



Carbon Removal

Putting Oil Back Underground

Peter Reinhardt, CEO
California Climate Change Scoping Plan Workshop
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Engineered Carbon Removal Offers Measurability & Permanence

CO₂ impact is certain

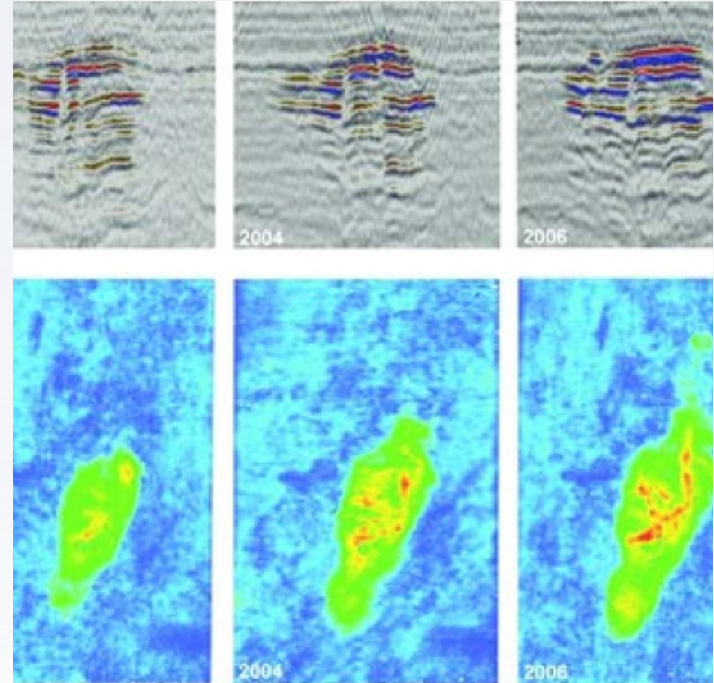
because CO₂e removal activities can be rigorously isolated, measured and monitored.



Carbon Engineering direct air capture plant rendering

CO₂ permanence is certain

due to simpler, well-understood chemistry and physics.



Seipner Field carbon sequestration experiment results



Bio-oil sequestration is a new engineered carbon removal pathway

PATENTED



1.

Cellulosic biomass already captures 100+ Gt CO₂/year. We collect it and heat it to 500°C without oxygen.



2.

The biomass breaks down into bio-oil, which is rich in carbon similar to crude oil but has higher oxygen and lower energy content (i.e. it's not useful as a fuel.)



3.

Bio-oil is prepared and injected into Class I industrial disposal wells or Class V salt caverns, where it is permanently stored. Bio-oil is denser than formation brine, meaning it naturally sinks and solidifies in place.

✿ **Biomass availability is enormous, but diffuse**

**GLOBAL
BIOMASS
WASTE IS
140 GT/YR**



CA Ag Waste
E.g. Central Valley



CA Nut Shells
E.g. Capay Canyon



CA Forest Residue
E.g. Sierras



Small, mobile bio-oil plants keep biomass supply-demand in check



Past: 1000 tpd cellulosic plants

\$65/ton biomass projections became
\$125/ton biomass reality
Broke local biomass supply-demand curve

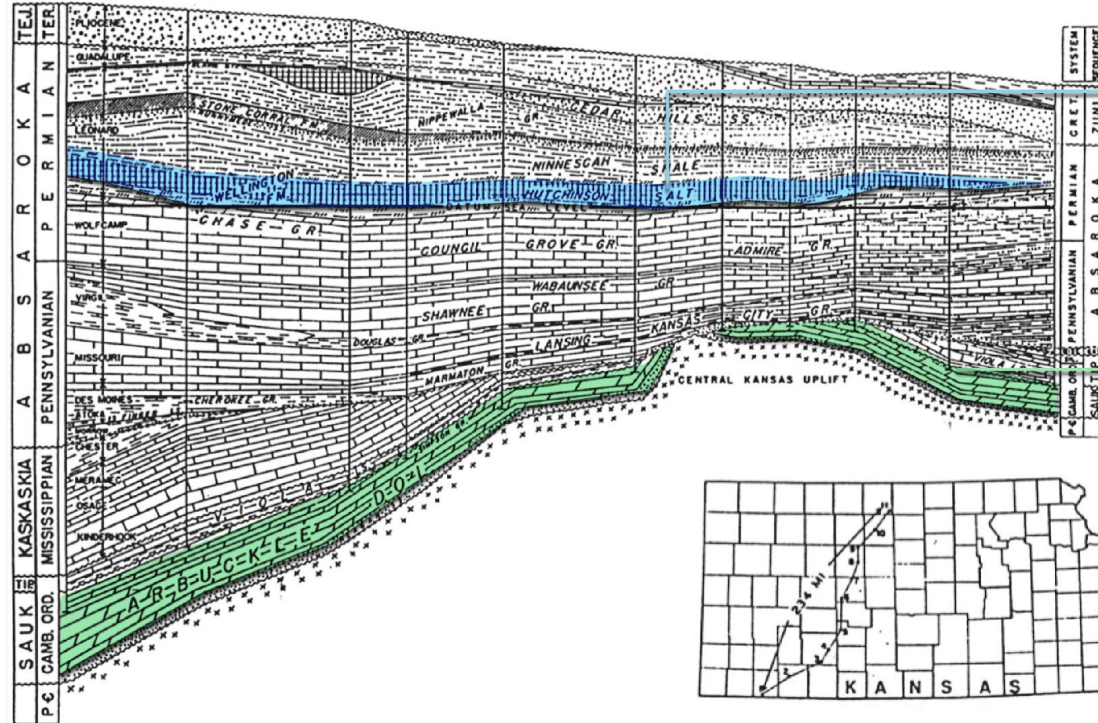


Charm: 10 tpd mobile plants

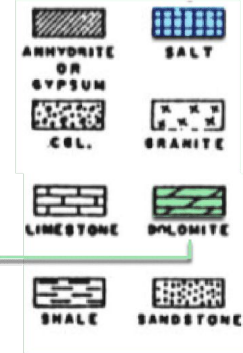
\$60/ton biomass costs, potentially lower,
due to diffuse mobile deployment
at the field edge to minimize transport costs.



Charm injects into salt caverns (Class V) and deep strata (Class I)



Lithology:



Lithology cross section from Seward County to Smith Count, Kansas

• = 1 GtC = 10^{12} kg of Carbon
 Stocks in GtC Flows in GtC / year

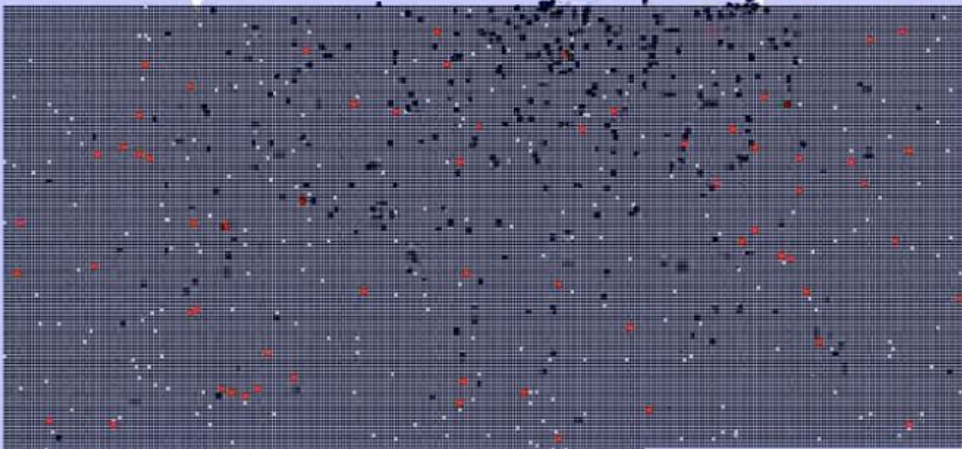
Earth's Carbon Cycle

1999

Atmosphere 787 GtC +198
 369 ppm +93

Ocean Life & Dissolved Organics 698 -2

Near Surface Dissolved CO₂ 930 +30



Intermediate and Deep Ocean 37197 +97

Symbol size reduced to fit. Each dot is still 1 GtC.

Total Ocean: 38825 +125

Gas Exchange

72.8

+12.4

73.0

+13.0

41.7

+4.4

50.9

+2.9

101.3

+0.3

92.7

+2.7

Respiration & Fire

114.6

+6.9

Photosynthesis

118.2

+9.3

Net Human Land Use Change
+1.2

Runoff

0.6

+0.0

Fossil Fuel Use and Industry

+6.7

Biosphere (Living & Dead) 2453 -47

Fossil Fuel Deposits 1193 -277

Volcanism 0.1

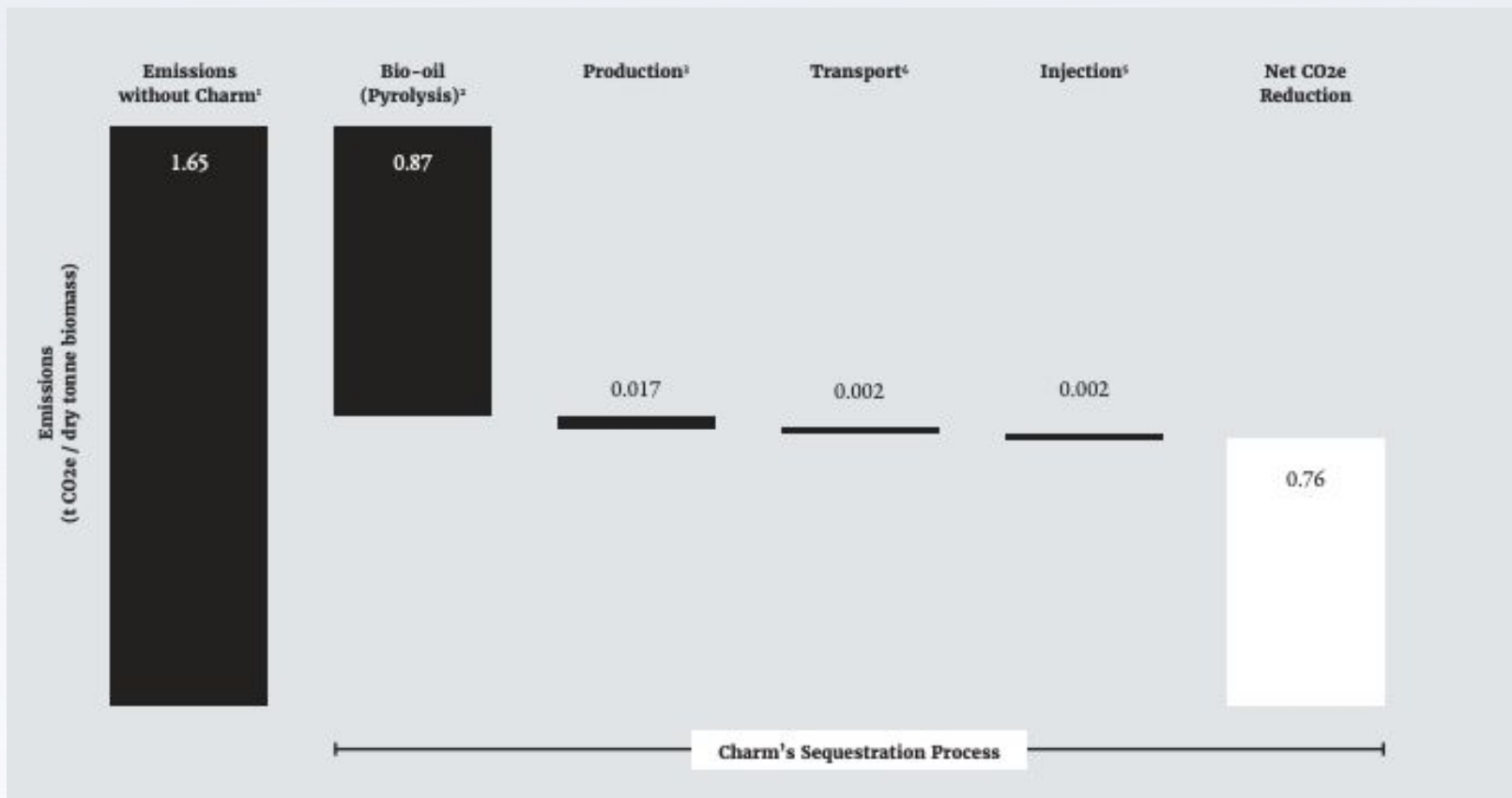
Weathering 0.1

Sediment Formation 0.2 +0.0

Rock in Earth's Crust: ~75,000,000



Life Cycle Analysis





Charm's first demo delivered 40% lower cost than DAC

10 months from invention to commercial injection



Charm Chief Scientist Shaun Meehan at rail transload, January 2021



Injection Site, January 2021



Charm has won every rigorously scientific carbon removal RFP

(OVER 3000 tons CO₂e removed to date)

25% of Stripe's 2020 RFP
at \$600/ton CO₂e

8% of Microsoft's 2020 RFP
at \$600/ton CO₂e

12% of Shopify's 2020 RFP
at \$600/ton CO₂e

Stripe's first negative emissions purchases
Ryan Orbach on May 18, 2020

To mitigate the threat of climate change, the majority of climate models agree that the world will need to remove carbon dioxide from the atmosphere at a scale of approximately 6 gigatons of CO₂ per year by 2050. That's equivalent of the United States' annual emissions.

Last year, Stripe announced our Negative Emissions Purchases (NEP) program, which will remove at least 50k tons of CO₂ per year to pay at any price, for the next 10 years. We've since built a small team within Stripe to manage these purchases. Our request for projects was open to a wide range of technologies, including:

- **Carbon capture:** These projects include planting trees or modifying agricultural practices to store more carbon in soil. These projects are relatively less expensive and benefit from immediate scale (see can-plant-trees-today), but have shorter long-term permanence since trees can be easily burned down and carbon storage in soil can be short-lived. These solutions alone are unlikely to sustain the necessary 6-15 gigatons of annual CO₂ removal.

416 tons CO₂/e gone forever... ahead of schedule

Microsoft's FY21 Carbon Removal Portfolio

Carbon negative | Contracted projects | Worldwide map | Project details

Category	Total Contracted	Contracted Volume
Forestry	1,1mn	Green Diamond: 240,000
		Natural Capital Partners: 209,800
		The Nature Conservancy: 202,369
		Silvia Terra: 200,000
		Cumberland Forest, LP managed: 153,000
		Climate Care Oxford: 7,000
Soil	193t	Land O'Lakes: 100,000
		Rabobank: 93,338
Bioenergy	2t	2,000
Biochar	2t	1,000
		500
Direct air capture	1,400	400
		1,400
Total	1.3mn	

Log Scale: 100, 10,000, 1,000,000

2K tons CO₂/e gone forever... ahead of schedule

PERMANENT CARBON REMOVAL

24% of land spend

Related stories

- DIRECT AIR CAPTURE**
Pulls carbon directly out of the air, then stores it safely and permanently.
- PRODUCT**
Investing and storing carbon directly into usable products, like concrete.
- OCEAN**
Maximizes the world's largest carbon sink and reduces ocean acidification.
- MINERALIZATION**
Takes carbon into a mineral that can be permanently stored away.
- COLLABORATION**
Partnering with like-minded organizations helps to reverse climate change.
- FOREST**
Protect, restore, and collect forests to allow trees to store more carbon.
- SOIL**
Takes specific farming techniques that increase soil health and its ability to store carbon.

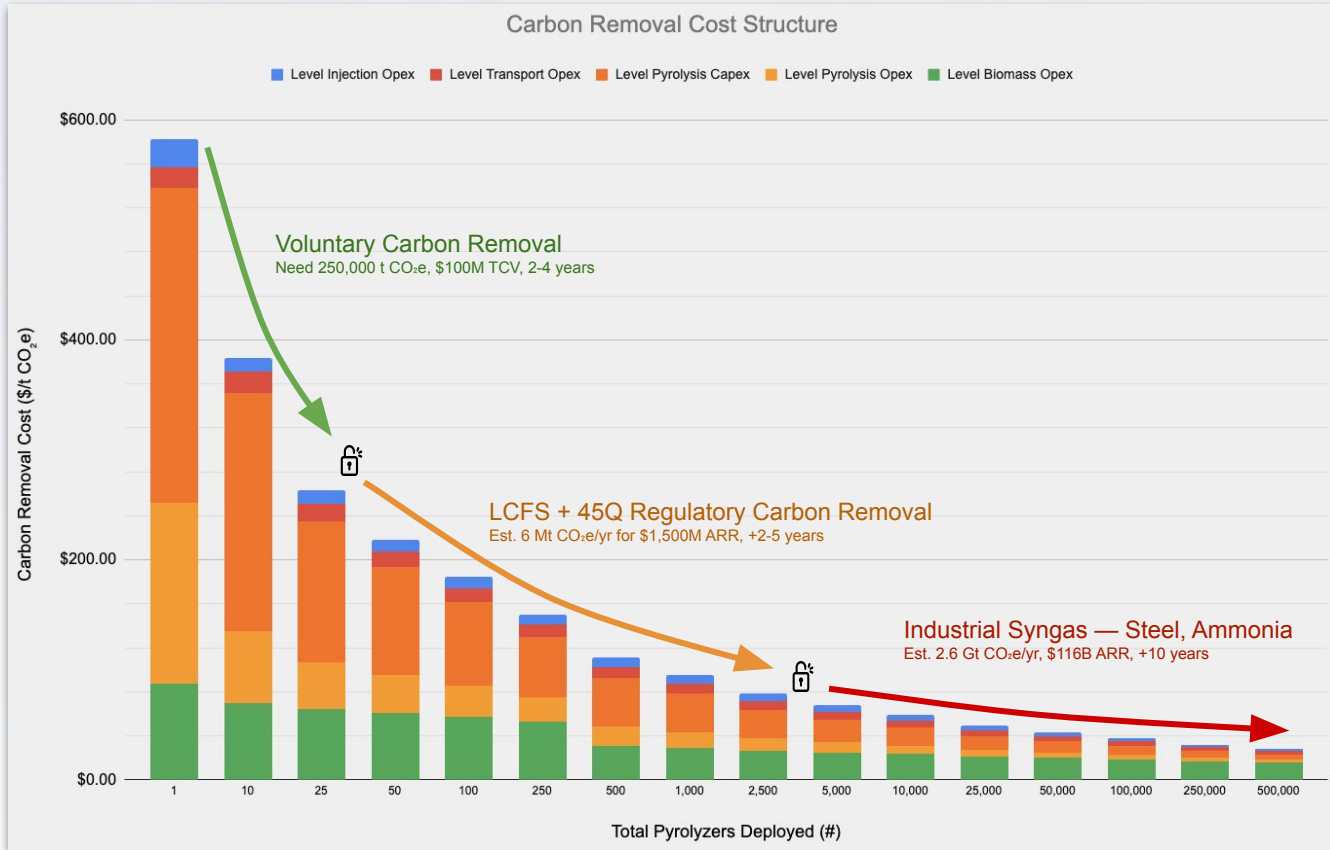
COMPANY SPOTLIGHT
Charm Industrial
Charm Industrial is on a mission to return the earth's atmosphere to 280 parts per million of CO₂, the level it sat at before the Industrial Revolution. They aim to do this by storing bio-oil deep underground.
Charm's approach is unique. They asked, what would be possible if bio-oil didn't need to be refined for fuel, and could go directly to market?
The thing is, bio-oil is rich with carbon from the product it came from—in Charm's case, sawdust and corn remnants. Instead of converting that oil into a usable product, Charm opts to permanently sequester it in the earth. Where? In industrial disposal wells and salt caverns underground.
Founded 2012
Location: San Francisco, CA, USA

2K tons CO₂/e gone forever... ahead of schedule



Charm can drive a declining cost curve from \$600 to \$50/ton CO₂e

And eliminate 10%+ of global CO₂ emissions in the process (2% from H₂ production, 8% from steel)





Thank You

Questions?

