# Carbon capture, use and storage in the power sector

## *C is the New Black*


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2°C scenario

1.5°C scenario

$CO_2$ emissions [tons/sec]

1'268

time since $CO_2$ budget exhausted

| year | month | day | hour | min | sec |
|---|---|---|---|---|---|
| 0 | 0 | 2 | 19 | 6 | 31 | 54 |

$CO_2$ budget left [tons]

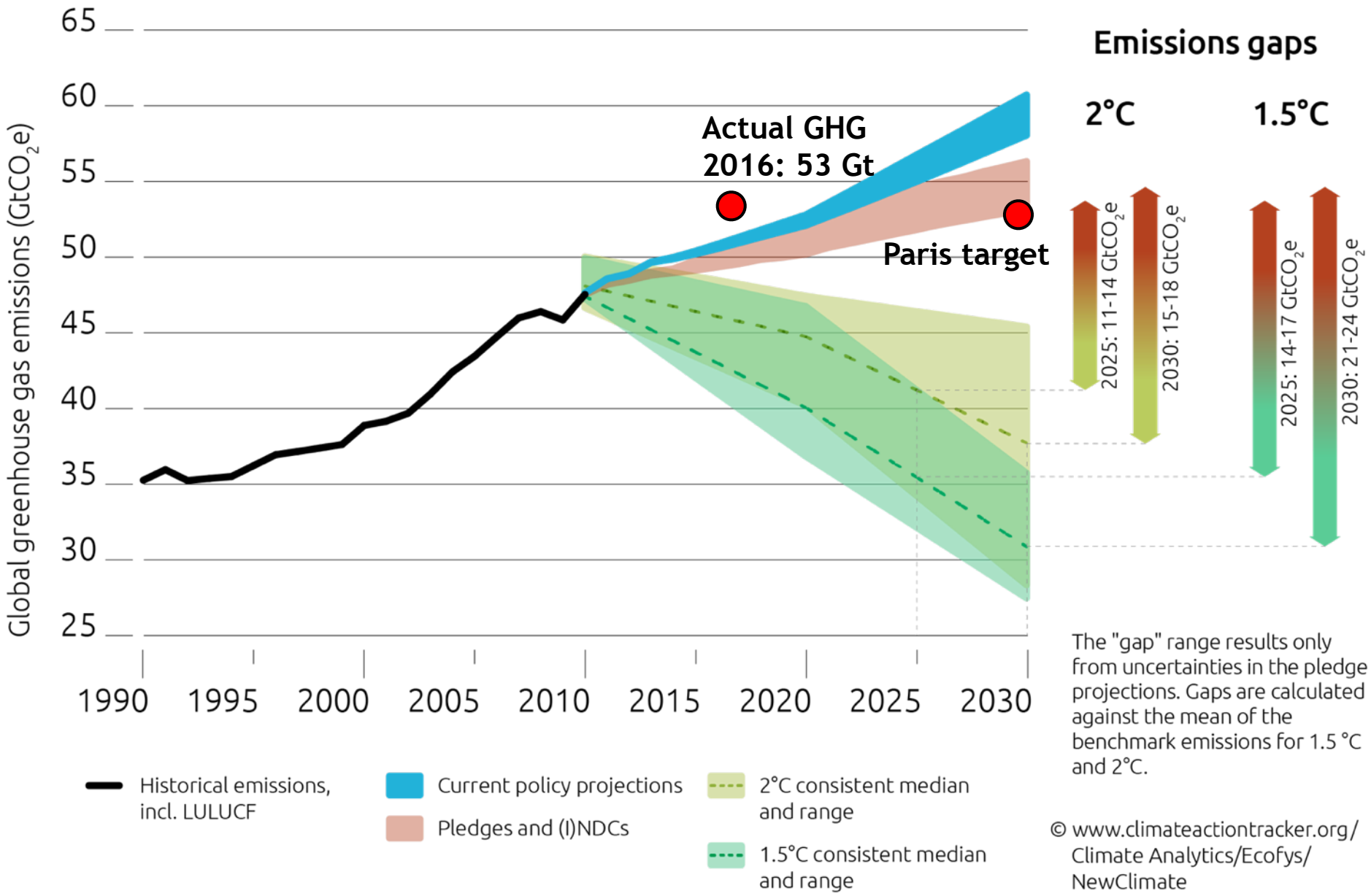
exhausted by: 306'146'222

upper estimate

medium estimate

lower estimate

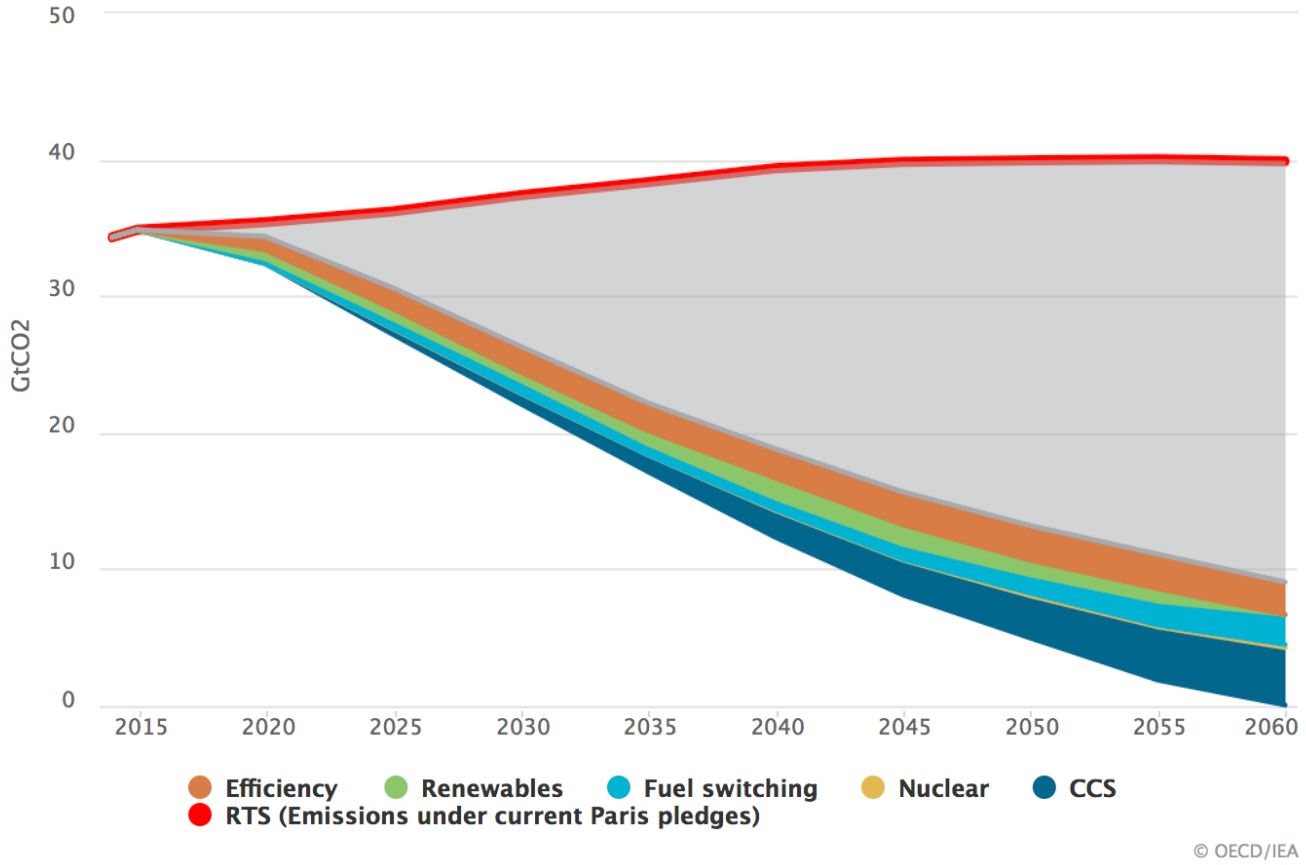
MCC




The "gap" range results only from uncertainties in the pledge projections. Gaps are calculated against the mean of the benchmark emissions for 1.5 °C and 2°C.

# Large-Scale C Management Required

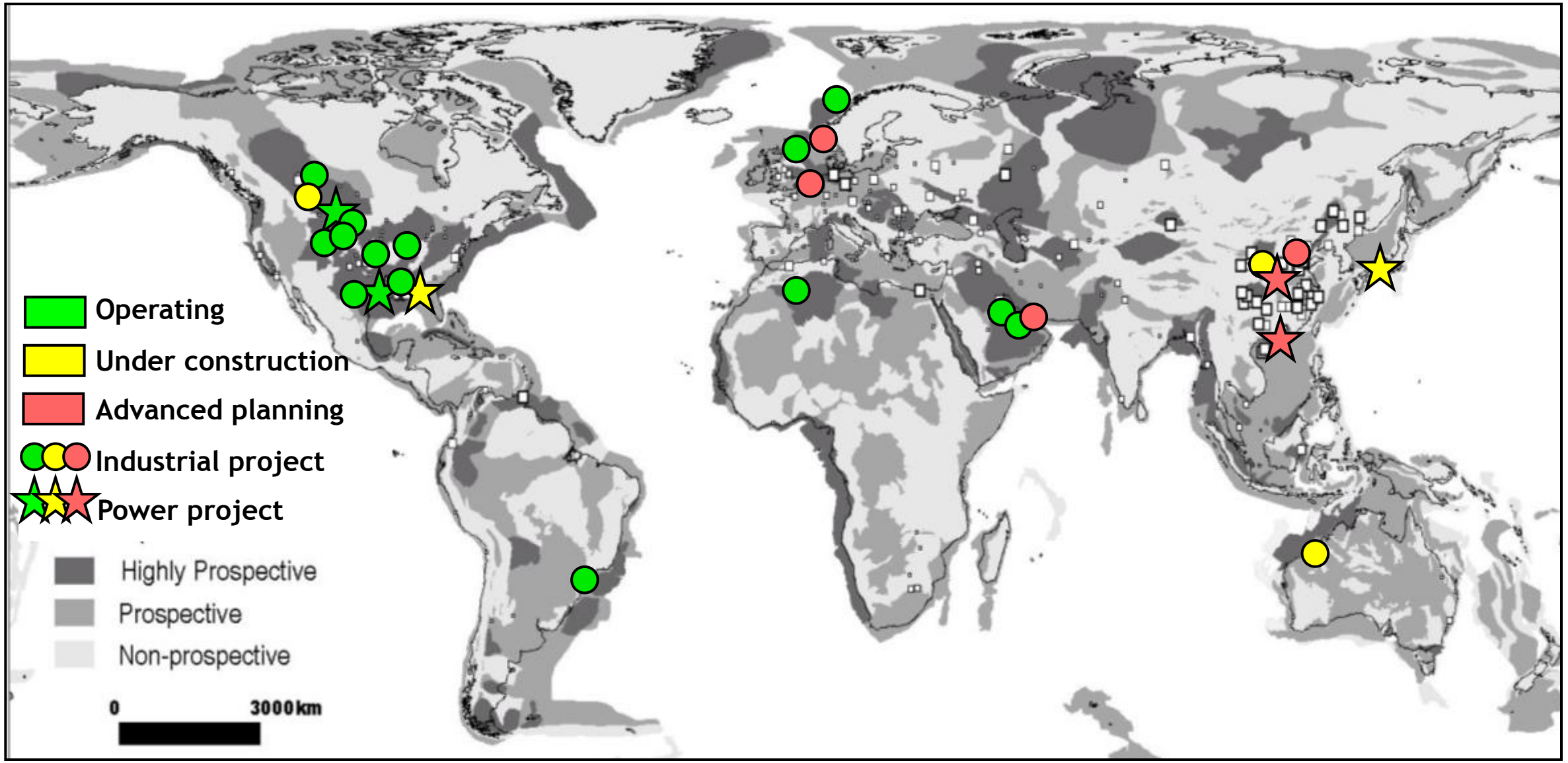
**There are very few pathways to 2°C or <2°C without large-scale C management**




**7 of 11 IPCC models require CCS for 2°C**

- **~14% of solution**
- **33% of next increment for 1.5 °C**

***A key component to deep decarbonization***

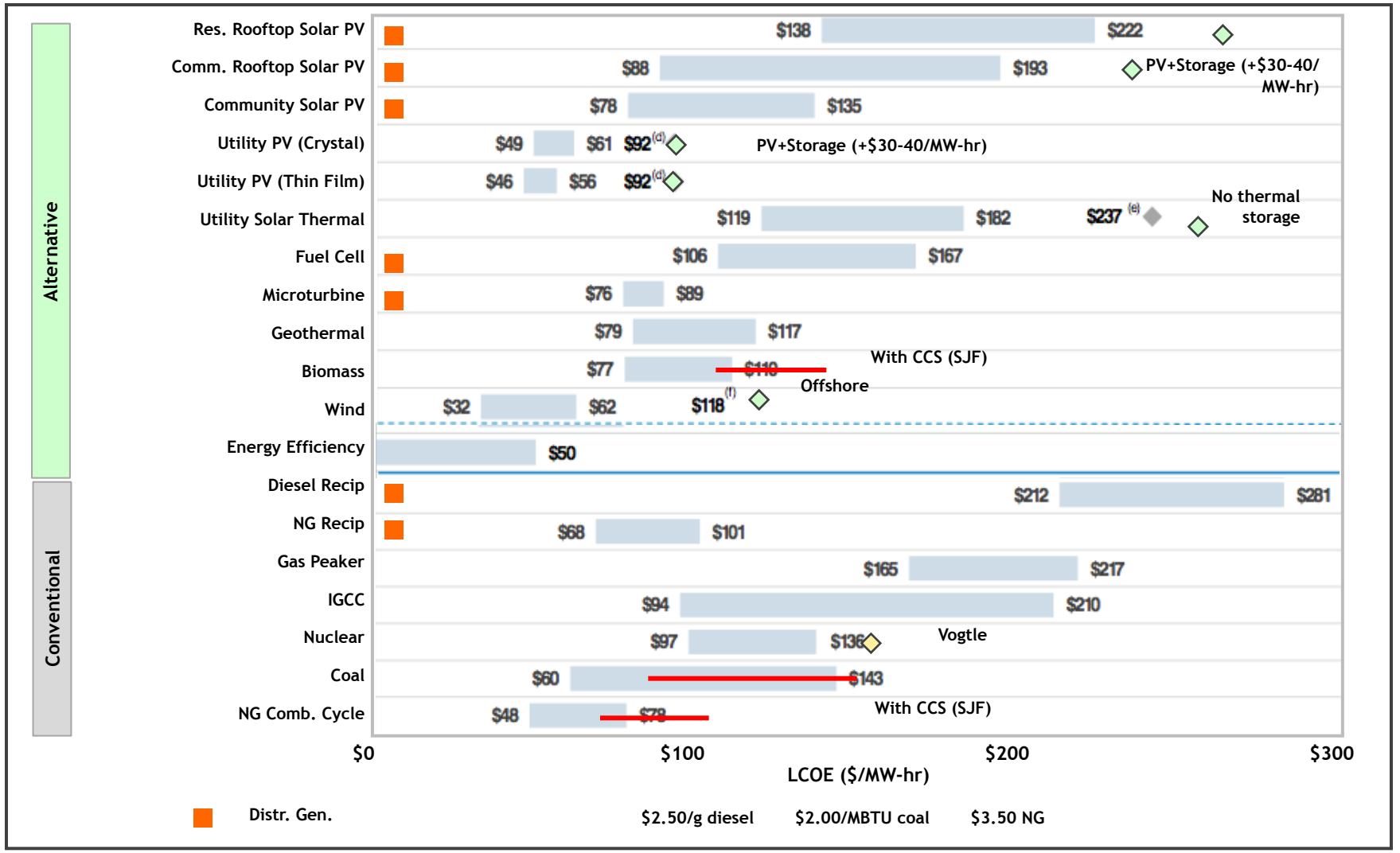



*17 operating plants, storing >22 Mtons CO2 each year*


**Fully operational Jan 2017. 1.4M tons/year, 90% capture**
**$100/ton $CO_2$ costs; next plant 30% less**

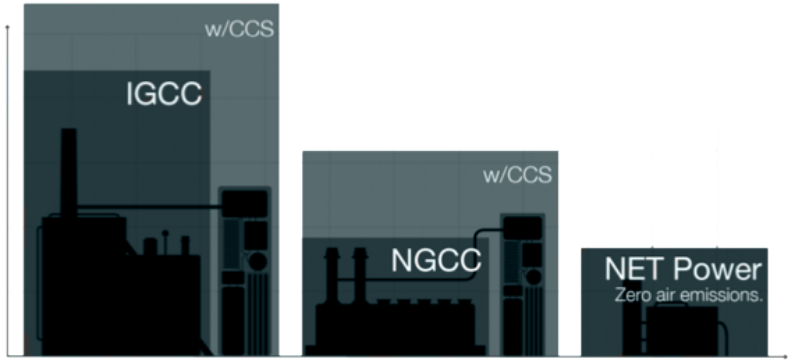

Shell Quest Project
Scottsford Upgrader, Alberta
Fully operational Sept. 2015
Over 2 Million tons/y into saline formations

# The market today (Unsubsidized LCOE – Lazard 2016)

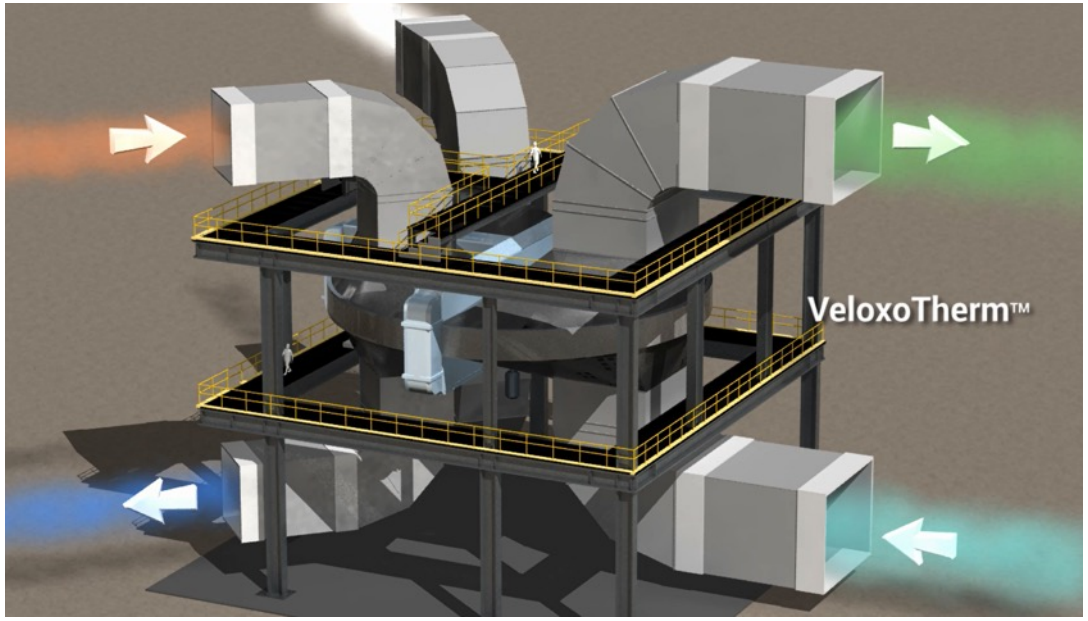


# New Tech: NetPower

- 100% $CO_2$ stream, at pressure
- Produces water
- $N^{th}$ plant: ~price parity to NGCC
- Can ramp up & down
- Addl. potential revenues



# New Tech: Inventys & Fuel Cell Energy (both NG focus)




- Solid sorbent + 3D printing
- Very low capital costs
- N$^{th}$ plant: ~$30/t $CO_2$
- Modular design
- New CEO

inventys

- Molten carbonate "afterburner"
- Produces extra power
- N$^{th}$ plant: unclear
- High efficiency, modular design
- Partnership with ExxonMobil & Southern Co.

FuelCell Energy
Ultra-Clean, Efficient, Reliable Power

# Policy aperture must expand

**Incentives (carrots)**

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

**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***

***We need more***

# FUTURE Act is now law (45Q tax credit reform)

Senate: FUTURE ACT (Heitkamp, Capito, Whitehouse, Barrasso) 25 sponsors
House: Carbon Capture Act (Conaway) 44 sponsors

- UNCAPPED
- $50/ton $CO_2$ for storage; $35/ton $CO_2$ for EOR & CO2U; $35 for direct air capture
- Non-refundable tax credit, transferable along chain of custody
- Projects qualify at 500,000 tons/y (power) or 100,000 tons/y (industrial)storage & EOR
- CO2U projects qualify at >25,000 tons $CO_2$/y
- Monitoring required to receive credit
- Active for 12 years for any project initiated within 7 years of enactment (+ inflation adjusted)

***New opportunities for projects and financing***

***Well assessed sites will allow rapid project development***

# FUTURE Act is now law (45Q tax credit reform)

| Type of CO2 Storage/Use | Minimum Size of Eligible Carbon Capture Plant by Type ($ktCO_2/yr$) | | | Relevant Level of Tax Credit in a Given Operational Year | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Power Plant | Other Industrial Facility | Direct Air Capture | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | Beyond 2026 |
| Dedicated Geological Storage | 500 | 100 | 100 | 28 | 31 | 34 | 36 | 39 | 42 | 45 | 47 | 50 | Indexed to Inflation |
| Storage via EOR | 500 | 100 | 100 | 17 | 19 | 22 | 24 | 26 | 28 | 31 | 33 | 35 | |
| Other Utilization Processes[1] | 25 | 25 | 25 | 17[2] | 19 | 22 | 24 | 26 | 28 | 31 | 33 | 35 | |

[1] Each $CO_2$ source cannot be greater than 500 ktCO2/yr

[2] Any credit will only apply to the portion of the converted CO2 that can be shown to reduce overall emissions

ENERGY FUTURES INITIATIVE

Source: Simon Bennett and Tristan Stanley, Commentary: US budget bill may help carbon capture get back on track, International Energy Agency.

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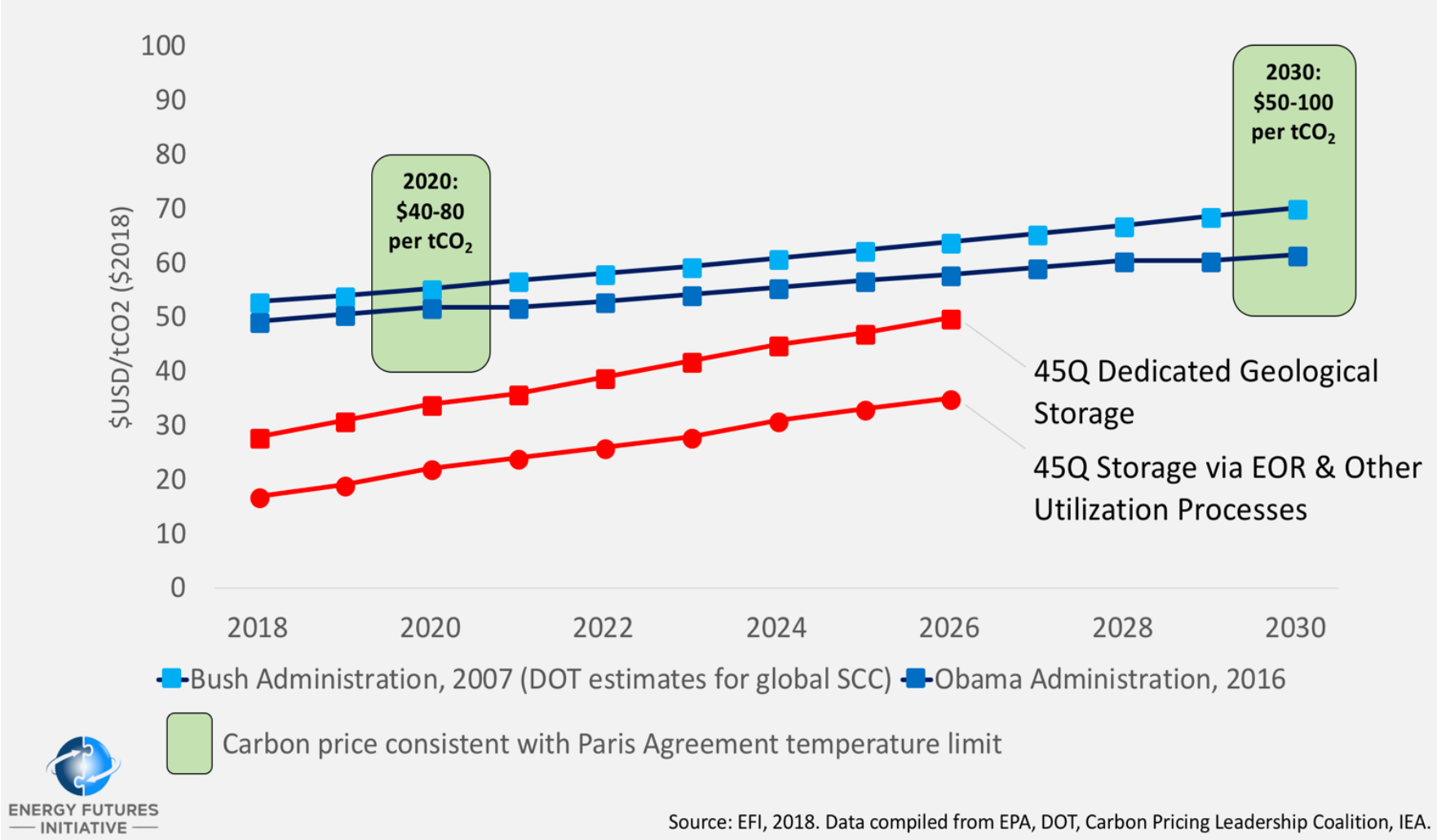


# Federal R&D Programs: Unprecedented funding

**Office of Fossil Energy: $727M total**
Clean Coal and Carbon Management

Maintains carbon capture and advanced cycle programs

Maintains carbon storage, including CarbonSAFE assessments

Maitains CO2 Utilization, possibly expands

**Office of Energy Efficiency and Renewable Energy: $2.3B**

Bioenergy Technology Office (BETO)

- CO2 to products program (including algae and biochemicals)
- Engineered Carbon Reduction Report (Rewiring C Economy)

**DOE Loan program Office**

# Federal R&D Programs: Unprecedented funding

| | FY17 Enacted | DOE FY18 Request | FY18 Omn3ibus | FY18 change from FY17 | FY18 change from FY17 |
|---|---|---|---|---|---|
| **Office of Science** | $5,392,000 | $4,472,516 | **$6,259,903** | $867,903 | 16% |
| **ARPA-E** | $306,000 | $20,000 | **$353,314** | $47,314 | 15% |
| **EERE** | $2,090,200 | $636,149 | **$2,321,778** | $231,578 | 11% |
| **OE** | $230,000 | $120,000 | **$248,329** | $18,329 | 8% |
| **Office of Nuclear Energy** | $1,016,616 | $703,000 | **$1,205,056** | $188,440 | 19% |
| **Fossil Energy R&D** | $668,000 | $280,000 | **$726,817** | $58,817 | 9% |
| **TitleXVII** | $7,000 | $- | **$23,000** | $16,000 | 229% |
| **ATVM** | $5,000 | $- | **$5,000** | $- | 0% |
| | $9,714,816 | $6,231,665 | **$11,143,197** | $1,428,381 | 15% |

# CA SB100: 100% Clean Energy Portfolio Standard by 2045

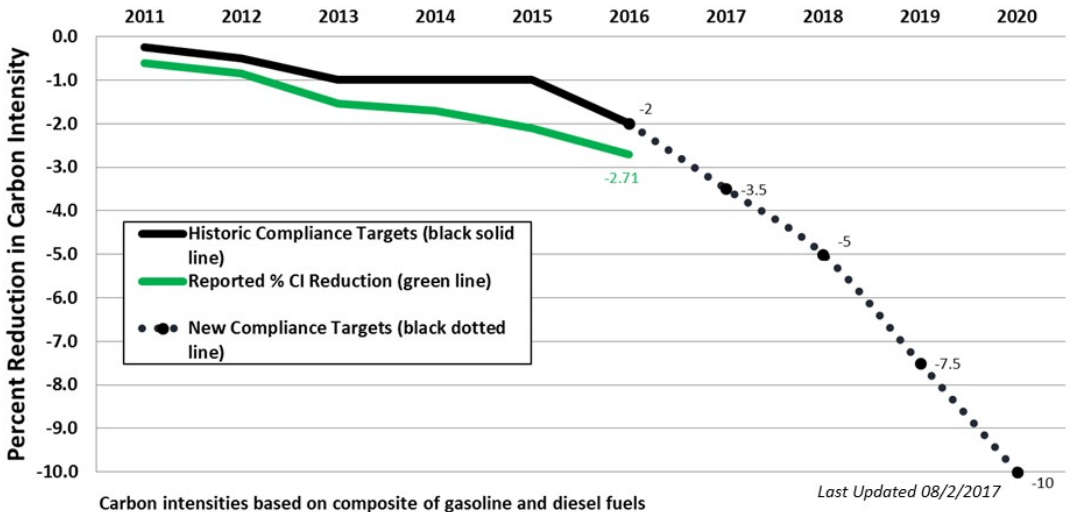
***EO B-55-18: 100% decarbonized by 2045, net r***

# CA Low-C fuels standard & Buy Clean CA

LCFS Price: $100-140/ton $CO_2$ now, WILL rise

- EOR in oilfields (CA or outside CA)
- Hydrogen & Biofuels (incl. biogas)
- Novel fuels (e.g., synthetic from $CO_2$) through 3-month data-based process
- Direct Air Capture (anywhere)

***Draft CCS protocol released March; ARB meeting Apr.***




Buy Clean CA Act (Nov. 2017)

- Today: steel, rebar, glass, fiberboard
- Amendment options: Cement, fuels, plastics, C fiber
- Washington, Oregon, Idaho considering

***Active lobbying in the CA legislature***

# 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): $100-120

**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

# The world's first commercial direct air capture plant Does the $CO_2$ work of 36,000 trees

**Restoration Engine:** turning $CO_2$ to stone: Climeworks + CarbFix
Hellisheidi Power Station, Reykjavik