



# Morning in Carbonville: From Zero to 5 Gigatons in 30 years

Dr. S. Julio Friedmann  
Chief Scientist & Chief Carbon Wrangler

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**Quick look at gigantic policy  
changes**

# A focus on Scaling Multiple Technologies

In addition to reducing greenhouse gas emissions at an unprecedented scale, a diverse portfolio of carbon removal and utilization technologies are required to meet climate targets.

## REMOVAL

**Managed ecosystems**  
*with co-benefits for people and nature*



Afforestation/  
Reforestation



Blue  
Carbon



Improved Forest  
Management (IFM)



Peatland & Wetland  
Restoration



Soil  
Carbon

**Hybrid and engineered solutions**



Carbon  
Mineralization



Bioenergy with Carbon  
Capture & Storage  
(BECCS)



Biochar



Direct Air  
Capture (DAC)



Ocean Alkalinity  
Enhancement (OAE)

**Frontier removal technologies**



Novel Soil Tech



Green Tree Burial



Macroalgae  
Cultivation



Advanced Plant  
Cultivars



Engineered Wood  
Products

## UTILIZATION



Carbon  
Utilization

Technologies that convert CO<sub>2</sub> into useful products such as fuels, building materials, and commodity chemicals.



Point Source Capture

Machines with special chemicals that bind CO<sub>2</sub> and remove it from industrial emissions sources.



Orca: The world's largest direct air capture plant  
Climeworks + CarbFix

Does the CO<sub>2</sub> work of 200,000 trees with 0.1% of the land





Mammoth: 40,000 tons in 2023  
Climeworks + CarbFix

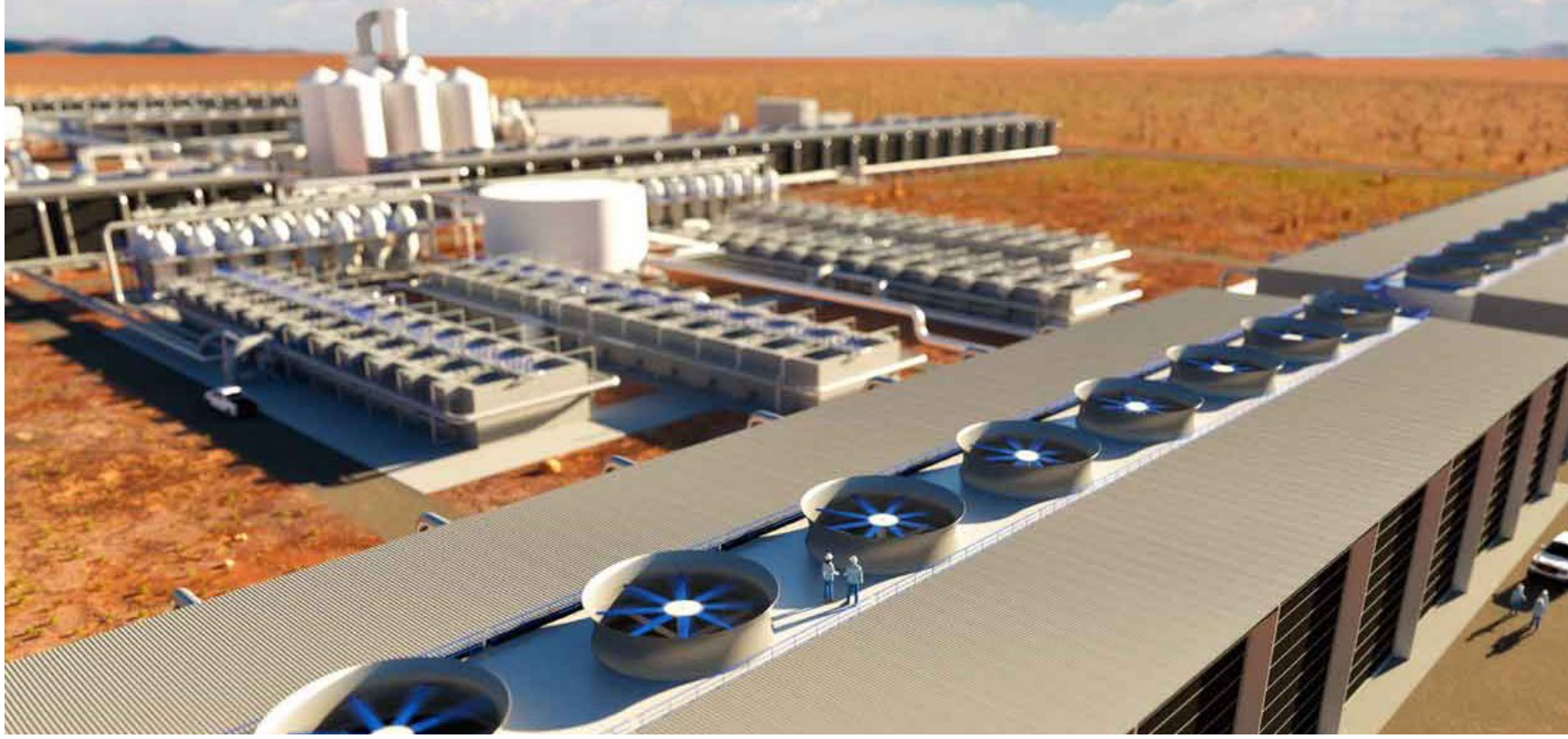


Does the CO<sub>2</sub> work of 2,000,000 trees with 0.1% of the land



## The first megaton project: 2025

Carbon Engineering, 1point 5 & Occidental Petroleum  
1,000,000 tons/year (CO<sub>2</sub> enhanced oil recovery + saline storage)



# The largest project announced: **Bison**



Carbon Capture & Frontier Carbon Solutions  
5,000,000 tons/year (saline storage) in 2030



# New companies, new processes, new tech

## Heirloom

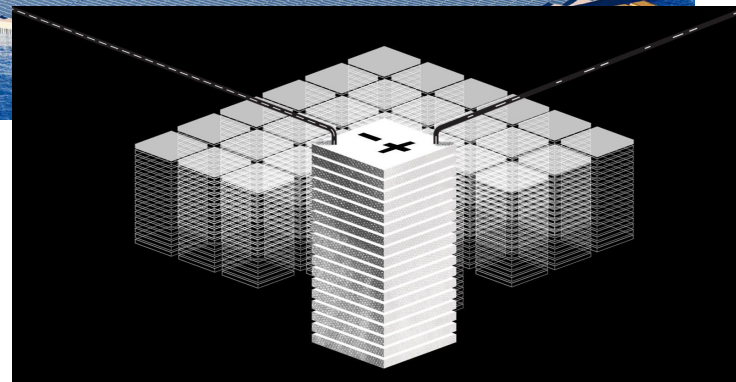
- Passive air contacting
- Dirt cheap (!) sorbents
- Dumb tech, smart robots

## Captura

- Ocean-based separations
- Electro-dialysis membrane
- Also reduces ocean acidification

## Verdax

- Electrical swing adsorption
- DAC + power + industrial
- Three pilots in design

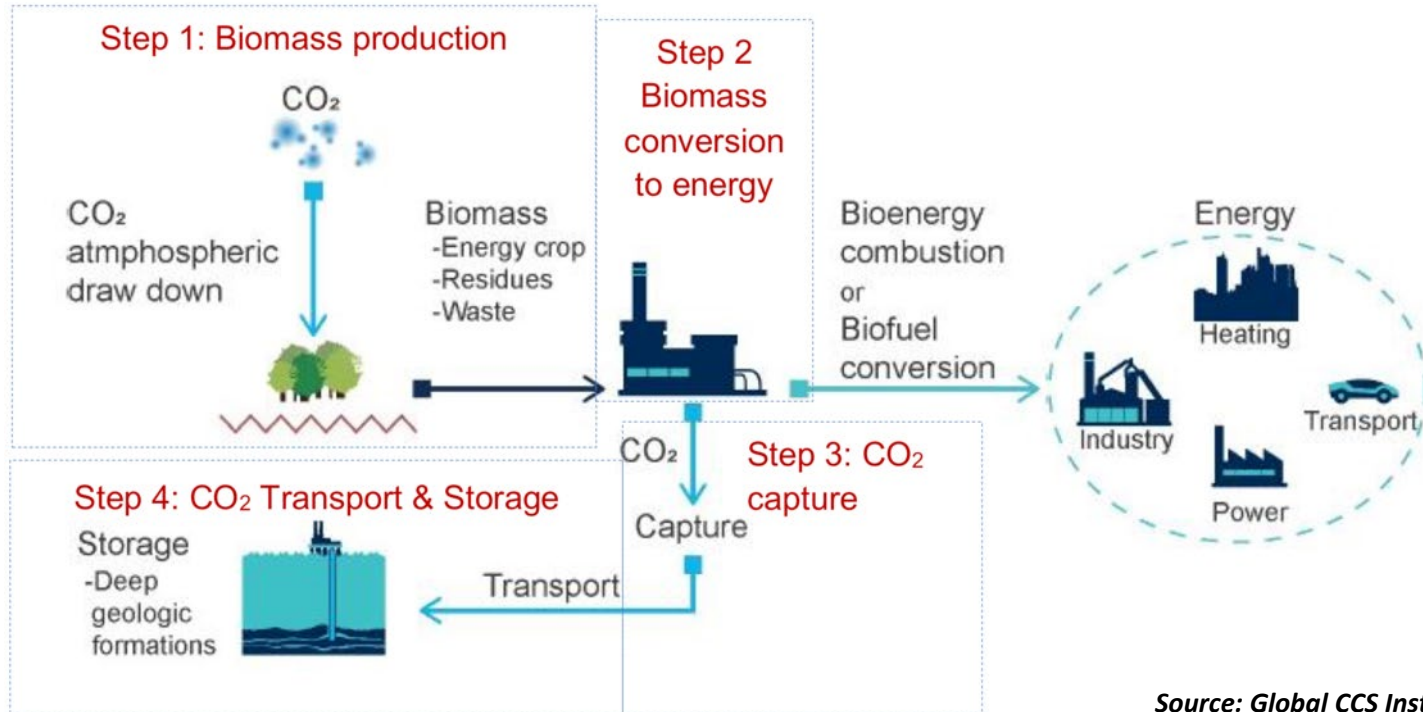




# Biomass + CCS (BECCS) coming on strong

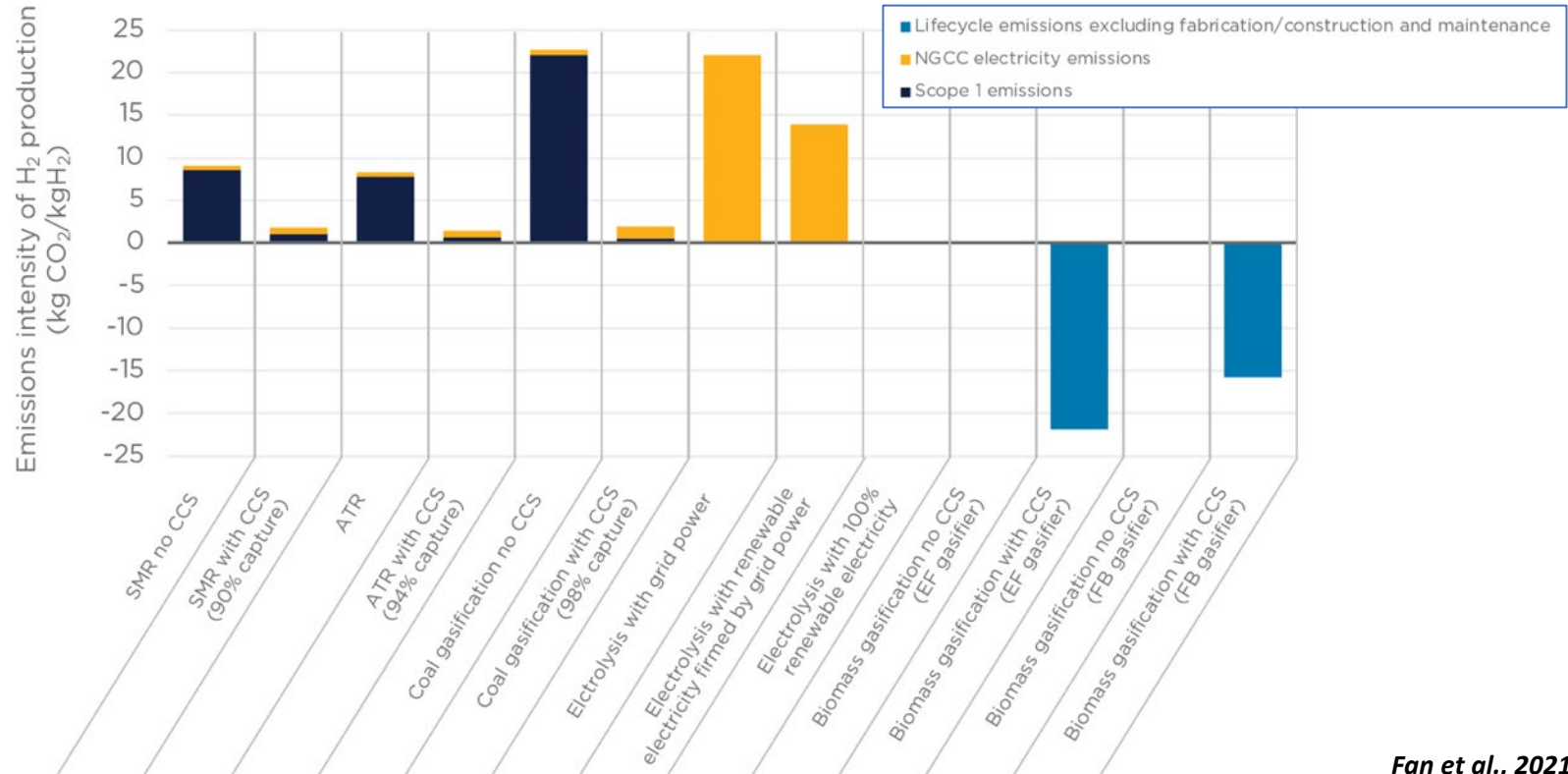
*Inputs: wastes, residues, crops*

*Outputs: power, hydrogen, fuel & CO<sub>2</sub>*



Source: Global CCS Institute, 2019

# Biohydrogen can remove huge amounts of CO<sub>2</sub>.







# Biomass can be used for carbon removal without energy production

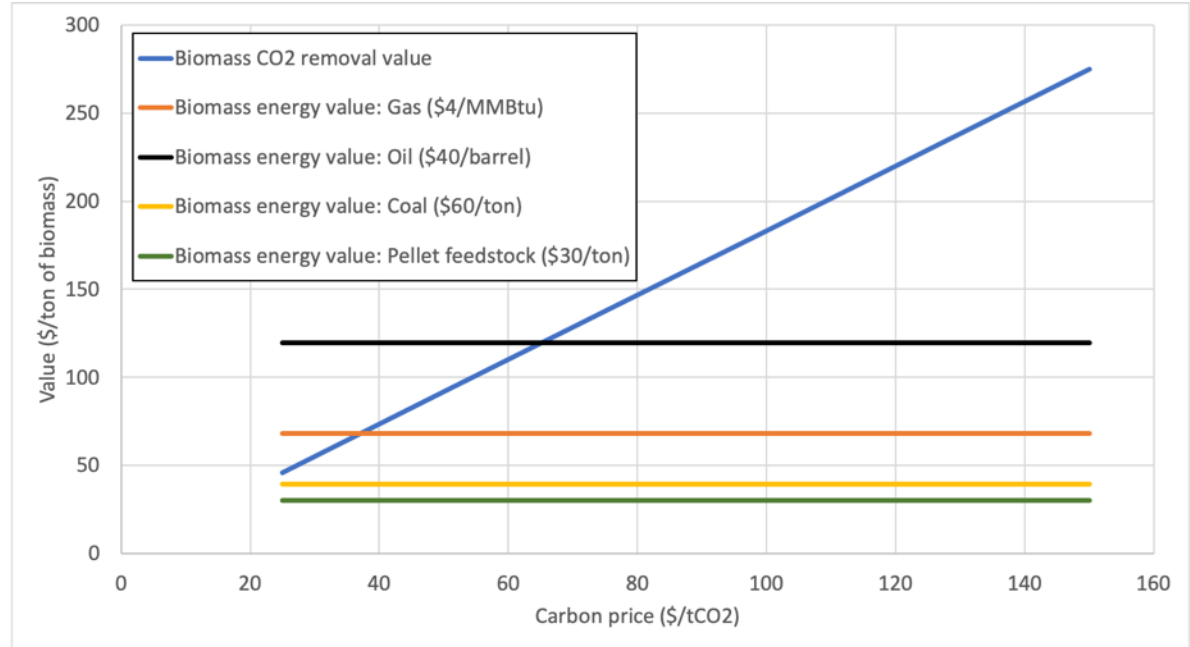
- Biochar from thermochemical biomass processing for soil improvements
- Engineered wood products for the construction market
- Bio-liquid production and direct injection to the subsurface
- Marine macroalgae production and abyssal dispatch
- Biofiber entombment in concrete





# Carbon removal value of biomass may exceed its energy value

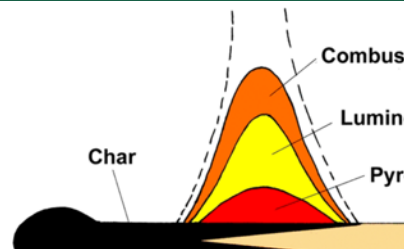
- Biomass is half carbon. One ton of biomass produces 1.8 tons of CO<sub>2</sub>.
- The value of this CO<sub>2</sub> depends on the carbon price.
- One ton of biomass (oven-dry) contains appr. 18 GJ of energy.
- This energy value is low compared to the CO<sub>2</sub> value in many cases.



# Pyrolysis – Charm bio-oil & bio-char

## Pyrolysis – like coffee roasting

- Heated without oxygen
- Biomass restructures – can for char
- Yields liquids, heat, and fuel



## Charm

- Produce bio-oil from pyrolysis
- Dispose of bio-oil in deep well
- Use agriwastes as feedstocks

• Blog / Aug 2, 2022 / 2 min. read

## A New Proto-Protocol for Bio-oil Sequestration

Carbon Direct and Eco-Engineers have developed a prototype protocol ("proto-protocol") on bio-oil sequestration, the first in a series of science-led dra

## Biochar

- Charcoal buried
- No energy produced
- Multi-hundred year durability







# Chokepoints and challenges

# The market is a mess

Renewable energy and avoided deforestation projects: 80%

Average prices remain low: \$3-4/tCO<sub>2</sub>  
unlikely to motivate significant abatement

< 3% of credits on the market are CO<sub>2</sub> 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

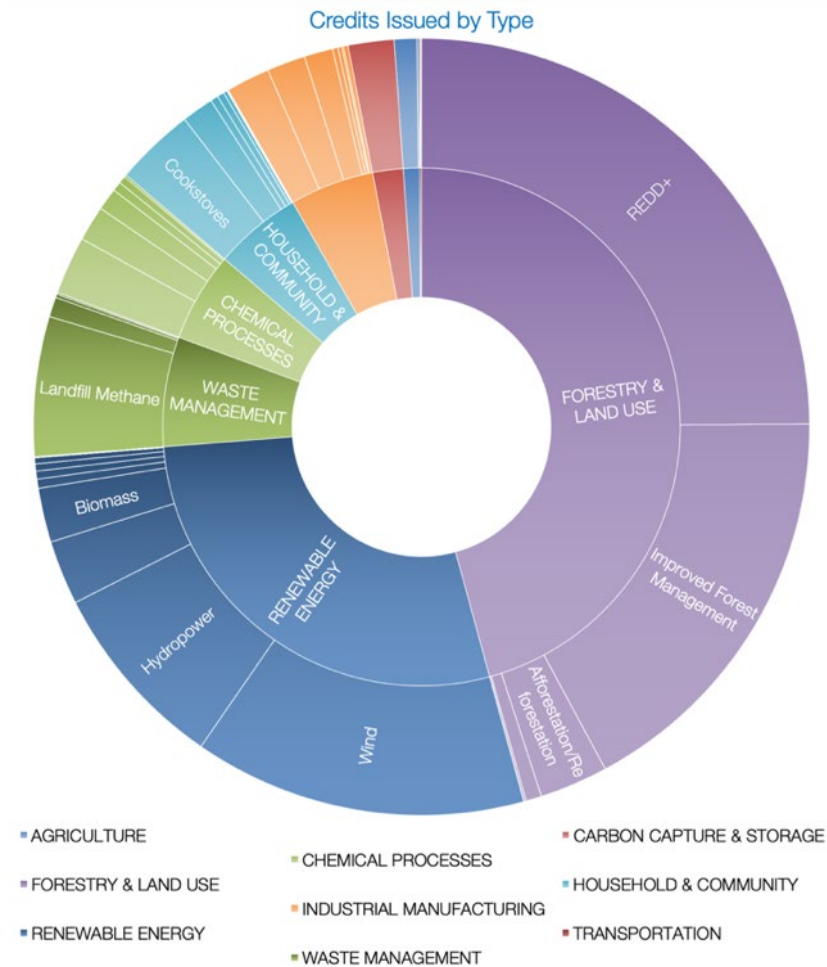
No accepted standards, protocols, or regulators

***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>

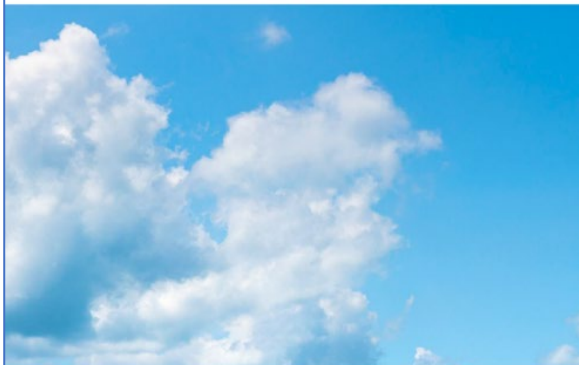
Eli Mitchell-Larson and Tim Bushman. (April 2021) Carbon Direct Commentary: Release of the Voluntary Registry Offsets Database – [see here](#).





# MSFT + CD: Criteria for high quality CDR

Criteria for  
high-quality carbon  
dioxide removal



*Additionality (with baselines)*

*Accounting methodology explained*

*Assess harms & benefits*

*Define and explain durability*

*Equity & justice assessed*

*Avoid leakage*

*Monitoring, reporting, verification (MRV)*

***Separating sense from nonsense  
is a scientific challenge***

# Three big chokepoints

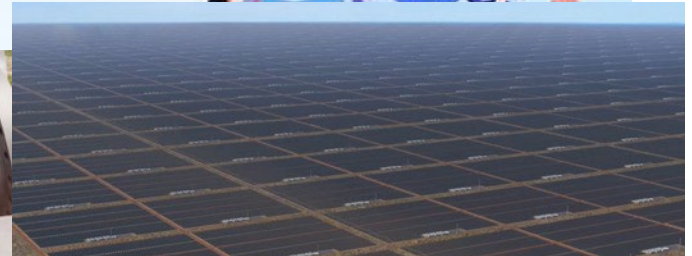
## Human Capital – not enough people

- Trades (e.g., specialty welders)
- Project managers
- Permitting, regulation, community engagement, communications....



## Infrastructure

- Power lines, renewable power
- CO2 storage sites & transportation
- Hydrogen pipelines, bunkering facilities



## Projects & risk capital

- Second valley of death
- Project development capital (DOE helps)
- Directly counter permitting risk





**Much can be done today  
and done well**



**There's much  
to do**

**Tech, markets  
and policy are  
changing  
rapidly**

### **Talk smart**

- Learn. Talk to experts
- Engage communities proactively – one mouth, two ears
- Seek political compromise nationally, locally, within sectors

### **Set standards**

- Proto-protocols => protocols => standards
- Work collaborative to keep good actors in market

### **Lean in**

- Invest in human capital development
- Advocate for smart policy that removes tons
- Reimagine risk – new partners & business models

***Ambition + humility + \$\$ = progress***

***Now is the time to invest and engage***

The background of the slide is a dense pattern of large, heart-shaped leaves, likely from a Philodendron or similar plant. The leaves are rendered in various shades of green, from a vibrant lime green to a deep, dark forest green. The lighting creates a soft gradient across the scene, with the top-left area being the brightest and the bottom-right area being the darkest. The veins of the leaves are clearly visible, adding texture to the overall composition.

**Thank you**

[jfriedmann@carbon-direct.com](mailto:jfriedmann@carbon-direct.com)