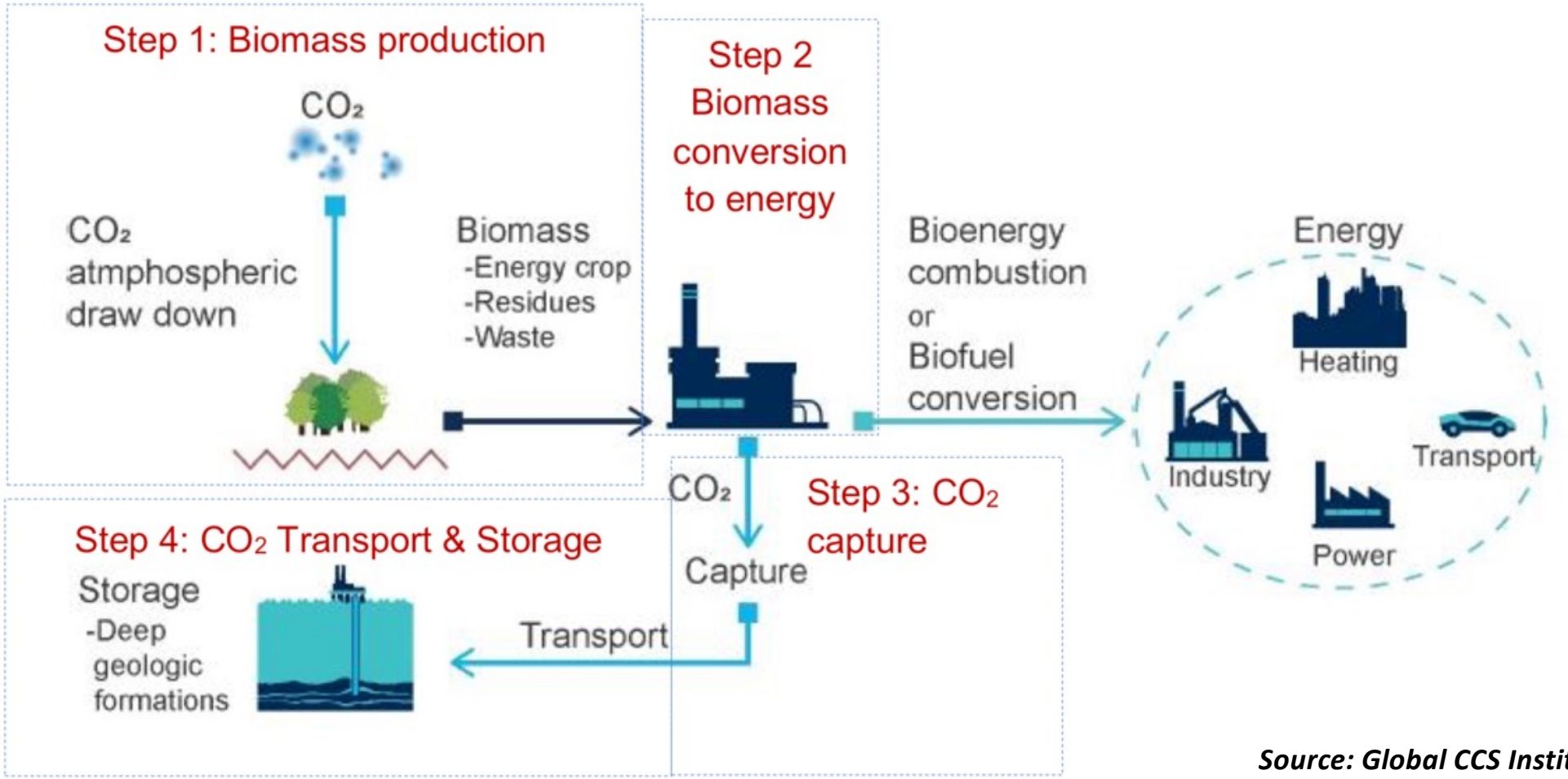
- Injecting CO_2-rich fluids into rock formations deep underground (in situ mineralization)
- Exposing crushed rocks on the Earth's surface to CO_2-bearing gases (ex situ/surface mineralization)



ICEF Roadmap, 2021

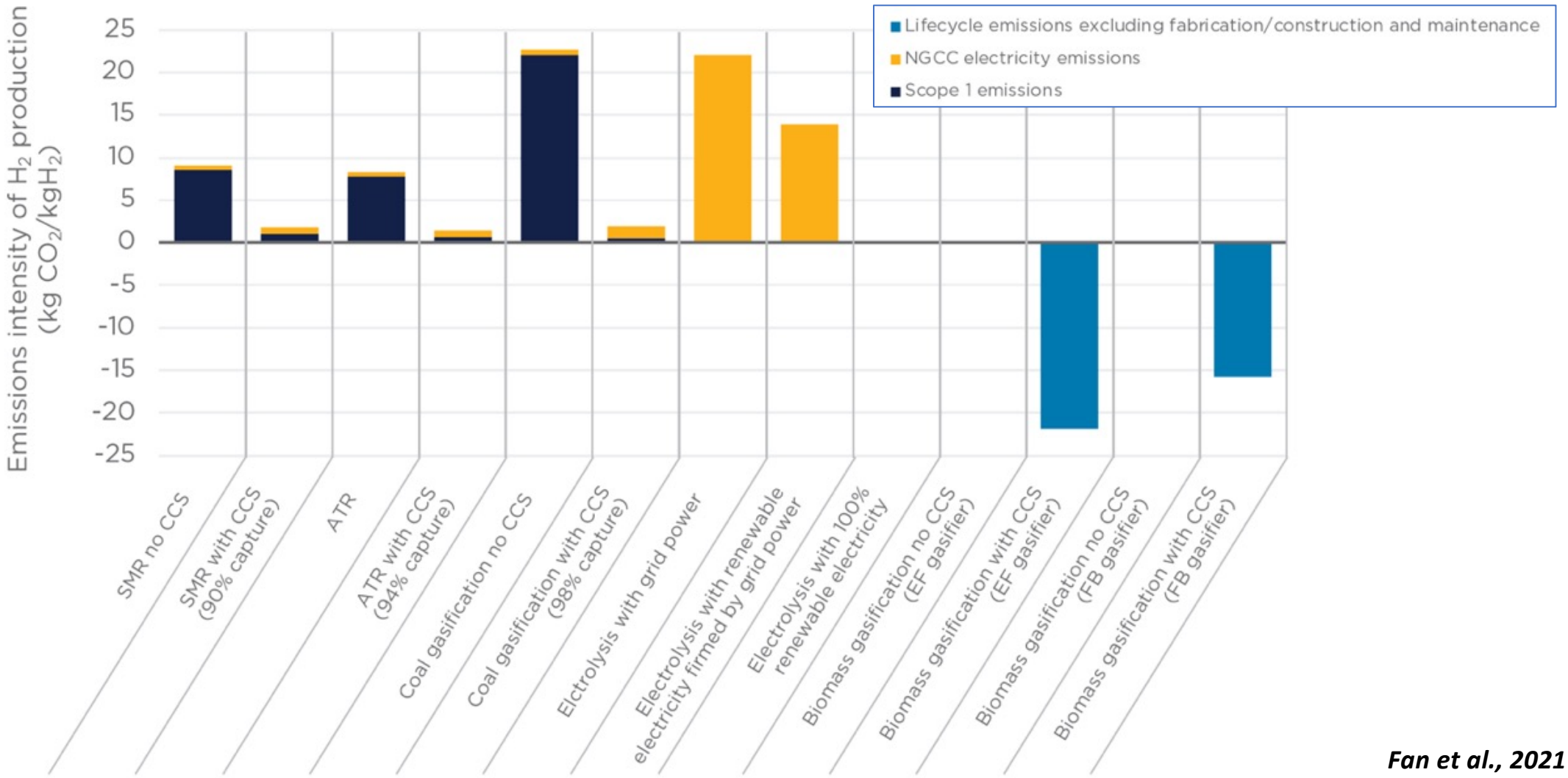
Bioenergy can remove CO_2 when paired with CCS

Inputs: wastes, residues, crops
Outputs: power, hydrogen, fuel & CO_2



Source: Global CCS Institute, 2019

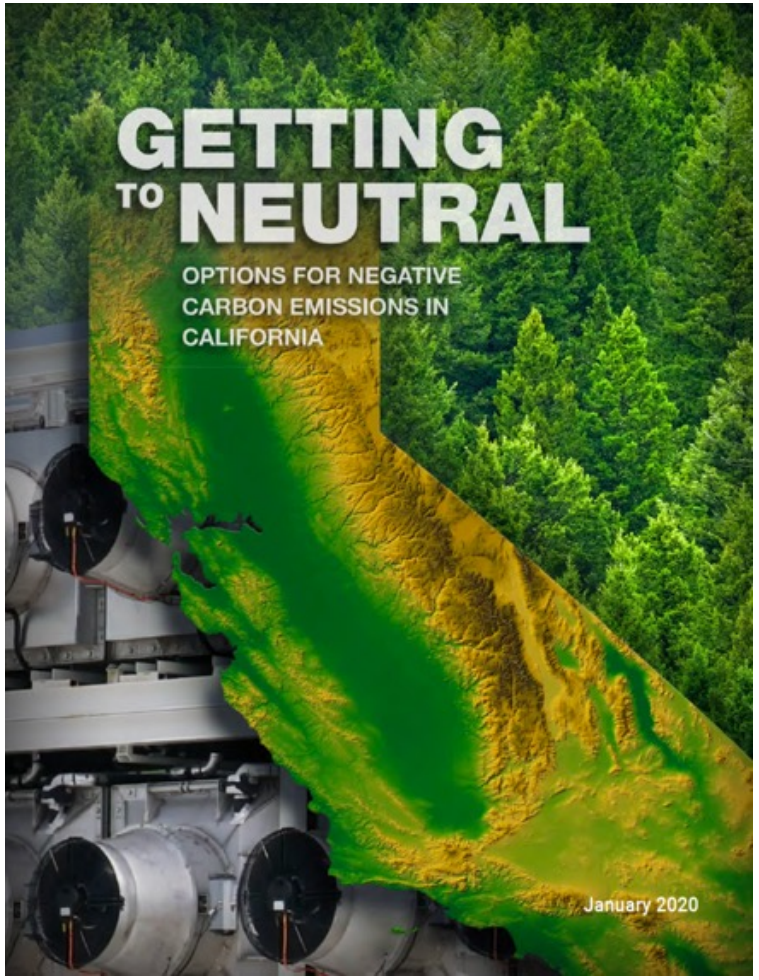
Biohydrogen can provide clean energy & remove CO_2



Fan et al., 2021

Source: Global CCS Institute, 2021

CA is pursuing ambitions net-zero program
Innovative approaches are at the heart of the roadmap



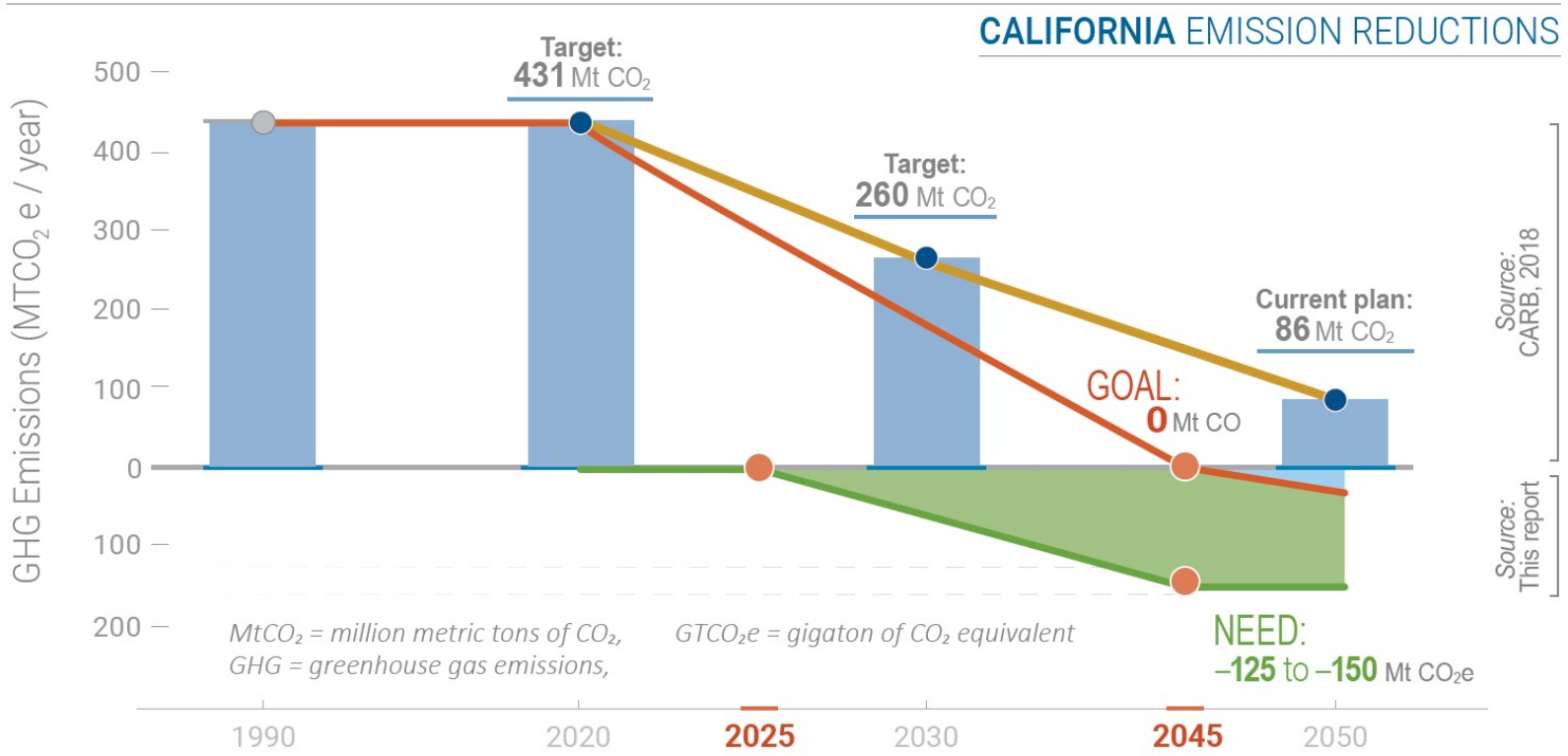
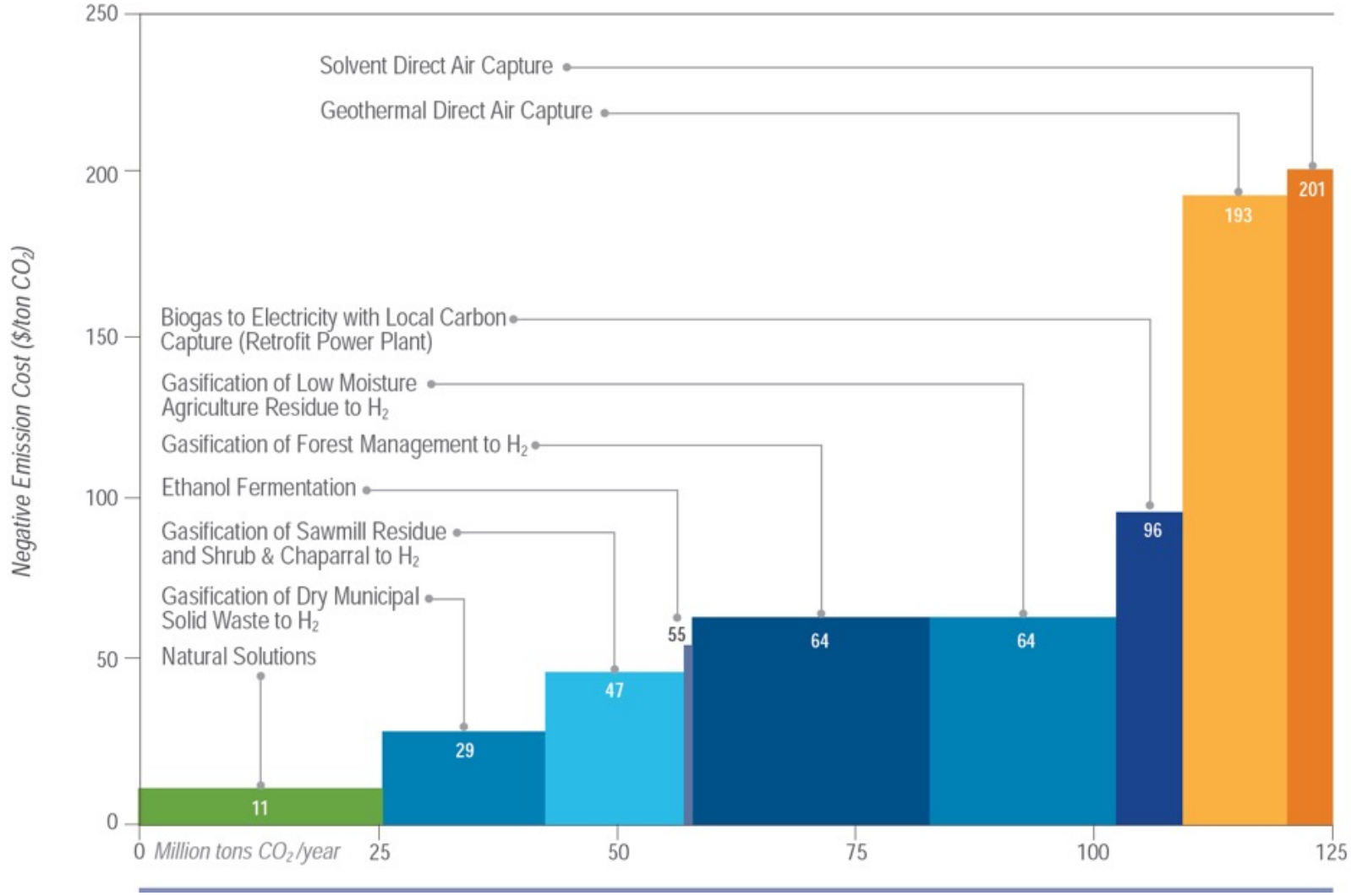


Figure ES-1. *Goals of California's emissions plan extrapolated to 2045 (CARB, 2017) with negative emissions estimates from this report.*

LLNL, 2020

https://www-gs.llnl.gov/content/assets/docs/energy/Getting_to_Neutral.pdf

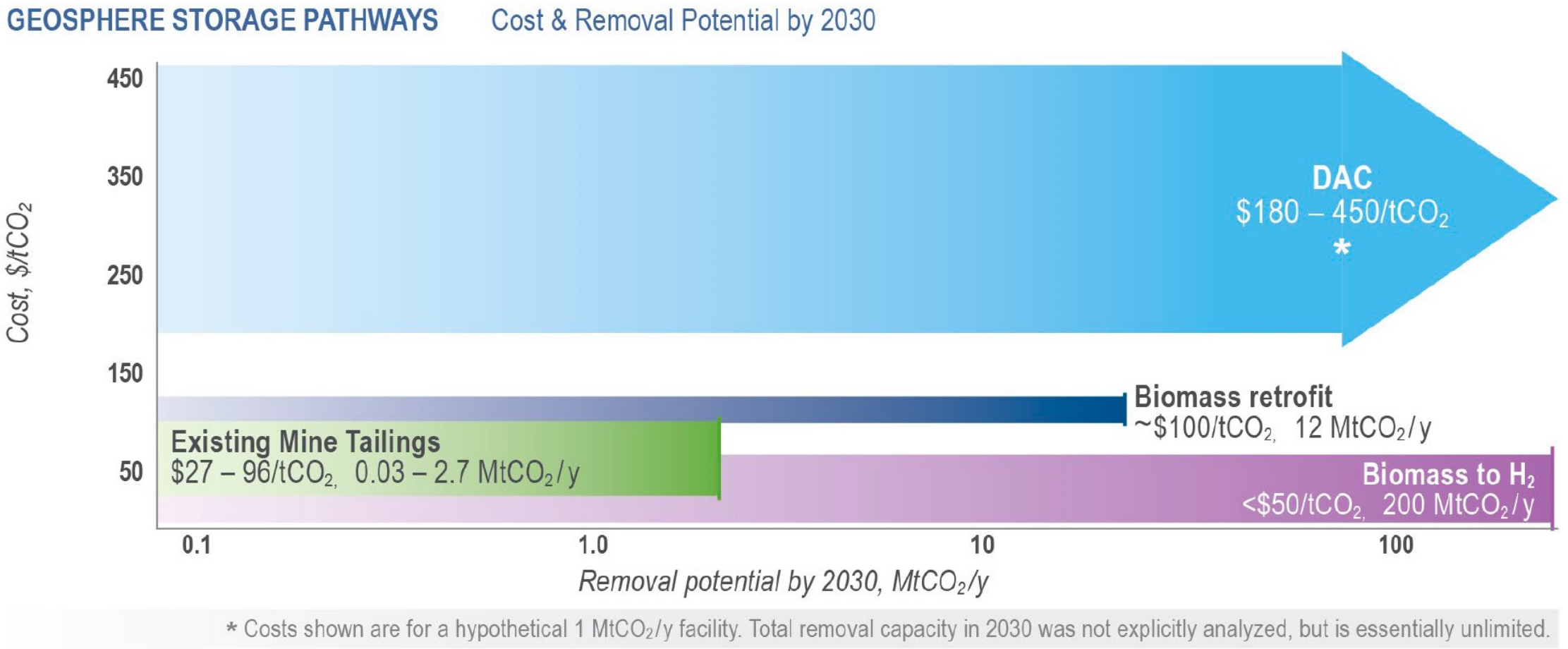
For CA net-zero 125 Mt/y: 70% involves bio-H_2 + CCS for fuel



LLNL, 2020

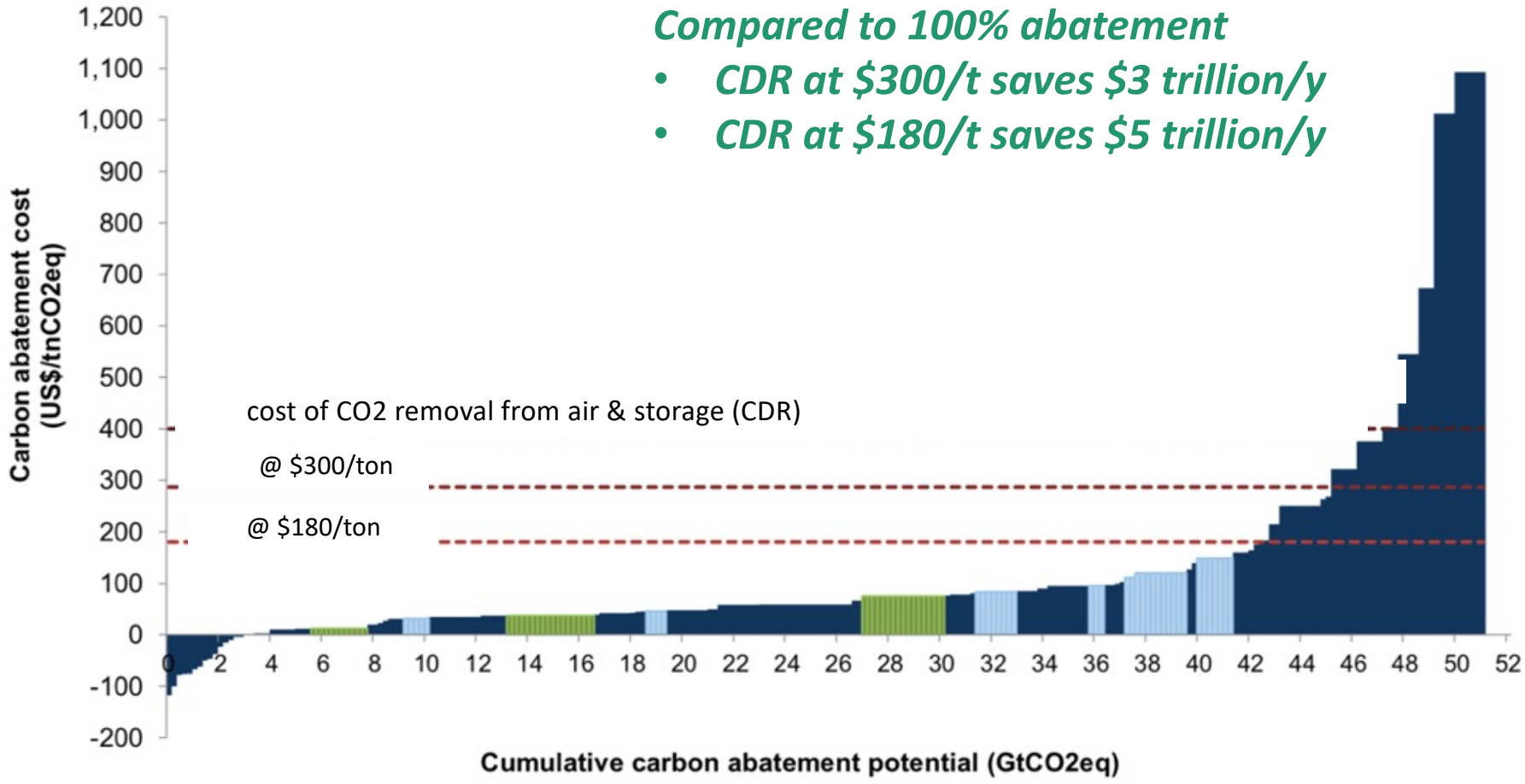
https://www-gs.llnl.gov/content/assets/docs/energy/Getting_to_Neutral.pdf

Many paths, large range of costs, all options required



Lawrence Livermore Natl. Lab, 2022

Carbon management saves time, money & reduces risk

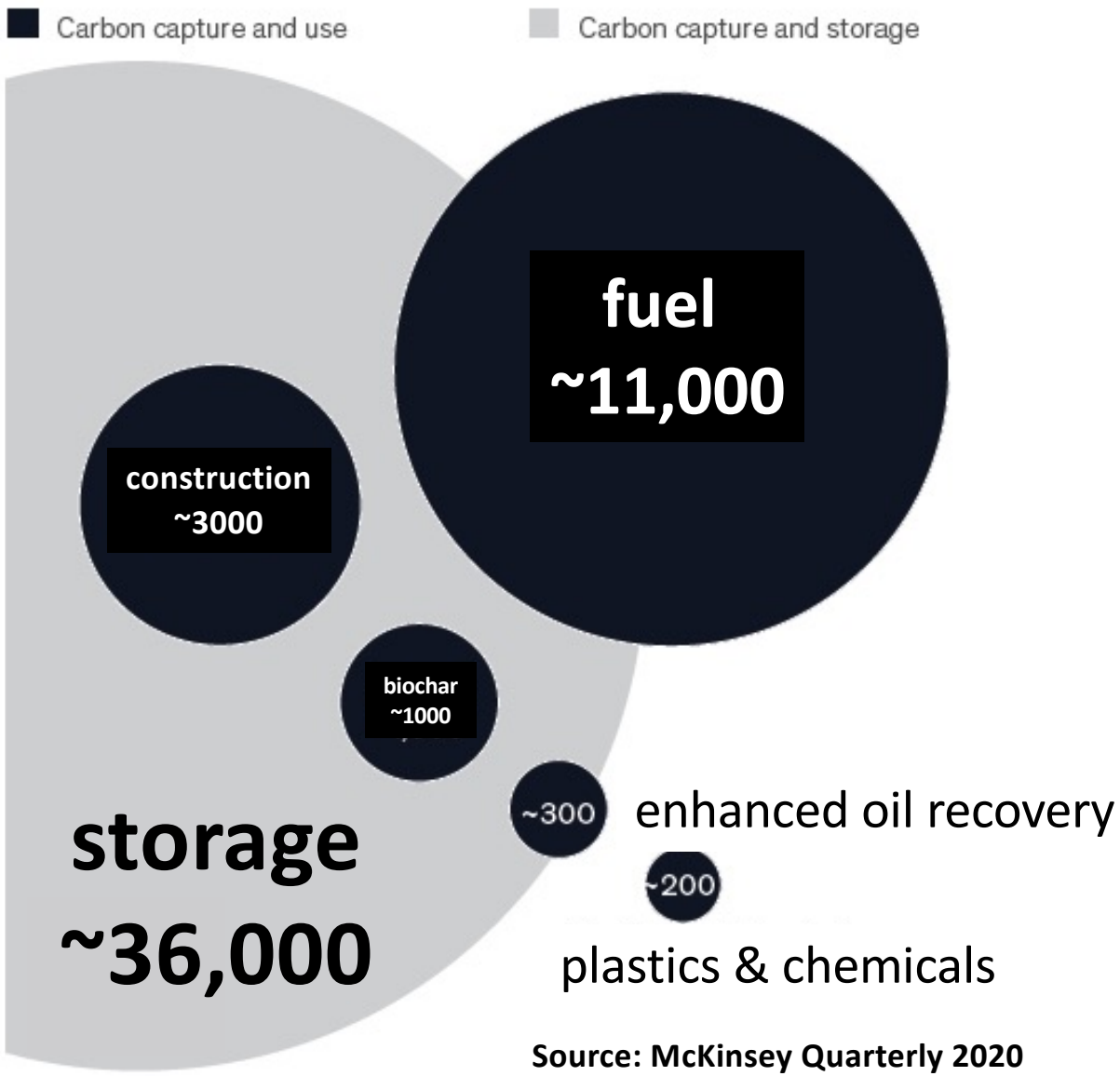


Compared to 100% abatement

- ***CDR at $300/t saves $3 trillion/y***
- ***CDR at $180/t saves $5 trillion/y***

Source: GoldmanSachs 2020

CO_2 recycling needs large markets to be climate relevant



enhanced oil recovery

plastics & chemicals

Source: McKinsey Quarterly 2020

Often called
Carbon-to-Value (C2V)

E-fuels: direct electrical conversion of CO_2 & water to fuel

Inputs

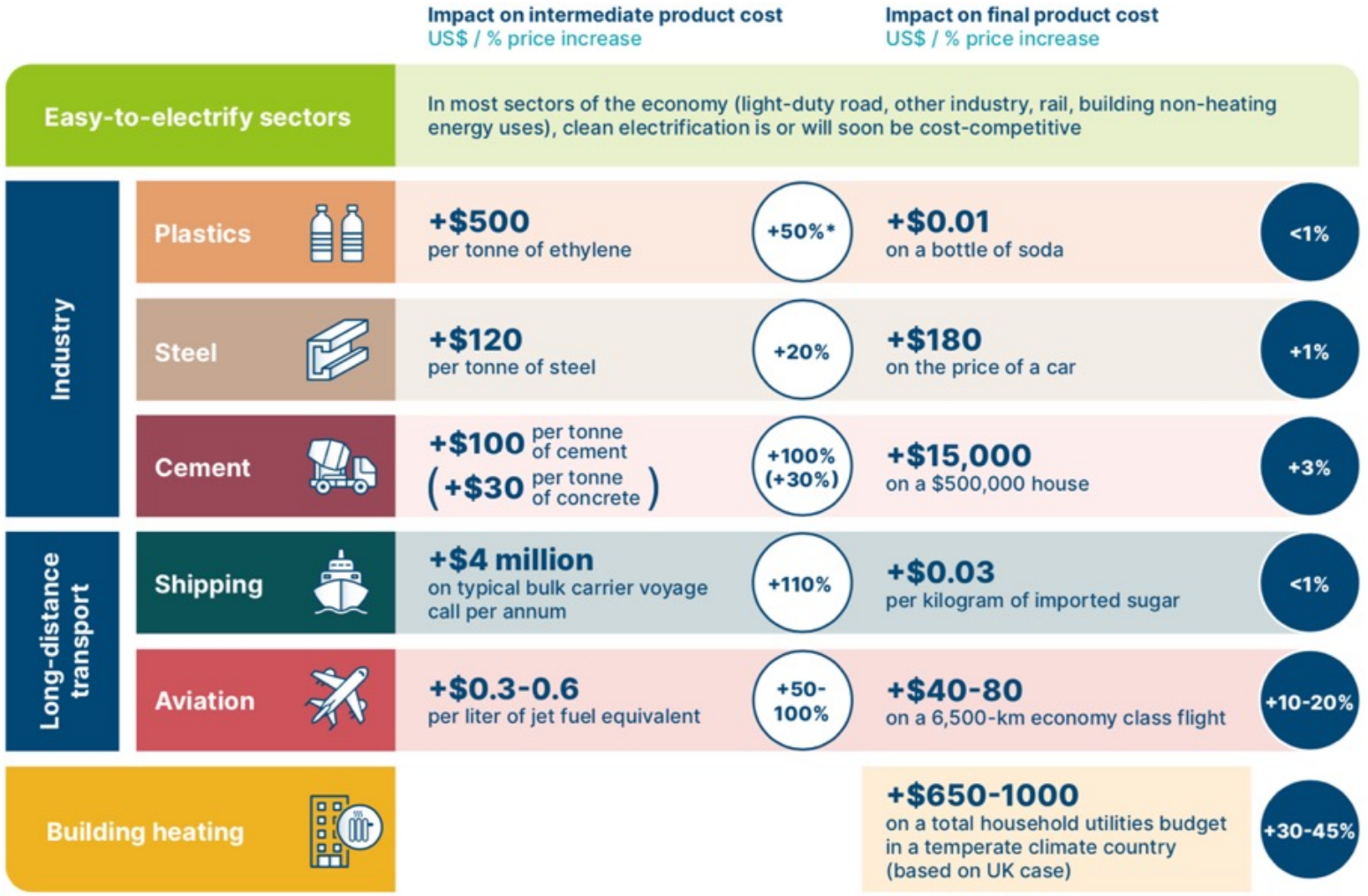
- Zero-C electricity
- CO_2
- Water (or H_2)

Products

- Fuels (jet-A, natural gas)
- Chemicals (methanol)

Benefits

- Existing infrastructure
- Displaces carbon-intensive fuels
- Domestic production



Source: Making Mission Possible (ETC 2020)

Investment and the market:
These few precepts keep in mind

The market is a mess

Renewable energy and avoided deforestation projects: 80%

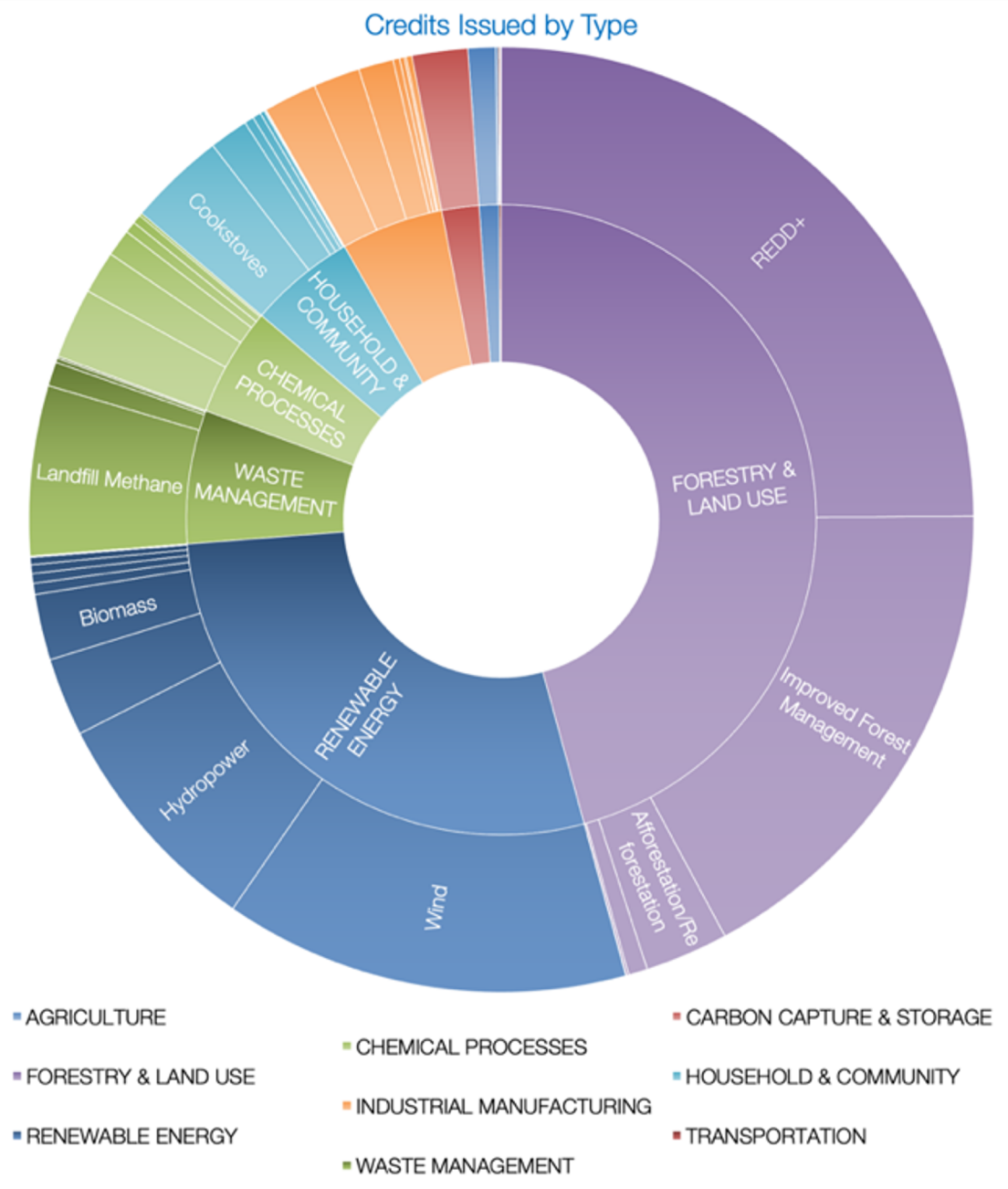
Average prices remain low: \$3-4/tCO_2
unlikely to motivate significant abatement

< 3% of credits on the market are CO_2 removals.
The rest are avoided/reduced or mixed projects (13%)

A glut of old surplus of credits: ~7 years vintage
could absorb offset demand for several years

No accepted standards, protocols, or regulators

VCM is anticipated to grow significantly, creating real opportunity for suppliers & other market makers



Sources:

Barbara Haya, Micah Elias, Ivy So. (2021, March 29). Voluntary Registry Offsets Database Pre-release Version, Berkeley Carbon Trading Project, Center for Environmental Public Policy, University of California, Berkeley. Retrieved from: https://gspp.berkeley.edu/faculty-and-impact/centers/cepp/projects/berkeley-carbon-trading-project/offsets-database

Eli Mitchell-Larson and Tim Bushman. (April 2021) Carbon Direct Commentary: Release of the Voluntary Registry Offsets Database – see here.

The market is a mess

nature climate change

ARTICLES

https://doi.org/10.1038/s41558-022-01379-5

Check for updates

Renewable energy certificates threaten the integrity of corporate science-based targets

Bloomberg Green

REUTERS

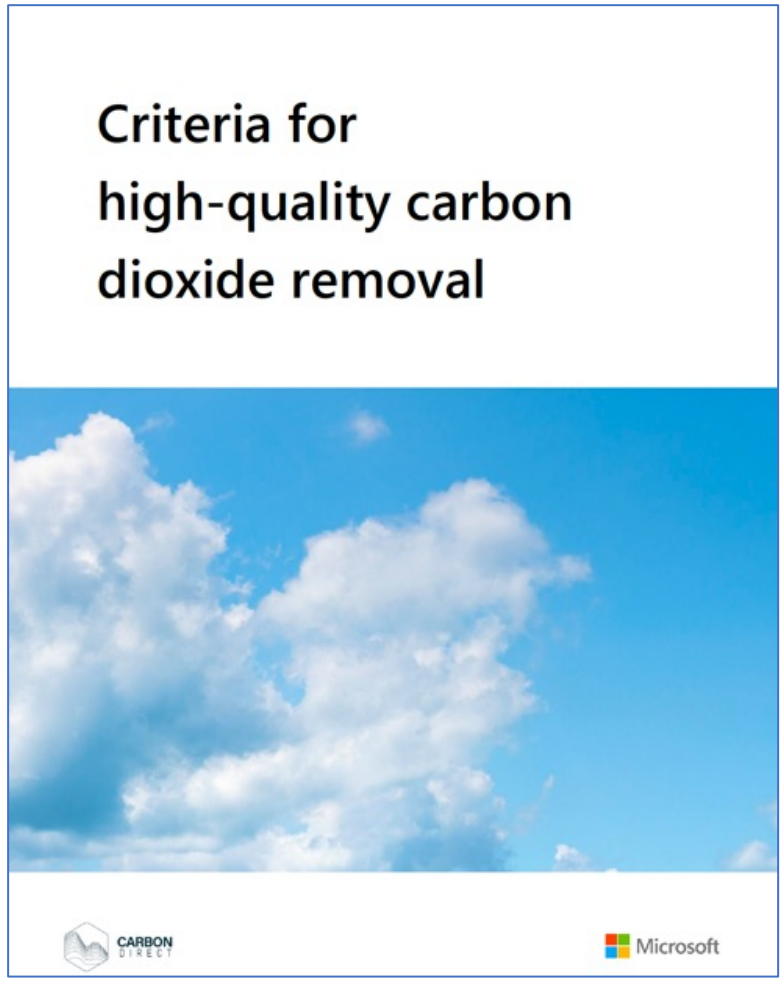
MIT Technology Review

Big Oil's Net-Zero Plans Show the Hard Limits of Carbon Offsets

The Real Trees Delivering Fake Corporate Climate Progress

North American farmers profit as consumers pressure food business to go green

MSFT + CD: Criteria for high quality CDR



Additionality (with baselines)

Accounting methodology explained

Assess harms & benefits

Define and explain durability

Equity & justice assessed

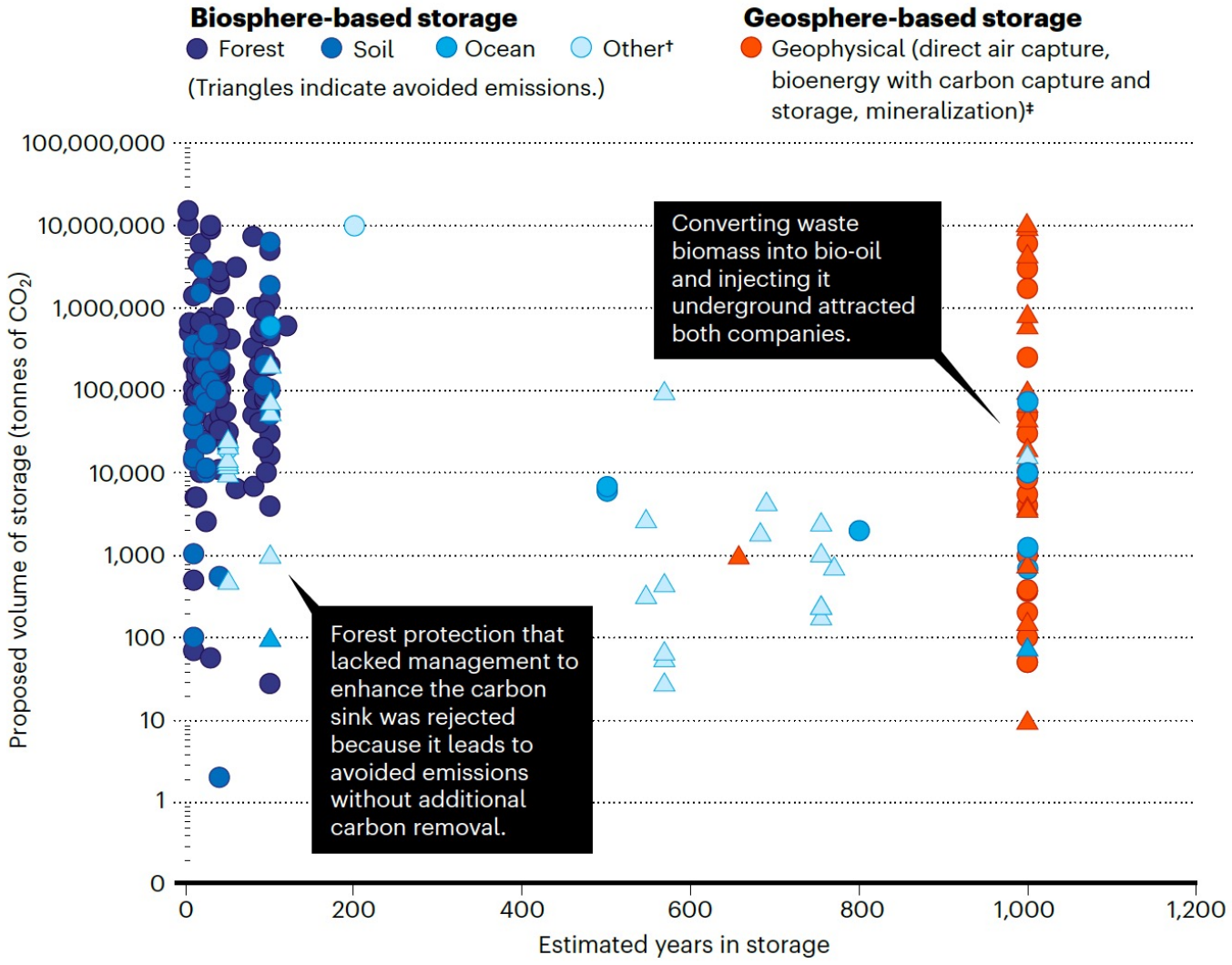
Avoid leakage

Monitoring, reporting, verification (MRV)

A mixed portfolio will perform best on cost, risk, and performance

Microsoft and Carbon Direct, 2022

A mixed portfolio: lowest cost & risk



Different degrees of sureness (science)

Different technical readiness & maturity

Different risks (additionality, reversal)

Different duration

Different cost

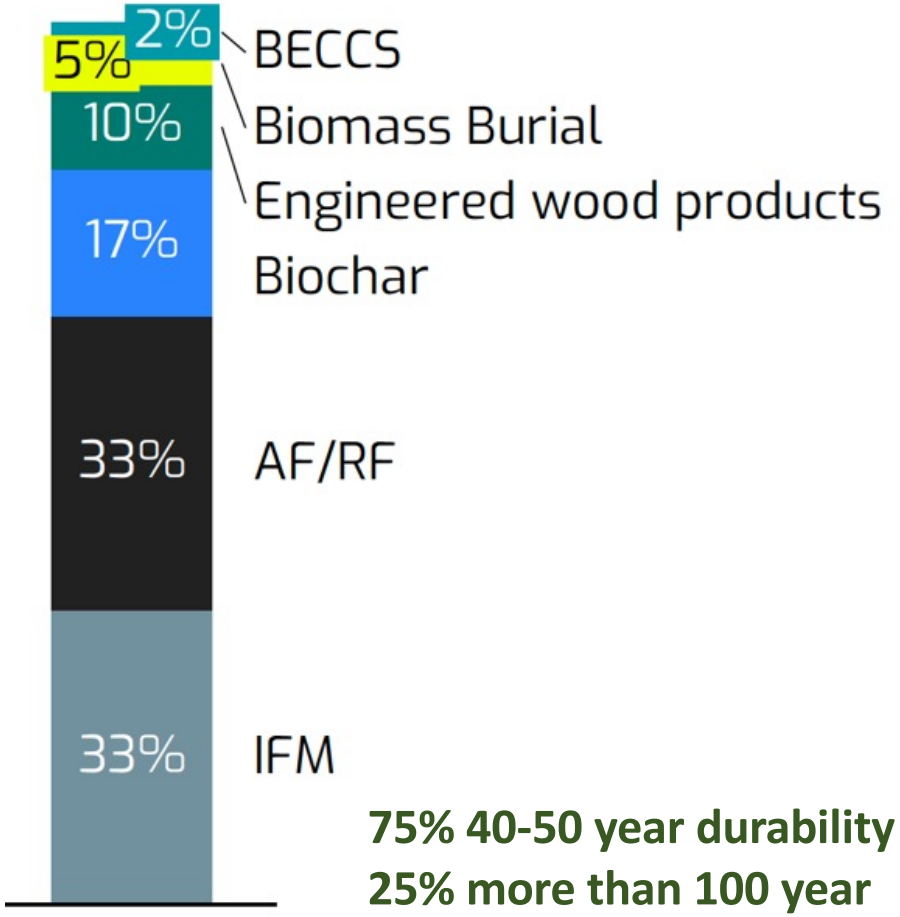
A mixed portfolio will perform best on cost, risk, and performance

Microsoft showed this in 2021

Joppa et al., 2022

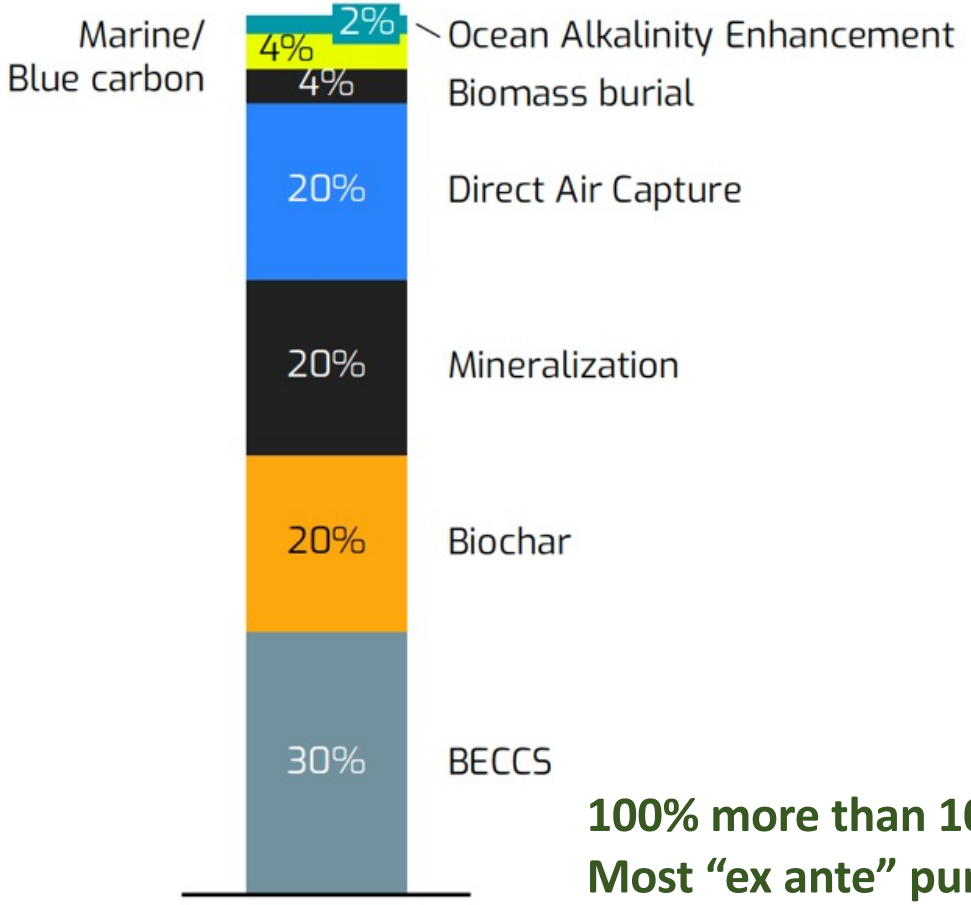
Two Illustrative portfolios of CO_2 removal

Mixed portfolio: ~$50/ton; 300 year durability



75% 40-50 year durability
25% more than 100 year

Innovation focus: ~$260/ton; 5000 year durability



100% more than 100 year
Most “ex ante” purchases


Policy is changing fast:
Focus on viable projects today

Scaling is chiefly a function of policy

Engineered CDR faces no global resource limits

- 10,000-20,000 Gt CO_2 storage capacity for DAC & BECCS. 50,000,000 Gt for mineralization
- 2.5-5.5 Gt per year residual (sustainable) biomass
- Earth abundant materials; well established supply chains

Cost is a function of policy first, technology second

- Deployment lowers costs AND encourages efficiency & innovation
- True for LEDs, solar, wind, batteries, semi-conductors….

We know what to do

- 0.1 Gt by 2030 (mixed portfolio)
- 1 Gt by 2040 (mixed portfolio)
- 10 Gt by 2050 (mixed portfolio)

Many policy approaches could accelerate CDR

Incentives

- Revenue enhancements
- Tax breaks
- Other capital treatments (first loss, acceleated depreciation, etc.)

Regulation

- Compliance
- Mandates
- Standards & Protocols

Other policy

- Grants (e.g., pilots & demos)
- Innovation
- Infrastructure

OECD Countries pursuing all these policies

Incentives

- Revenue enhancements: UK (CFD)
- Tax breaks: **45Q today ($35/t)**; pending enhancements ($180/t)
- Other capital treatments: **US (DAC Prize)**

Regulation

- Compliance: California (LCFS); US (Clean power standards)
- Mandates: Maybe Saudi Arabia, China, UAE
- Standards & Protocols: EU (Sust. Carbon Cycles certification); ICAO (CORSIA updates); IC-VCM

Other policy

- Procurement: **UK (5M tons by 2025); EU (5M tons by 2030)**; US (FCRLA; CREST Act; NY & CA)
- Grants (e.g., pilots & demos): **US (DAC Hubs)**; CREST Act
- Innovation: **US, UK, EU, JAP, CHI, GER, CAN**
- Infrastructure: **EU, US, SWE, DEN, ICE, CAN, UK…**

The US has legislated much, with more to come

U.S. Tax Code, Section 45Q

- **Today:** Saline Fm. storage **$50/t**; Use **$35/t**; DAC **$35/t**
- **Under negotiation:** Saline Fm. storage **$85/t**; Use **$60/t**; DAC **$180/t**

U.S. Infrastructure Investment and Jobs Act

- **$7.49 billion** for Fossil Energy and Carbon Management,
  - **$3.5 billion** for DAC Hubs
  - **~$310 million** for CO2U Program
  - **$2 billion** for CO2 storage site qualification
- **$2.1 billion** for the CO2 Transportation Infrastructure Finance and Innovation Program
- **$8 billion** for Hydrogen Hubs; **$2.85 billion** for National Forests; **$696 million** for Wildfire Mgmt.

Other

- **CA LCFS ($200-150/t) –** greater stringency expected (i.e., 40% reduction by 2030; net-zero by 2045)
- **OR** – also LCFS
- **WA** – Cap & invest program + LCFS design

The US has legislated much, with more to come

U.S. Tax Code, Section 45X

- **Clean hydrogen at $3/kg** – includes bio-hydrogen with CCS (BECCS)

Other federal bills

- **CREST Act**
  - **New R&D provisions** for Bio-oil; BiCRS; Soils; C Mineralization; Oceans; Geol. Assessments
  - **Reverse Auction:** $20M in 2023 & 2024 ramp to $60M in 2026
- **Federal Carbon Removal Leadership Act:** procurement schedule ramping to $50M/y in 2030s

States

- **CA; NY –** Independent procurement bills
- **WA** – LCFS design

Early action by companies

XPRIZE

- NRG-COSIA: CO_2 utilization prize
- Musk: $100M CO_2 removal prize

CDR purchases

- Airbus & SK: 100,000 t/y DAC (1point5)
- Microsoft, Stripe, Alphabet, Salesforce: $2 billion commitment
- Net zero commitments: tacit CO_2 removal commitments

First Movers Coalition: new CO_2 removal plank announced at Davos

- Commit 50,000 tons or $25 million on CDR by 2030
- 1000-year standard with MRV (all engineered)
- Frontier Initiative/SouthPole Facility/Breakthrough Energy
- **Carbon Direct implementation partner**

There's much to do

Tech, markets and policy are changing rapidly

Talk smart

- Science means "All of the Above" (beyond moral hazard)
- Engage communities proactively
- Seek political compromise nationally, locally, within sectors

Set standards

- Full life-cycle accounting – don't tilt the table
- Seek to align standards internationally from the outset

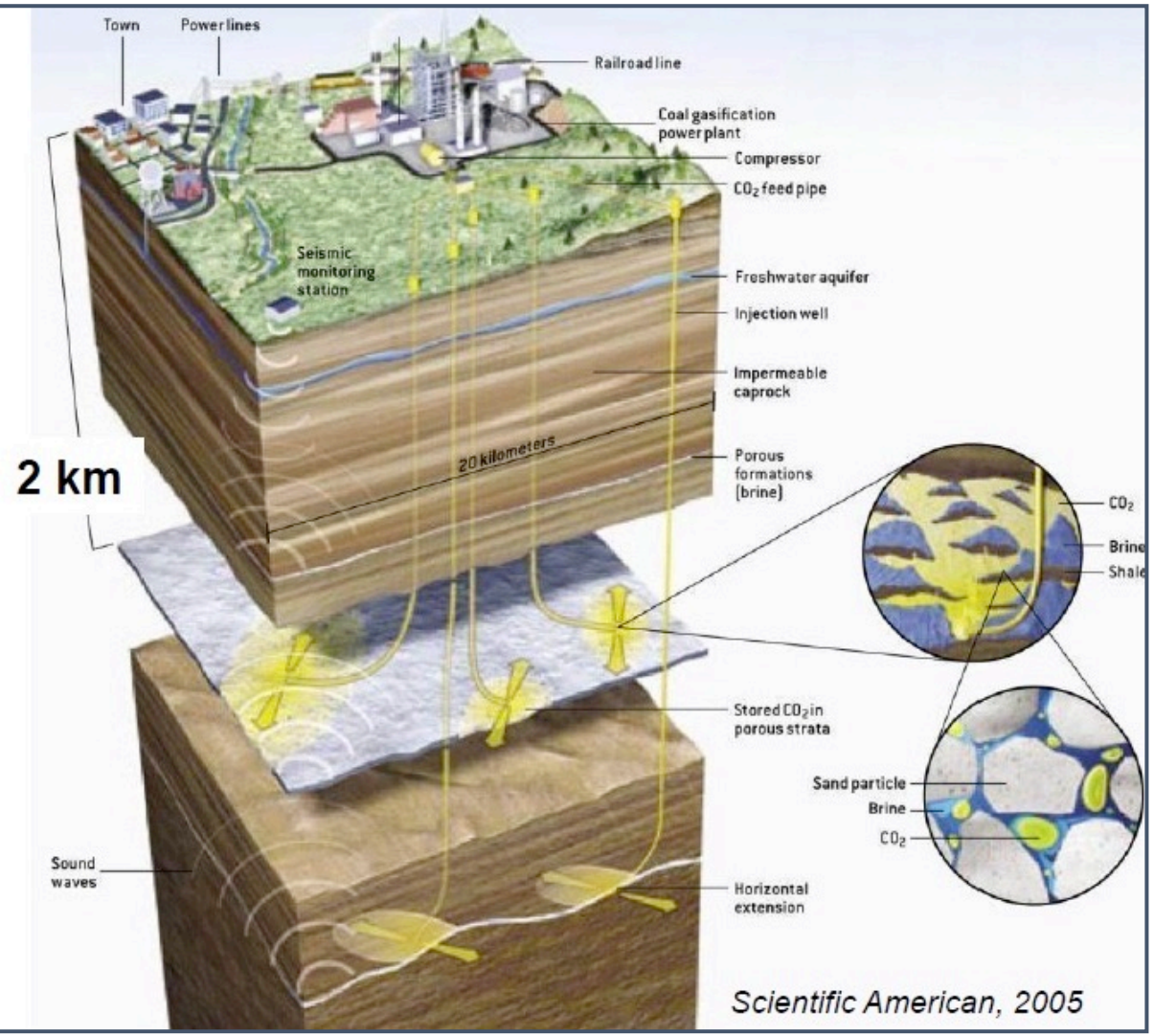
Encourage early action

- Fist Movers Coalition
- Develop contracting practice, supply chains, infrastructure
- First loss policies would help de-risk projects

Now is the time to invest and engage

Appendix:
Extra Slides Just in Case

In CCUS CO_2 is separated, concentrated & injected deep underground



Capture: chemical or physical separation of CO_2 from dilute sources

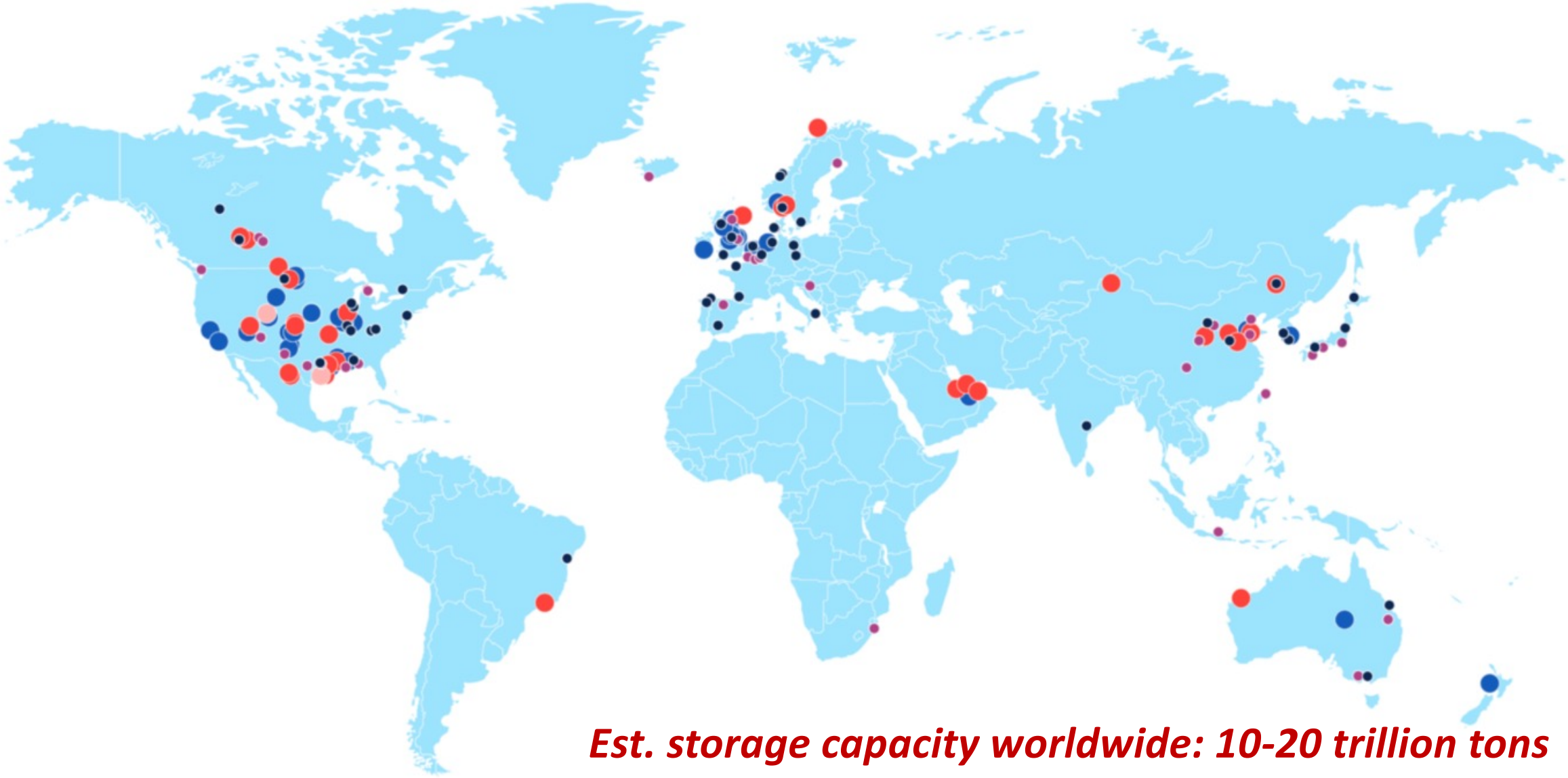
- Power plants
- Industrial sites
- Air & Oceans (Direct Air Capture)

Storage: > 1km depth

- Porous & permeable units
- Large capacity
- Good seals and cap rock

Two main targets

- Saline formations (>2800 Gtons in N. Am.)
- Depleted oil & gas fields (potential for EOR)



Est. storage capacity worldwide: 10-20 trillion tons

22 Operating facilities: 65 in adv. planning or construction

CCUS is a mature, cost effective technology for CO_2 reduction & removal


What will it really take
Ambition + humility + investment

Thank you

Net-Zero Asset Owner Alliance