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Convening Global Experts to Guide Decision Making

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Reframing Carbon Capture and Reuse: Building a New Industry

August 21st from 2:15 - 3:45 PM EDT. Webinar Registration: 1000

Clark Miller
Associate Director of ASU's School for the Future of Innovation In Society
Webinar Moderator

Anthony Hobley
CEO, Carbon Tracker Initiative

Ken Alex
Director of Policy and Research
California Governor's Office

Julio Friedmann
CEO of Carbon Wrangler

Edward Saltzberg
Managing Director
Security & Sustainability Forum

Julie Ann Wrigley Global Institute of Sustainability
Arizona State University

Carbon Tracker Initiative

Carbon Wrangler LLC

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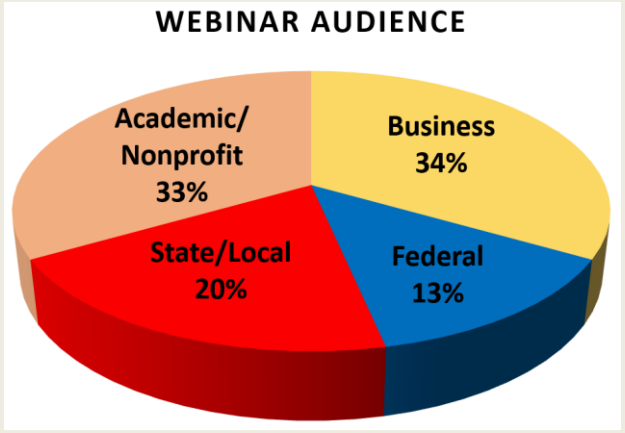
- *Others*

Who Follows Us?

20,000 Global Sustainability Professionals



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Julie Ann Wrigley Global Institute of Sustainability
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Download ASU's Workshop Report: Building Research Programs to Support 21st Century Economic Opportunity

Webinar 1: **Reframing Carbon Capture and Reuse: Building a New Industry** – August 21

Webinar 2: **Bipartisan Panel Discussion on Carbon Pricing (with Senator Sheldon Whitehouse)** August 29

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Agenda

Julie Ann Wrigley Global Institute of Sustainability
Arizona State University

1. **Opening :** Edward Saltzberg
2. **Introduction:** Clark Miller, Webinar Moderator
   - ***Anthony Hobley*** – *Speeding the transition*
   - ***Ken Alex*** - *Observations from California*
   - ***Julio Friedmann*** : *The new carbon economy, challenges and opportunities*
3. **Discussion Panel (15 minutes)**
4. **Audience Q&A: (20 minutes) -** Use the box in the Go to Webinar window
5. **Panel Summary (2 minutes)**
6. **Closing**

Download the slides and report in the Go to Webinar Window.

Video will be posted by tomorrow.

(Please Take the Brief Exit Survey.)

Security And Sustainability Forum
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Moderator

Arizona State University

Clark A. Miller is Associate Professor of Science and Technology Studies and Associate Director of the School for the Future of Innovation in Society at Arizona State University..

Meet the Panel

Julie Ann Wrigley Global Institute of Sustainability
Arizona State University

Anthony Hobley
Chief Executive Officer of the Carbon Tracker Initiative

Ken Alex
Director of the Governor's Office of Planning and Research - California State Government

Julio Friedmann
CEO of Carbon Wrangler and former Principal Deputy Assistant Secretary for the Office of Fossil Energy

CCS: BROADER CONTEXT

Fudge Factor or Plausible Reality?

Anthony Hobley
CEO
Carbon Tracker Initiative

Impact Highlights

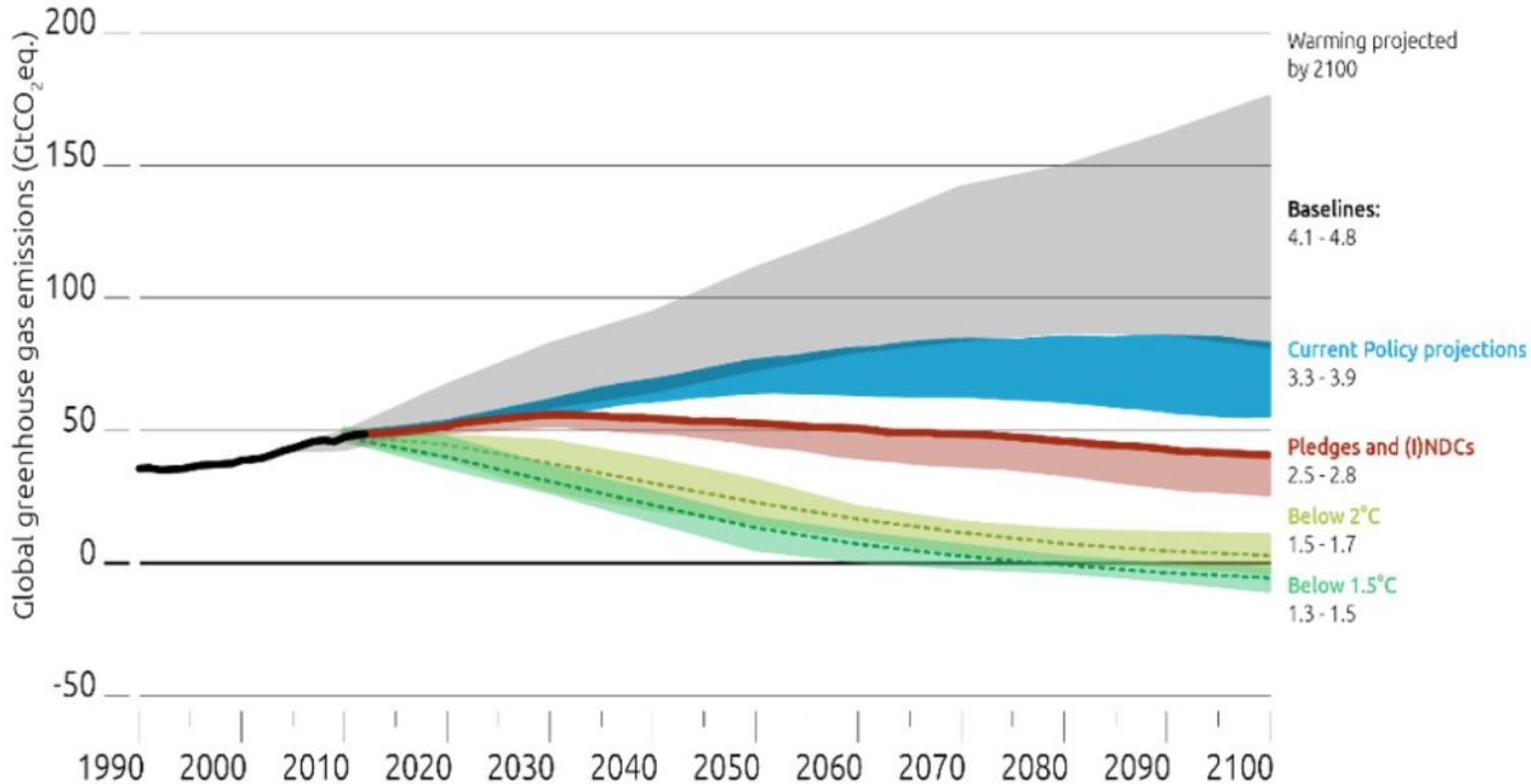
Redefining the debate

“Of all the recent ideas climate change campaigners have come up with to convince the world to do more to curb global warming, none has been as potent as the concept of stranded fossil fuel assets.”

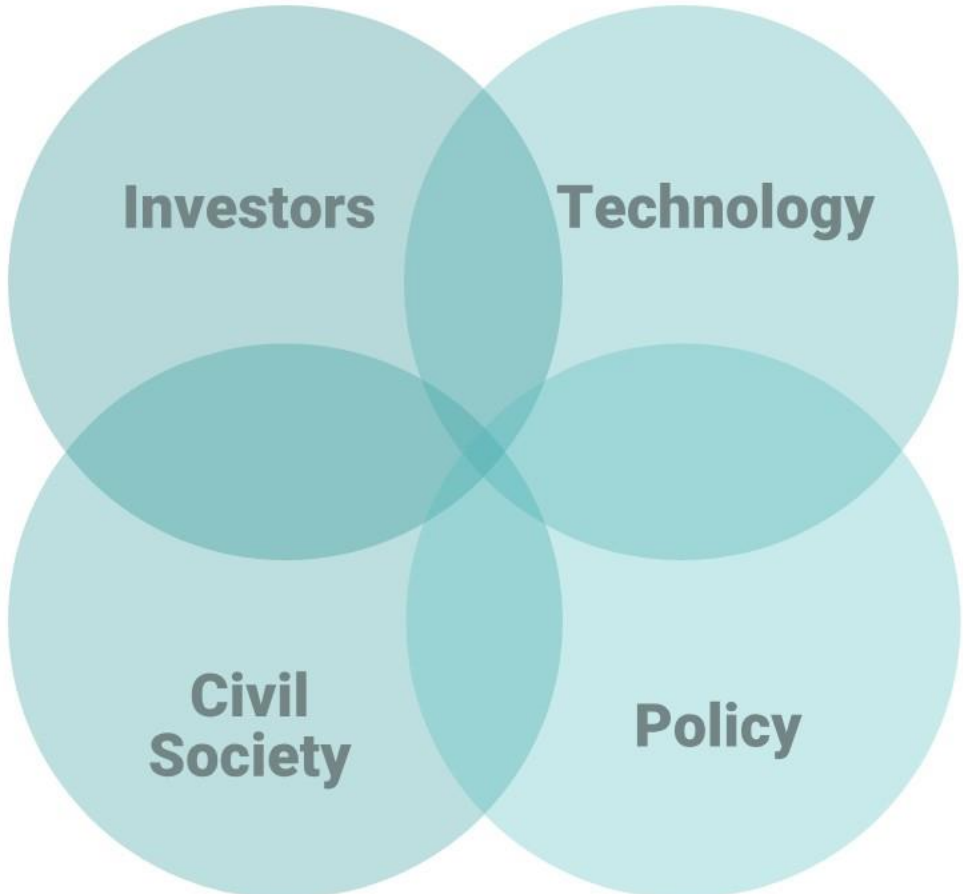
“Carbon Tracker has changed the financial language of climate change.”

The Carbon Budget

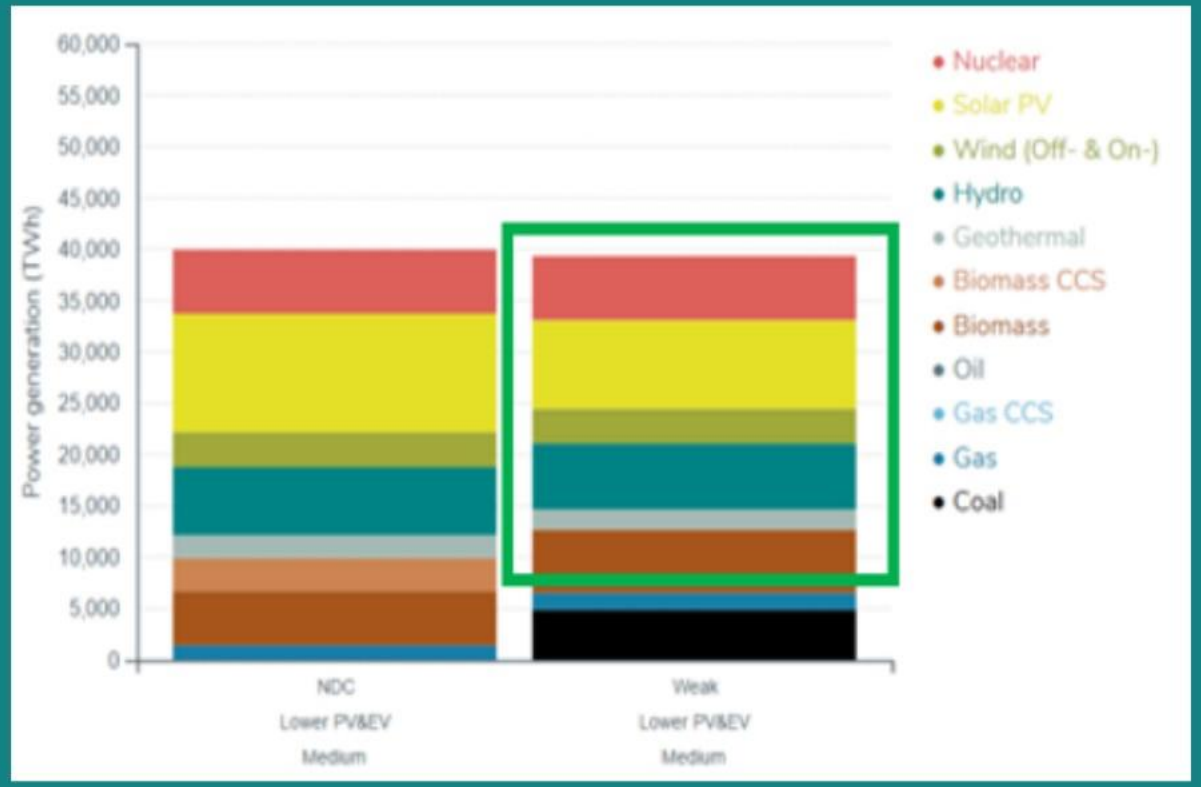
Direction is not the issue, but speed



How do we ensure the transition is fast enough?



Policy can assist the transition, but can't stop it



- Even with weak global climate policies, by 2050:
- Over 70% of world power could come from non-fossil fuels
- More than 65% of world vehicles could be electric

Expect the Unexpected, Carbon Tracker, 2017

Financial Case Against Coal

$104bn At risk of becoming stranded in a 2°C scenario

$10bn A year could be saved by phasing out unprofitable coal

2021

New wind will be cheaper than existing coal

2023

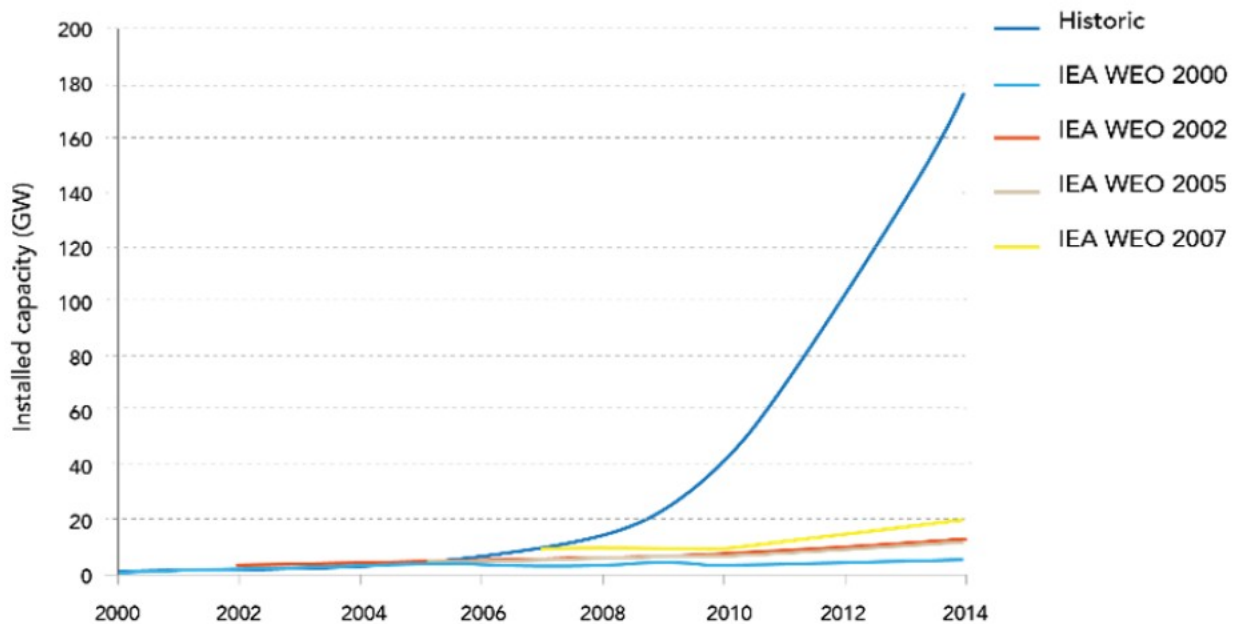
New solar PV will be cheaper than existing coal

Technology-driven transition

Half the names that appeared on the Fortune 500 in 2000, have now disappeared from the list

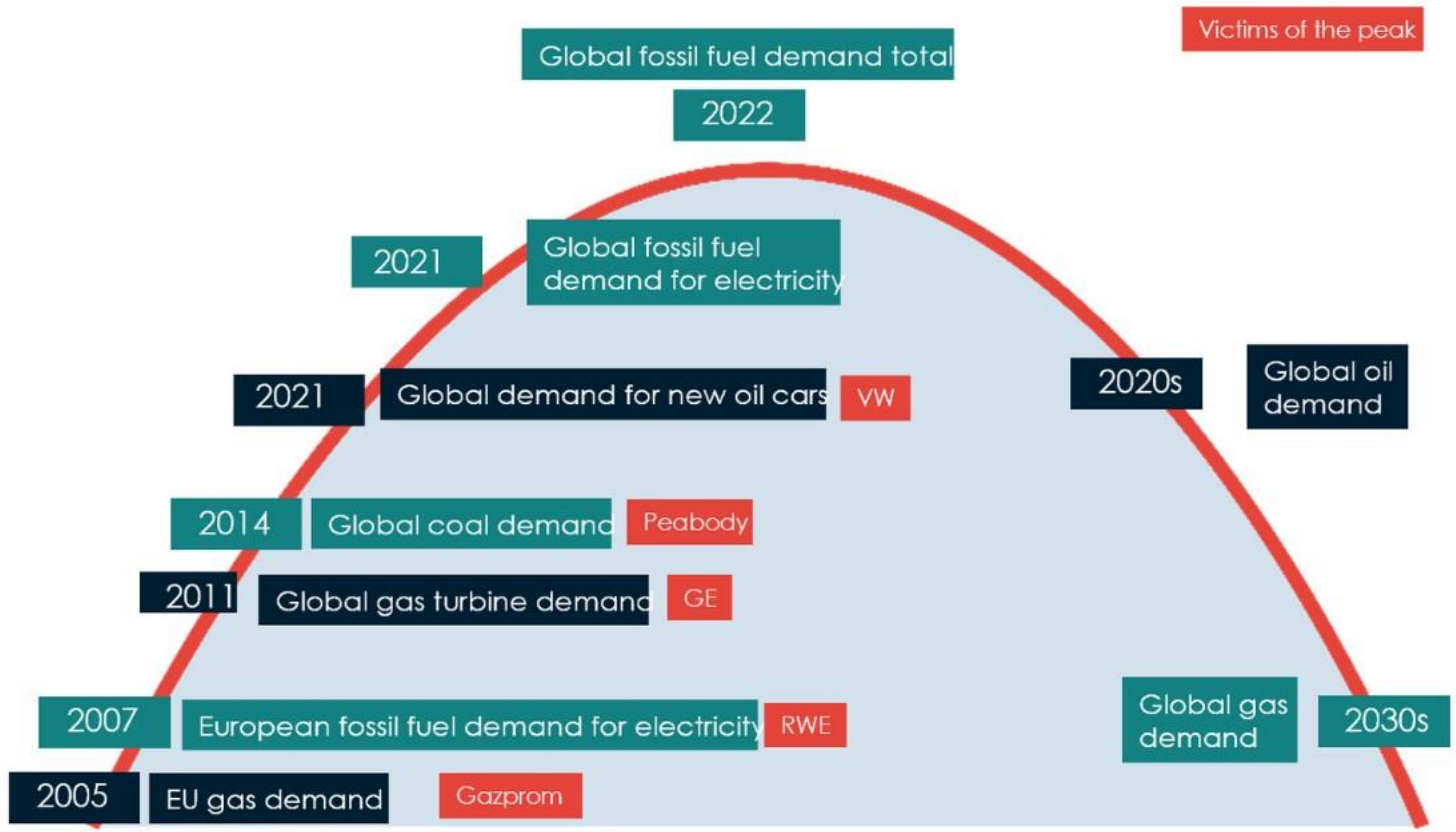
Far-reaching changes occur faster than expected

IEA solar PV capacity forecasts against actual



N.B. The IEA has now revised its medium-term forecast for wind & solar up by 13% since 2015

Could global fossil fuel demand peak in 2022?



Disclosure shines a light on risk

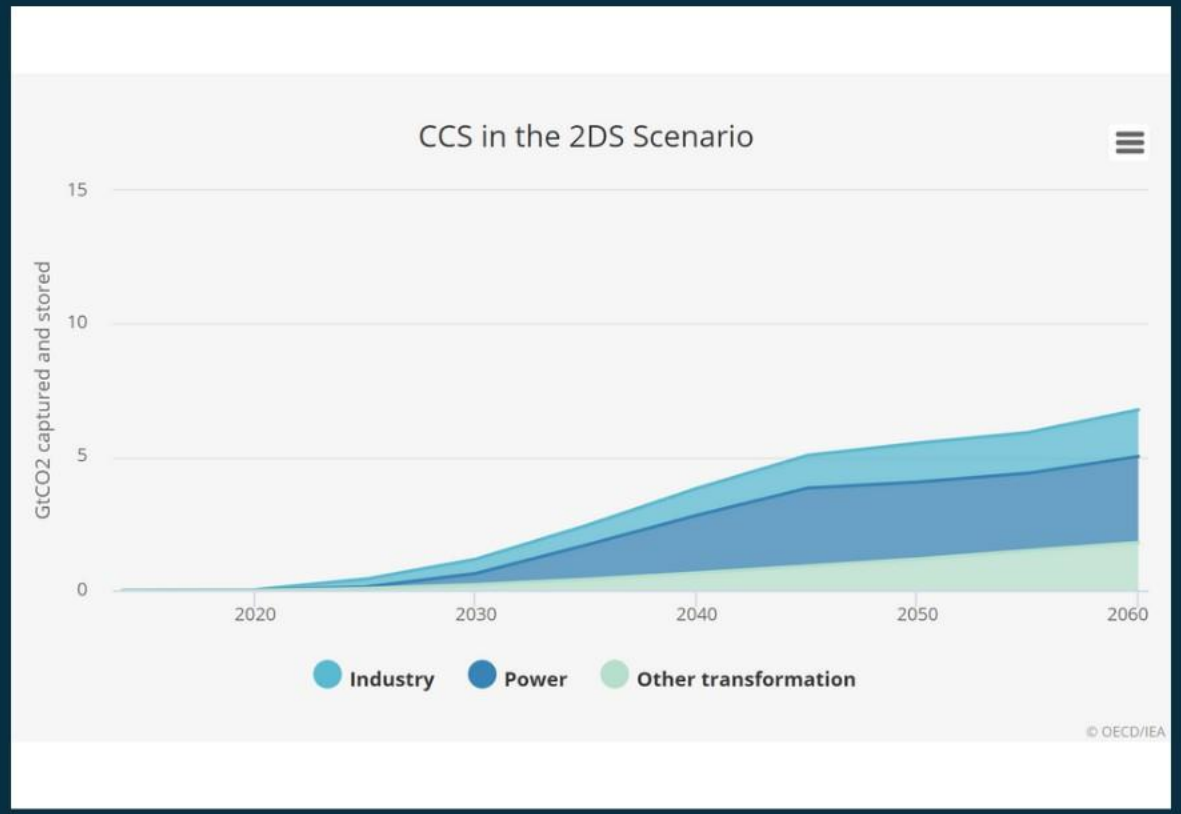
There is great need to...

1. **Translate the impact of clean technology & climate policy on company assets on a quantitative & comparable basis**

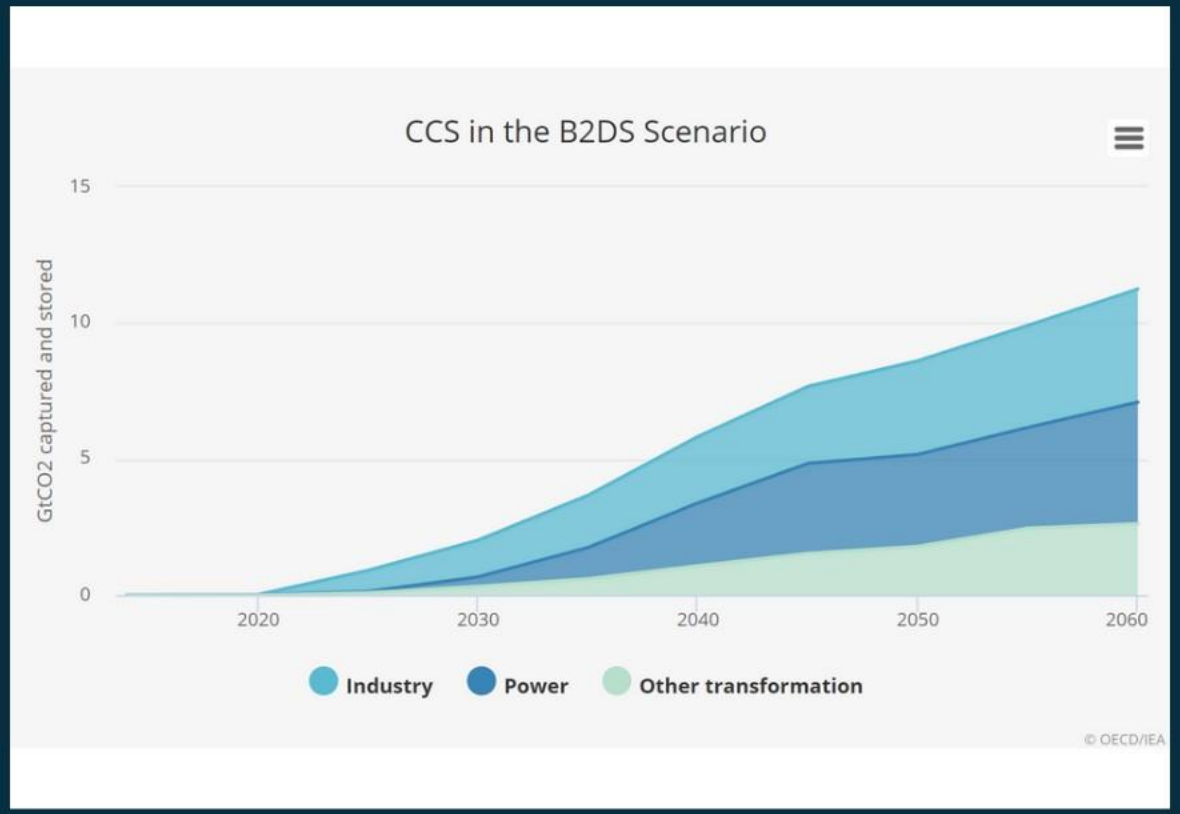
2. **Improve disclosure of the assumptions underpinning company forecasts to allow investors to scrutinize them on a forward looking quantitative basis**

3. **Set a reference scenario (pathway) against which shareholders can judge a companies progress towards Paris**

Scenarios and CCS



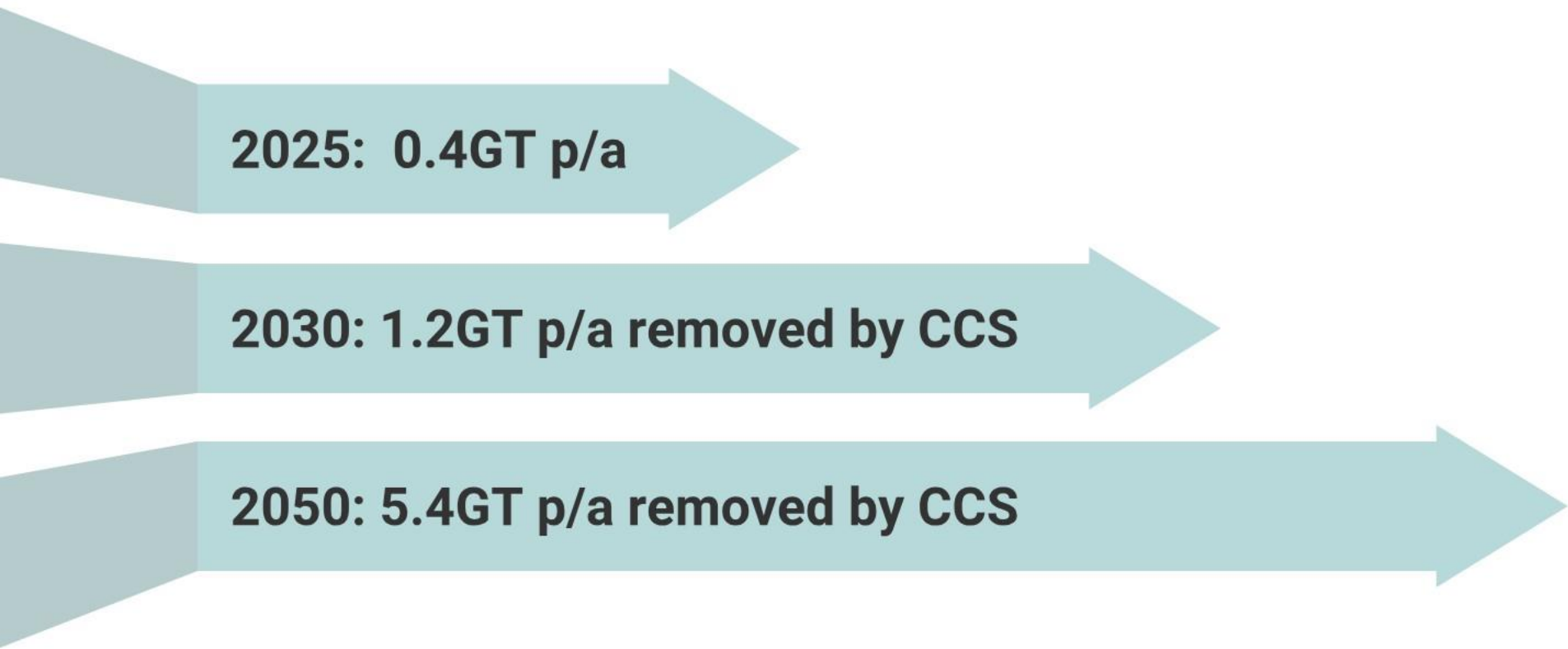
IEA 2DS Scenario



IEA B2DS Scenario

Scenarios and CCS

2DS Scenario



IEA's 2DS scenario includes significant removal of carbon dioxide by CCS

IEA figures

Scenarios and CCS

B2DS Scenario

2025: 0.9GT p/a

2030: 2GT p/a removed by CCS

2050: 8.4GT p/a removed by CCS

B2DS scenario has an even more idealistic growth of CCS technology and usage

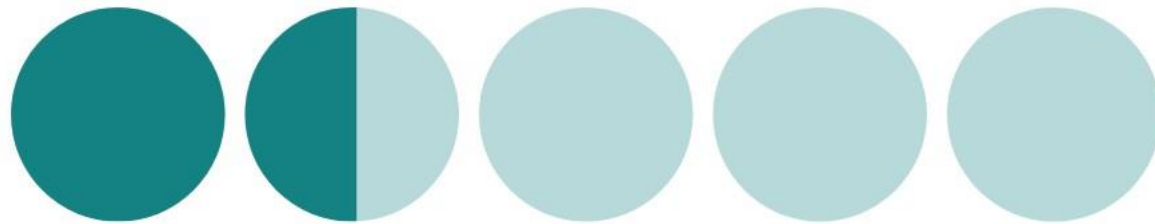
IEA figures

CCS will be necessary to reach net-zero

But it is not a magic bullet...

How heavily does B2DS rely on CCS?

30%



In the period 2018-2060 CCS captures another ~third on top of the direct emissions

To reach these levels, we need to be building about 5 CCS plants a week

Carbon capture as it stands

17 large scale facilities operating globally

220m tonnes (0.22Gt) of carbon had captured to date

4 more plants under construction operating by 2018

These 21 plants have combined capture capacity of 0.037Gt p/a

GCCSI 2017 Report

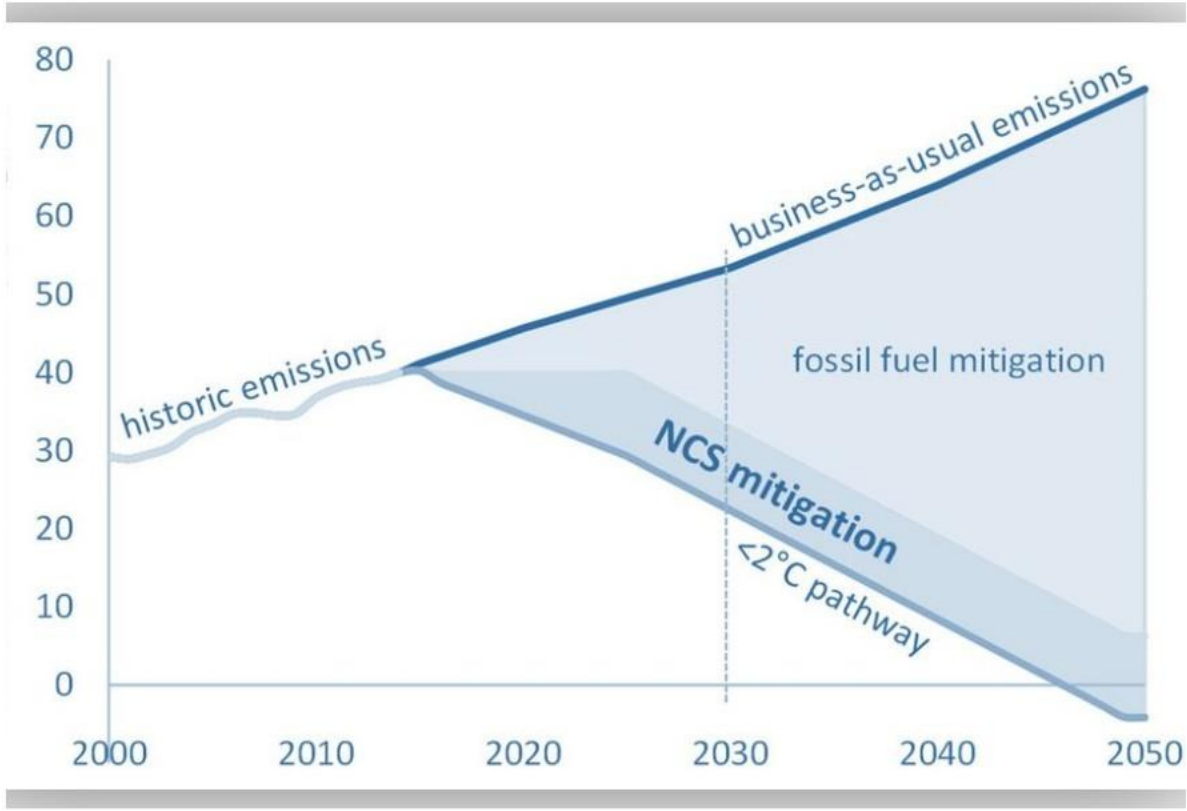
Other negative emission

Forest Regrowth

Ocean Fertilisation

Biochar

Potential Contribution of natural climate solutions (NCS) to stabilizing warming to below 2 °C

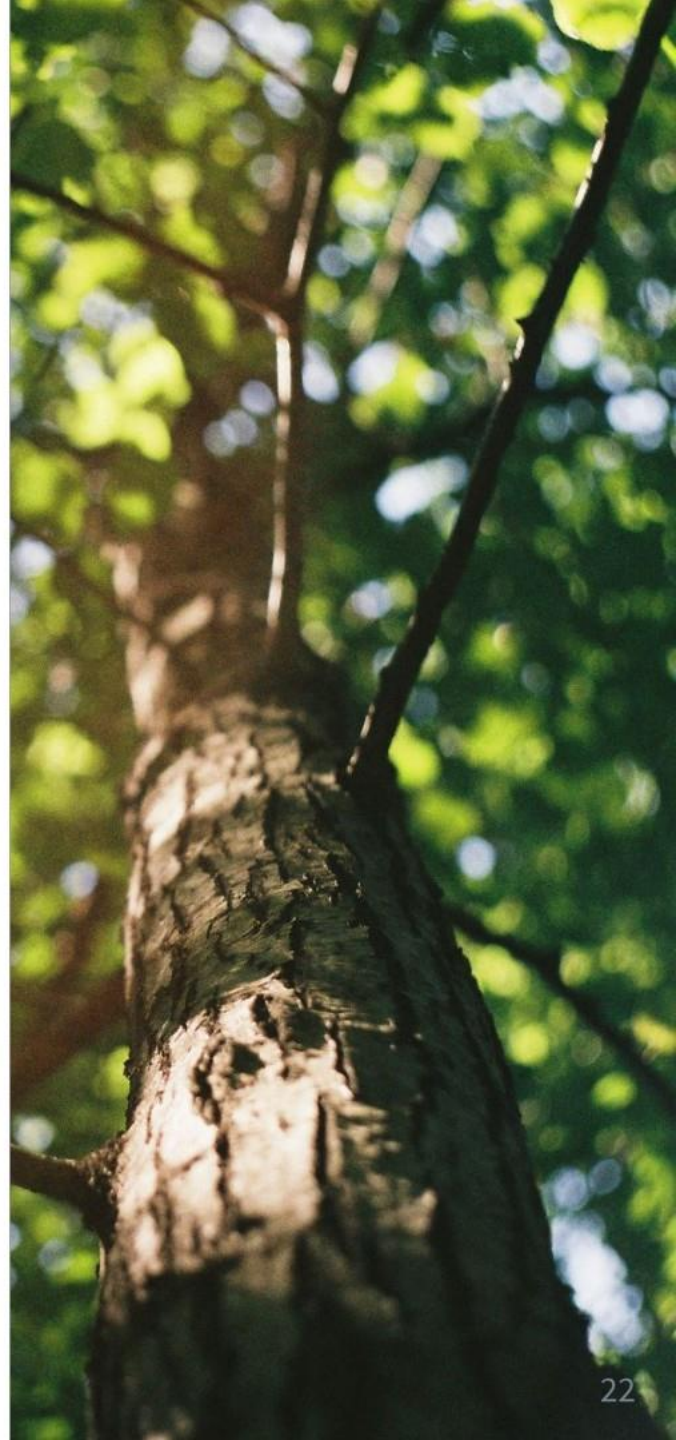


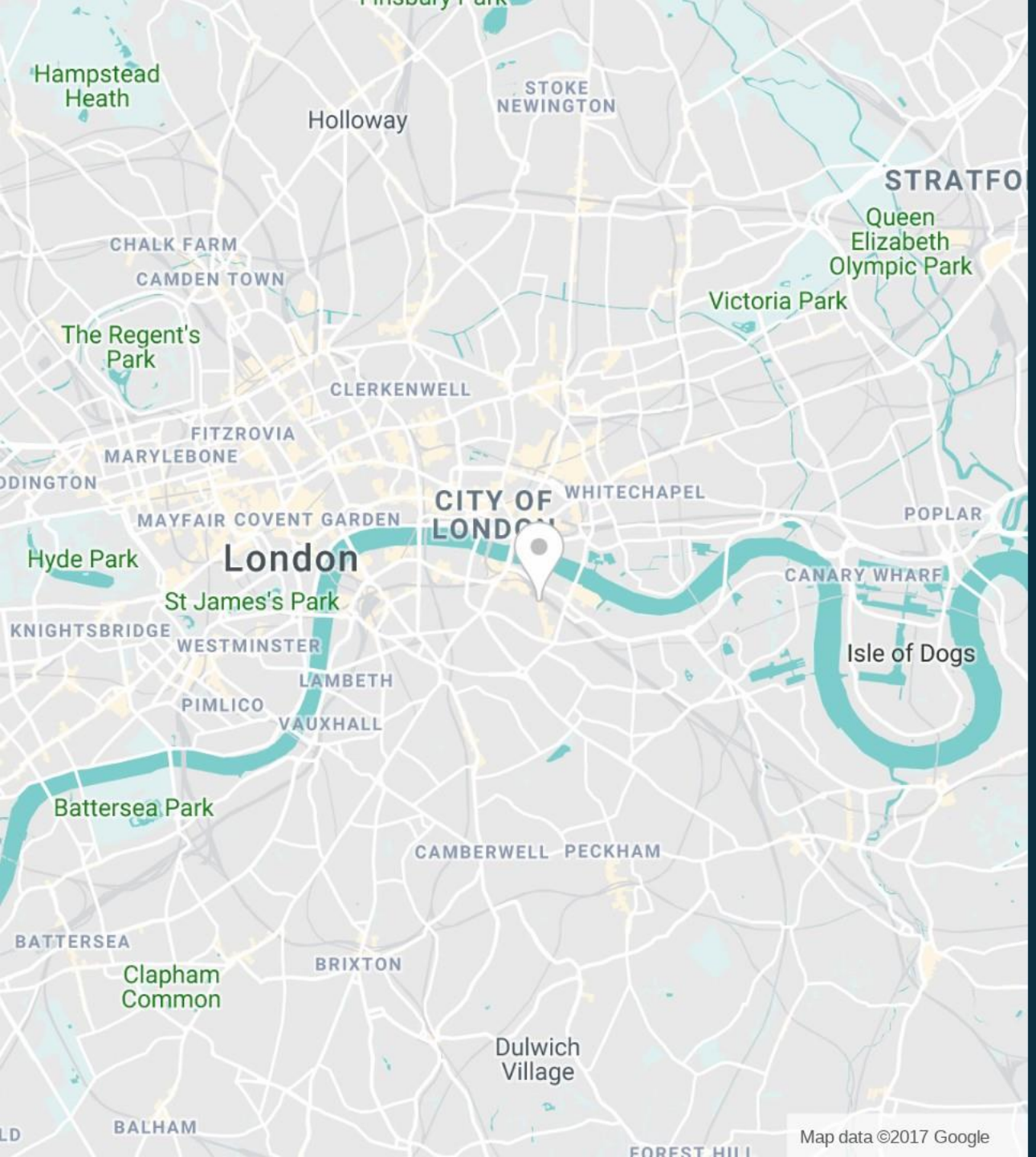
- **Natural climate solutions (biological carbon capture & storage from forest conservation, afforestation, mangroves, reforestation, wetlands etc) can provide 37% of cost-effective CO2 mitigation needed through 2030 for a >66% chance of holding warming to below 2 °C**

Bronson W Griscom et al. PNAS 2017

Takeaways and questions to consider...

1. Do scenarios rely too heavily on CCS?
2. Is this rapid deployment realistic?
3. Where should we focus efforts?





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Observations from California

Ken Alex

Director of the Governor's Office of Planning and Research - California State Government

ASU Reframing Carbon Capture and Reuse Webinar

August 21, 2018

carbon capture

- Many Approaches
- Part of Scoping Plan
- Demonstration Projects (funding)

Climate Smart Ag

- Healthy Soils
- Biochar
- Gypsum
- Cattle Rotation
- See: https://www.cdfa.ca.gov/climatesmartag/

Cement and Concrete

- For example:
- C02ncrete: http://newsroom.ucla.edu/stories/reimagining-co2:-ucla-team-advances-to-carbon-xprize-finals
- Blue Planet: http://www.blueplanet-ltd.com/

Other Approaches

- EOR
- Flaring gas
- Direct Air
- Etc.

Hurdles

- For example: Regulatory Approval of Cement/Concrete
- EOR: Promoting oil?
- Biochar, gypsum research
- Speed, scale: Demos, focused research, state/academic, Under2

The New C Economy: Revitalizing America through un-emissions

C is the New Black

Dr. S. Julio Friedmann, CEO
Carbon Wrangler LLC
@CarbonWrangler
碳 牧马人

Carbon is the Backbone of the US Economy

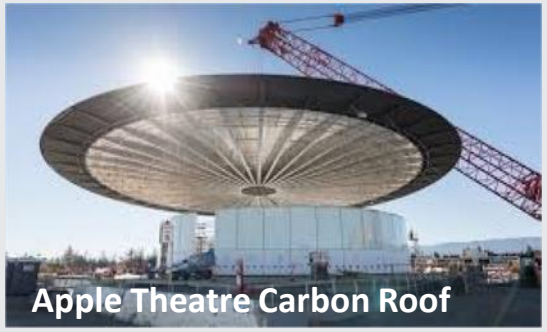
Advanced Polymers

Polyurethane Insulation

Polycarbonate Windows

Advanced Materials

Carbon Fiber Concrete I-75 Repair



Apple Theatre Carbon Roof

Chemicals and Fuels

Carbon-based markets are huge and expanding

Next innovation imperative: negative emissions

Forestry/Land

Agriculture

Energy

Manufacturing

Mining

Ecosystem Restoration

Biochar

Timber

Land Management

BIOLOGICAL

Bioenergy + CCS

Direct Air Capture

Carbon Negative Materials

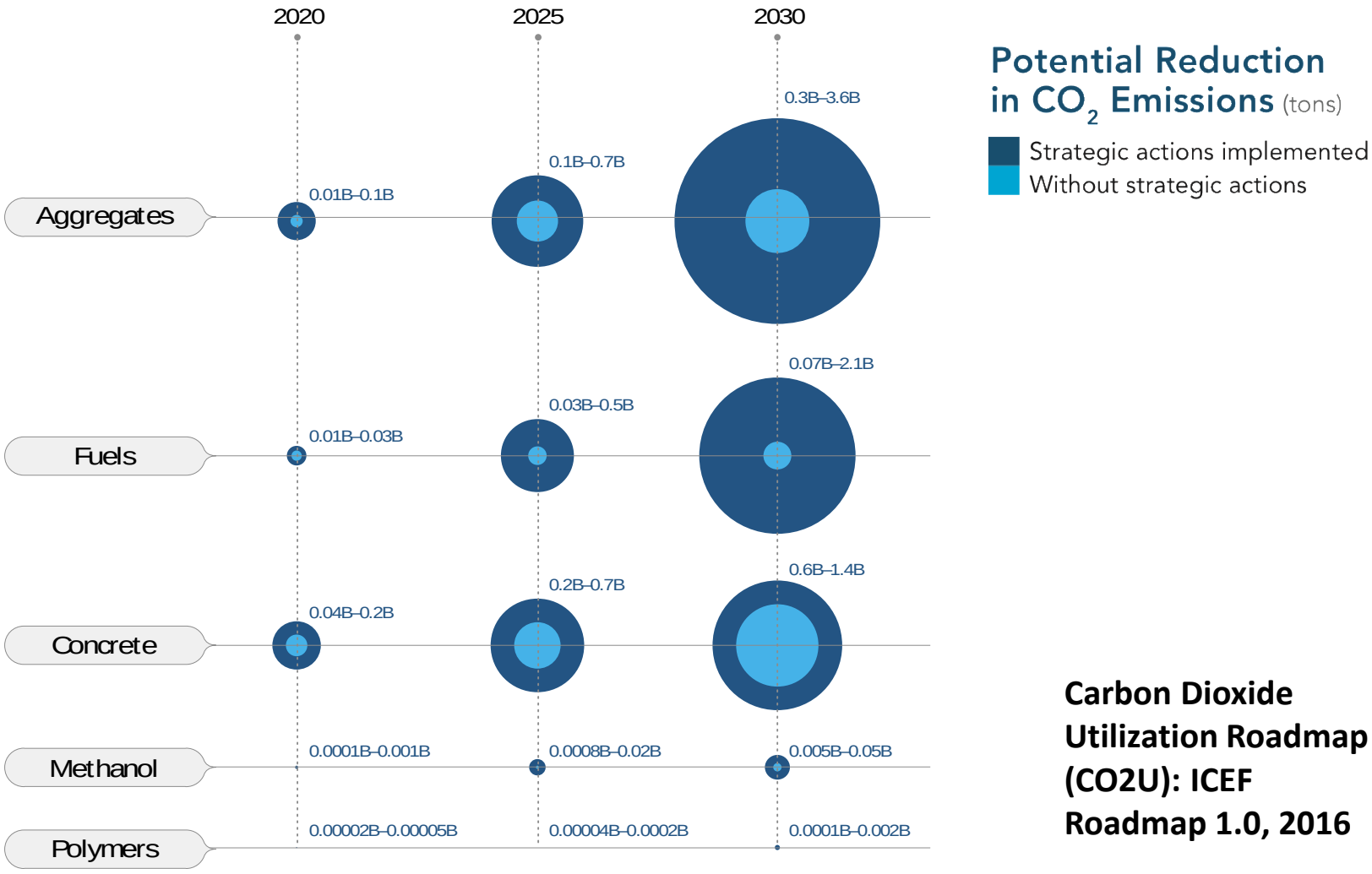
Enhanced Weathering

CHEMICAL

Center for Carbon Removal

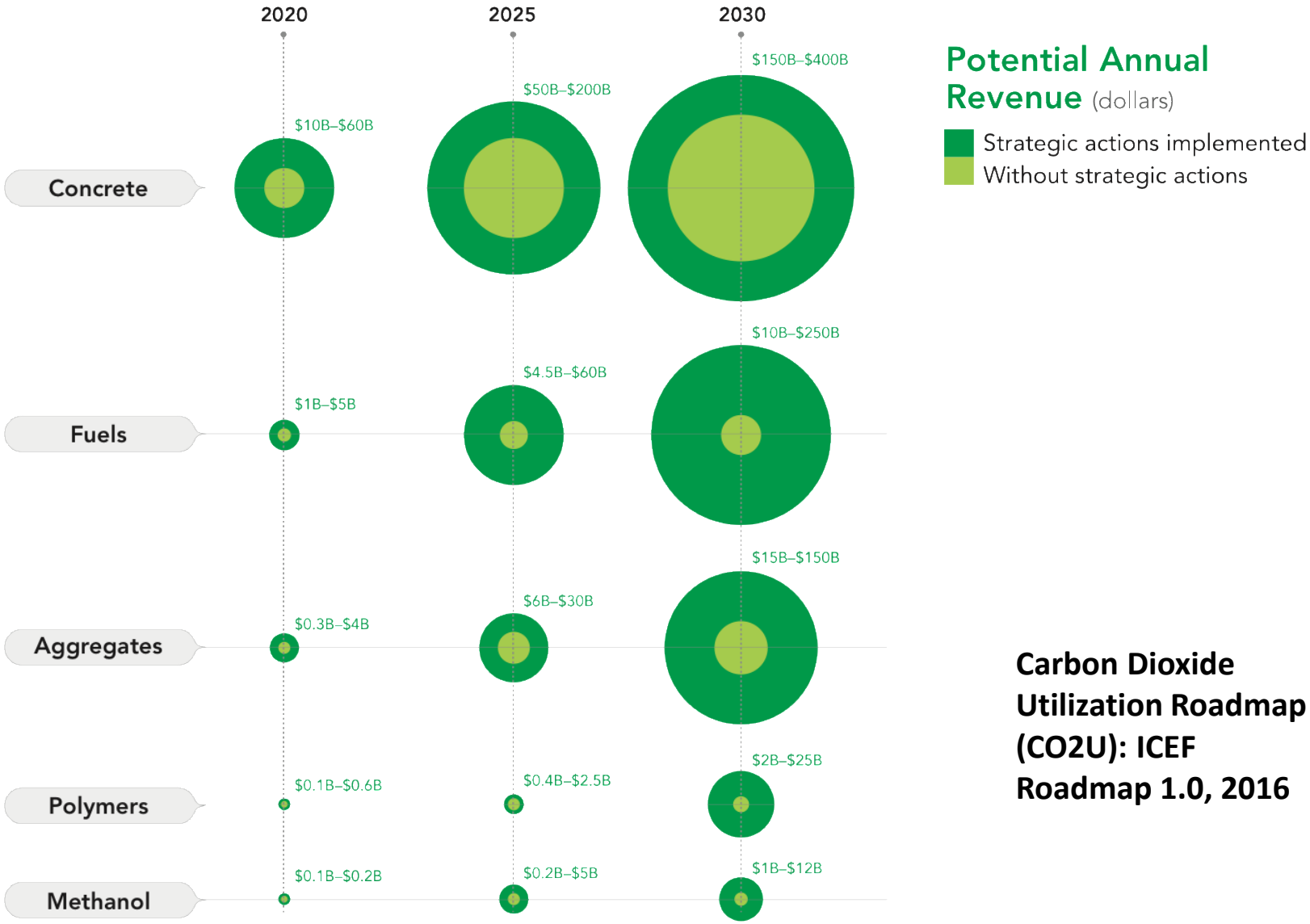
Engineered solutions provide an assured backstop for the climate

New C Economy: Thriving economy that consumes more than emits



Carbon Dioxide Utilization Roadmap (CO2U): ICEF Roadmap 1.0, 2016

New C Economy: Thriving economy that consumes more than emits



Carbon Dioxide Utilization Roadmap (CO2U): ICEF Roadmap 1.0, 2016

New Tech: Solidia & CarbonCure (both cement/concrete)

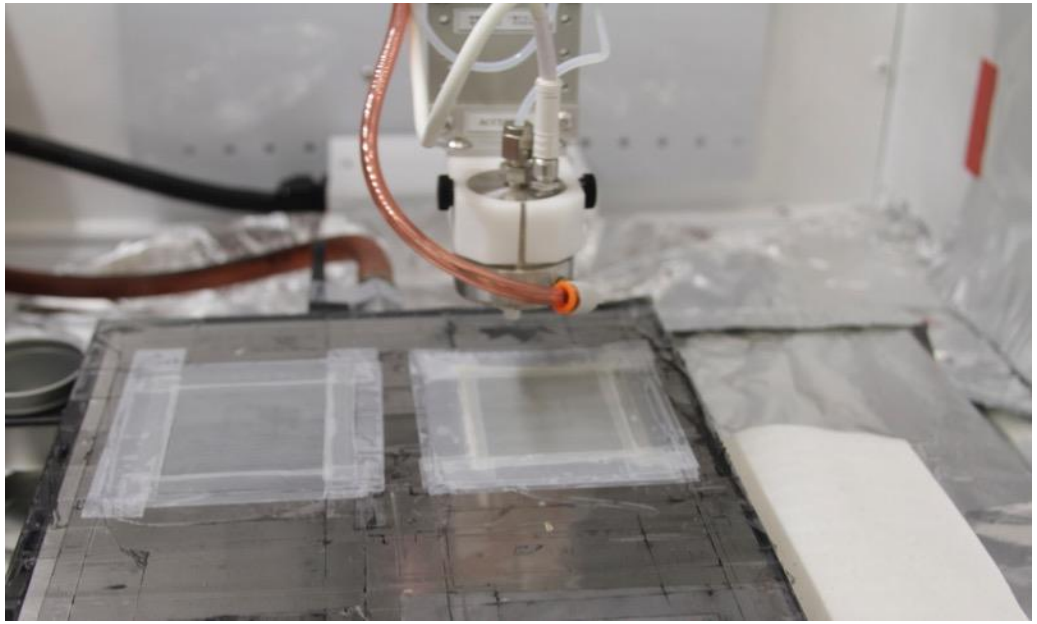
- Uses CO_2 to cure cement (15-30%)
- Higher quality products
- N^{th} plant: ~ market parity
- Within existing assets
- Large, active production

Solidia Technologies

- Uses CO_2 to cure cement (2-20%)
- Higher quality products
- N^{th} plant: ~ market parity
- Within existing assets
- NRG/Cosia XPrize finalist

CARBON CURE™

New Tech: Opus 12 & Greyrock (both CO_2-to-fuels)



- Electrocatalysis
- CO, methane, methanol as products
- N^{th} plant: unclear
- Modular production
- Great narrative

OPUS12

- Thermal (modified Fischer-Tropsche)
- Gasoline & diesel (high selectivity)
- N^{th} plant: unclear
- Modular production
- Operating plant

GREYROCK

New Tech: Monolith & Solid C Products (both durable C)

- Thermal + methane
- C black product
- N^{th} plant: near market parity
- Commercial project (Lincoln, NE)

MONOLITH

- Thermal catalysis
- C black + C nanotubes
- N^{th} plant: unclear
- Deep IP position
- Not yet commercial

SCP
SOLID CARBON PRODUCTS

The world's first commercial direct air capture plant: Zurich


Generation Engine: turning CO_2 to fuel: Carbon Engineering & Greyrock
Squamish, British Columbia

Bioenergy with CCS: Fuels fast; power hard

Creates energy (power & fuels)

Draws CO2 from air forever

- **Challenges with handling, drying, feed**
- **Challenges with scale-up, harvest radius**
- **Challenges with competition and value**
- **Challenges with life cycle, leakage…**


Asbestos mine wastes, Quebec
4 G tons ready for mineralization (100 M tons CO_2 likely)
83,000 tons/y CO_2 captured - ~300,000 tons avoided

Key Gaps to a New Carbon Economy

Markets where low-C and neg-C are valued

Life-Cycle Analysis systems: widespread & standardized

Carbon Registry: Accepted platform for validation C reductions & content

Tools for validation & verification (e.g., soil C methodologies and sensors)

Technical solutions and LESP (legal, economic, social, political) frameworks

- New materials, reactors, devices
- New organisms, practices, systems of accounting
- New disciplines, cases, jurisprudence, civil findings, communications networks…
- Human capital
  - People to create solutions and business
  - Institutions to train and support them

Policy aperture must expand

Incentives (carrots)

- Tax credits, feed-in tariffs, contract for differences, trading schemes, etc.
- Dramatic increase in RD&D (AEIC& PCAST recommend x4 increase)
- State-sponsored “strategic” projects (China’s 5-year plan)
- Broader clean financing mechanisms (CEPS vs. RPS; LCFS vs. RFS)
- Procurement authorities

Disincentives (sticks)

- Carbon tax (e.g., Norway)
- Regulatory caps (e.g., CPP, California’s SB 1368)
- Border adjustable carbon tariffs

No low-C MW left behind; More shots on goal

Today's carbon prices in policy

Carbon Taxes ($US/ton CO_2):

Sweden: $167 Switzerland (2020): $200 Norway: $80-85 (on industry)

Canada: $8, rising to $40 in 2022 (Alberta: $24; Manitoba: $20; BC: $10)

Carbon trading systems:

European Trading System: ~$10-12 (last year, ~$6-10). RGGI: $3-4 CA: $10-15

China Carbon Market: (Beijing: $6-7; Shanghai $4-6; Shenzhen, $4-6)

CA Low-carbon fuel standard:

Emissions standards (LCFS): $150 - 200

For Comparison (units in $/ton eq. for CO_2 reduction)

EV subsidy, CA: ~$1000

EnergieWende, GER: $300 Wind Prod. Tax Credit: $60-120

Est. current CA RPS system costs: $120-160

Projected CA RPS system costs (50%): $400-1200

New knowledge enterprise required

The New Carbon Economy Consortium

Key purpose: Create and sustain a new knowledge enterprise

- Need new technologies, new approaches, new disciplines
- Need new human capital and institutions
- Both technical and social science subjects central to success

Focused on "carbon to value" and carbon harvesting

- Soils, forests, blue carbon
- DAC, mineralization, CO2U, BECCS
- Social, political, economic R&D
- R&D infrastructure (testbeds, centers, datasets)

New R&D Innovation Plan in works (September)

- Calls for new R&D investments (fed., state, indust.)
- Explicitly suggests LESP & Technical work
- Requests major boost in human capital development
- Suggests new institutions & actors engage

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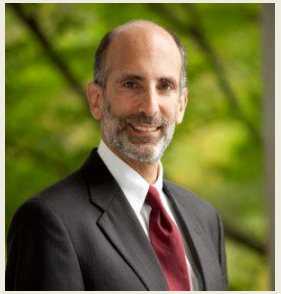
Panel Discussion and Q&A

Julie Ann Wrigley Global Institute of Sustainability
Arizona State University

Clark Miller
Clark.Miller@asu.edu



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