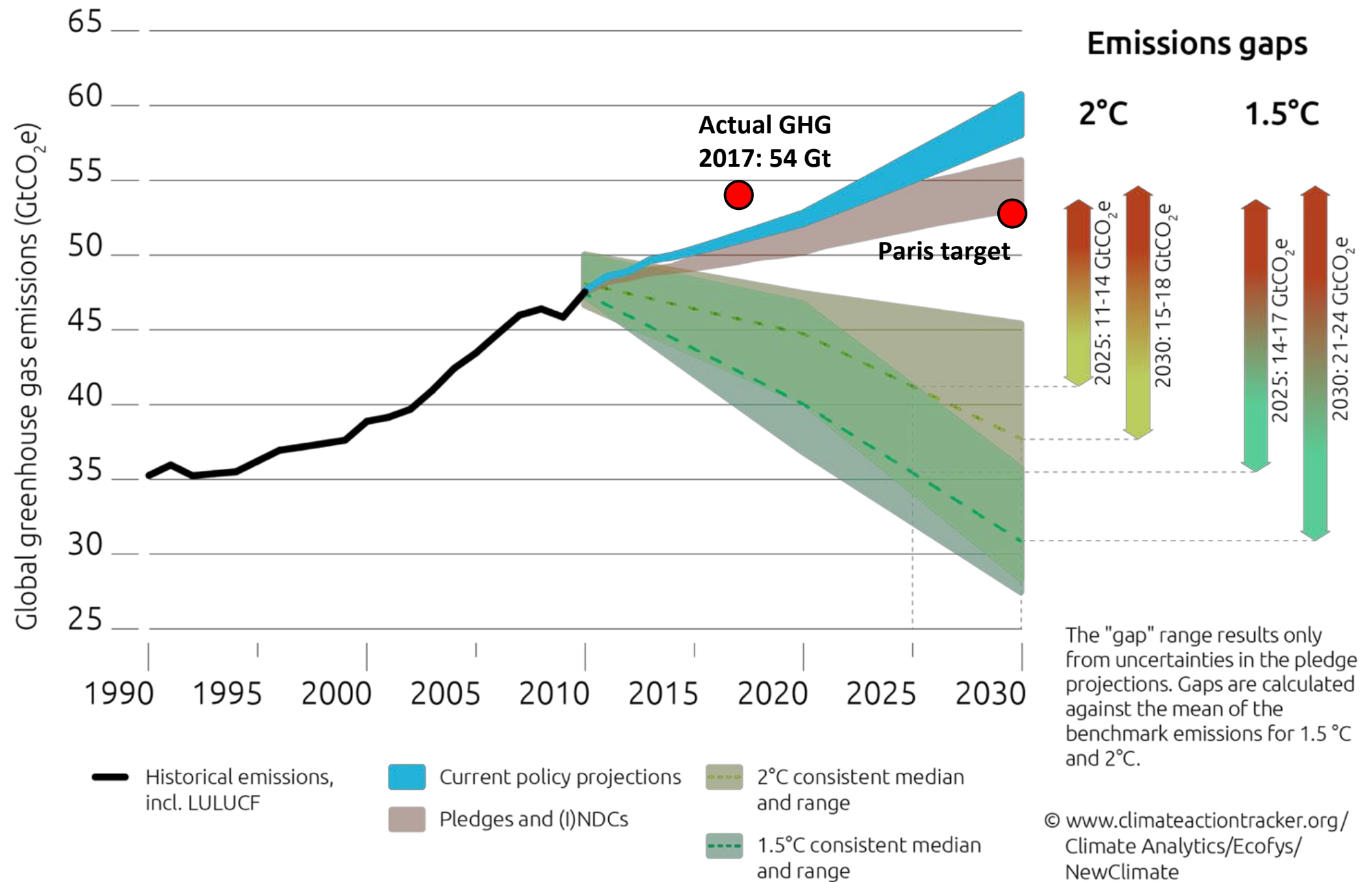


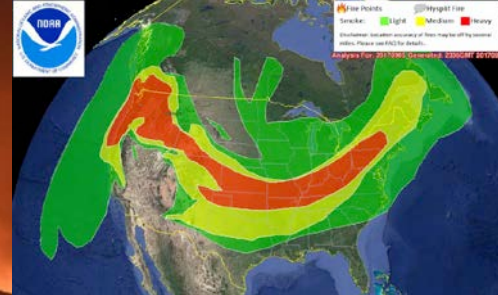
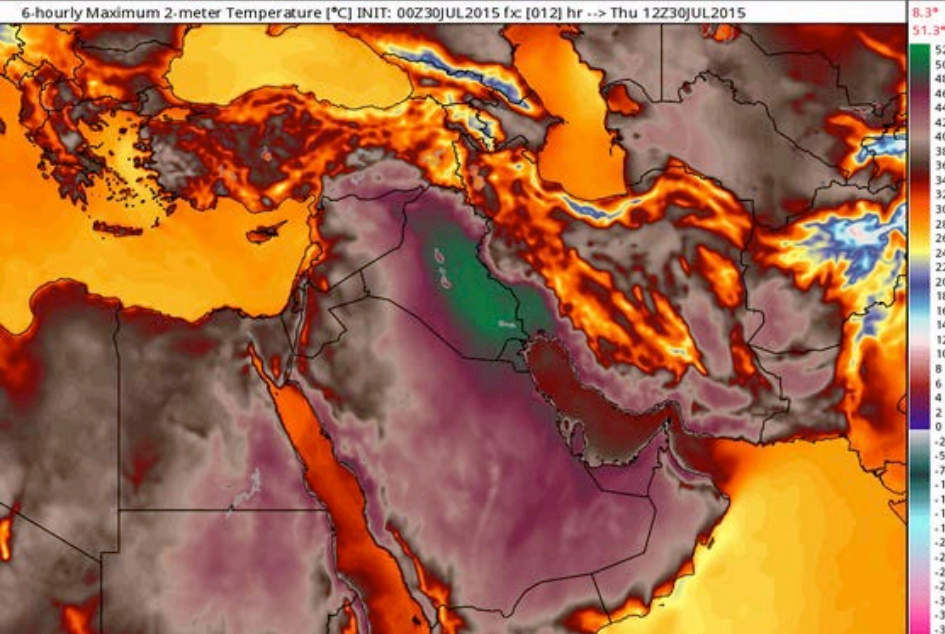


Carbon Capture and CO₂ Use Landscape: Technology, Companies, and Policy

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Ocean Acidification
Sea-level rise
Infection diseases
Biodiversity
Ecosystem stress
Desertification

Hockey-stick problems require hockey-stick engagement: We Need More



NATURAL

FORESTRY / AGRICULTURE



Afforestation/ Reforestation

Tree growth takes up CO₂ from the atmosphere



Biochar

Partly burnt biomass is added to soil absorbing additional CO₂



Soil Carbon Sequestration

Land management changes increase the soil carbon content, resulting in a net removal of CO₂ from the atmosphere



Other Land-Use/ Wetlands

Restoration or construction of high carbon density, anaerobic ecosystems

COMBINED

NATURAL + TECHNOLOGICAL



Bioenergy with Carbon Capture and Storage (BECCS)

Plants turn CO₂ into biomass that fuels energy systems; CO₂ from conversion is stored underground

TECHNOLOGICAL

ENERGY / INDUSTRY



Accelerated Weathering

Natural minerals react with CO₂ and bind them in new minerals



Direct Air Capture

CO₂ is removed from ambient air and stored underground



Ocean Alkalinity Enhancement

Alkaline materials are added to the ocean to enhance atmospheric drawdown and negate acidification



CO₂ to Durable Carbon

CO₂ is removed from the atmosphere and bound in long-lived materials

- Less costly
- Closer to deployment
- More vulnerable to reversal

- More costly ←
- Greater R&D needs ←
- Less vulnerable to reversal ←

Key Companies and Projects: Carbon Removal/Direct Air Capture

Climeworks



- Sorbent-based
- Modular design (50 t/y)
- Operating commercial projects in Zurich and Iceland

Carbon Engineering



- Solvent-based
- All units have catalog numbers + innovation inside the boxes
- Operating CO2-to-fuel project

Global Thermostat



- Sorbent-based tech
- Claim v. low heat of recovery, low opex
- Pilot plant in Palo Alto (SRI)
- Strong partners
- Not operating

Most companies 20-30 employees, looking for first project

Restoration Engine: turning CO₂ to stone: Climeworks + CarbFix
Hellisheidi Power Station, Reykjavik



Production Engine: turning CO₂ to fuel: Carbon Engineering+ Greyrock
Squamish, British Columbia



Market options to support C Removal with DAC

Negative Emissions Services (RE-1)

- Can be block-chain enabled (Nori)
- Limited market today (function of price)

Conversion to durable carbon

- Cement/aggregate
- C Fiber & composites
- Plastics

Conversion to recycled carbon (PE-1)

- Feedstocks
- Fuels



***The costs, price, and value of these market options
Are unknown and largely unexplored***



Policy options to support C Removal with DAC

Tax provisions

- FUTURE Act
- Tax breaks for "Insets"

Procurement Authorities

- Outright purchases (cities, govts.)
- Low-C materials made with DAC

Standards

- Low-carbon fuel standard (revision)

Granting programs

- Small DOE program; UK Govt. (BIES)
- Loan program office

Regulatory

- NEPA review changes
- New source review clarity

***Deployment requires policy to set the market
(just like with other cleantech)***

Emerging potential projects & opportunities (California specials)

Buy California Act (starts January 2019)

- State procurements preference for low-C materials
- Steel, rebar, cement, mineral wood board insulation
- Based on LCA

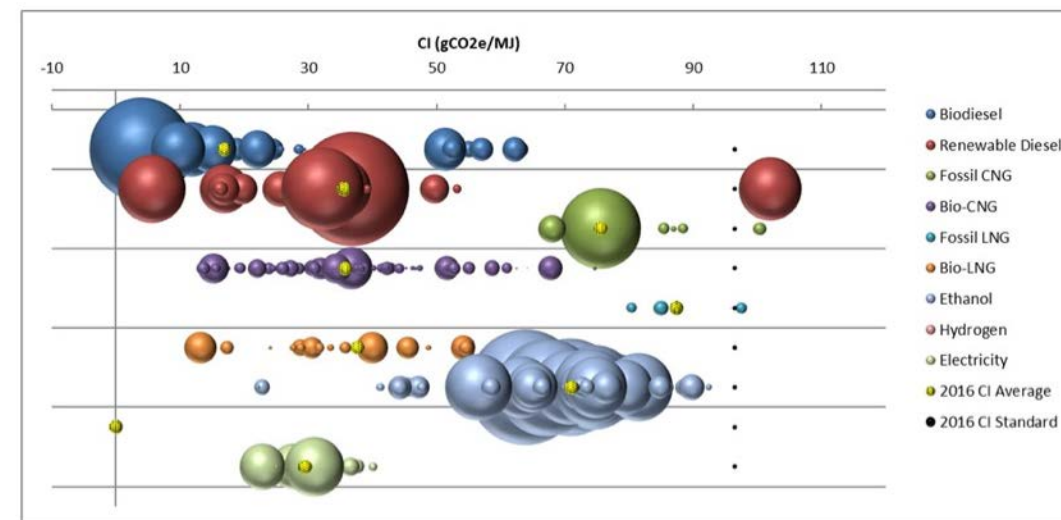
Low-C Fuel Standard update (starts January 2019)

- Innovative fuels
- Updated standards & protocols in progress
- Current trading over \$100/ton CO₂

Ports (California and Washington)

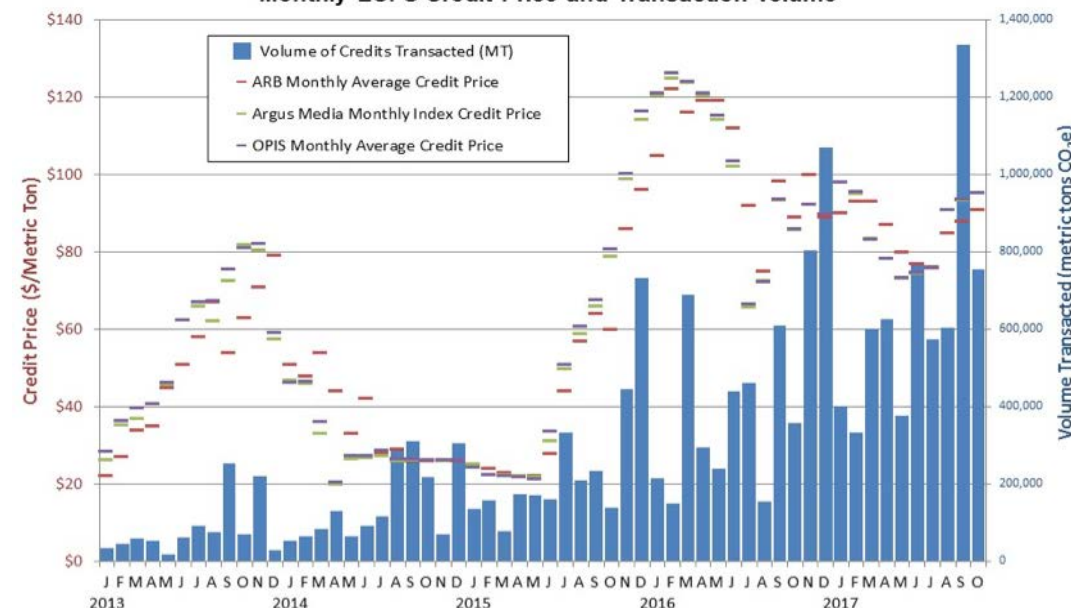
- Strong drivers to reduce C and pollution
- For boats, ferries, and port vehicles
- Opportunities for sales of fuels (diesel, methanol, CH₄)

2016 Volume-weighted Average Carbon Intensity by Fuel Type



Last Updated 08/02/2017

Monthly LCFS Credit Price and Transaction Volume



Last Updated 11/15/2017