GE
Energy

Carbon Capture and Sequestration Abilities of IGCC Technology

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The Generation Planner's Dilemma

Legislative & Regulatory Uncertainty

Public Utility Commissions *"Give me the lowest cost"*

Political & Enviro *"Give me Carbon Capture Now"*

Escalating plant costs

Carbon credit prices and incentives

Technology Readiness

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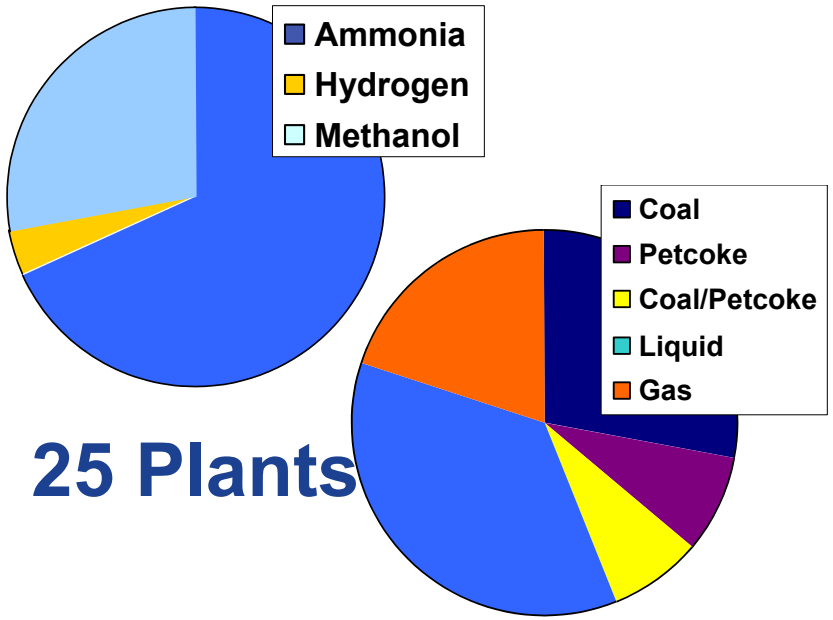
IGCC Key Systems Proven for CCS

Process Block

Shift+Capture Experience

- Ammonia Plant
- Methanol Process
- Refinery Hydrogen



25 Plants

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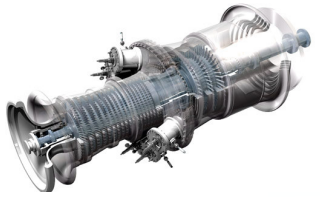
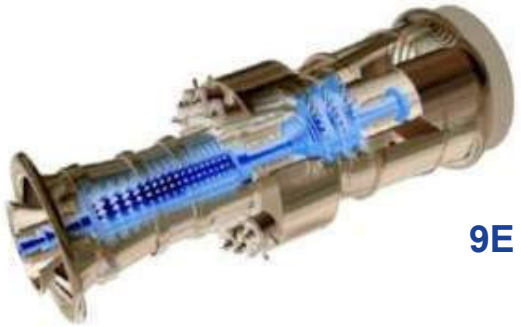
Hydrogen Turbines

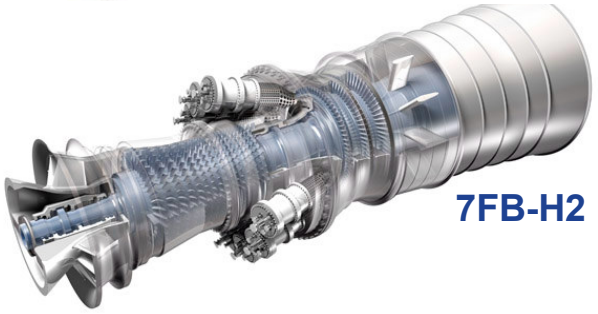


6B

7EA



9E



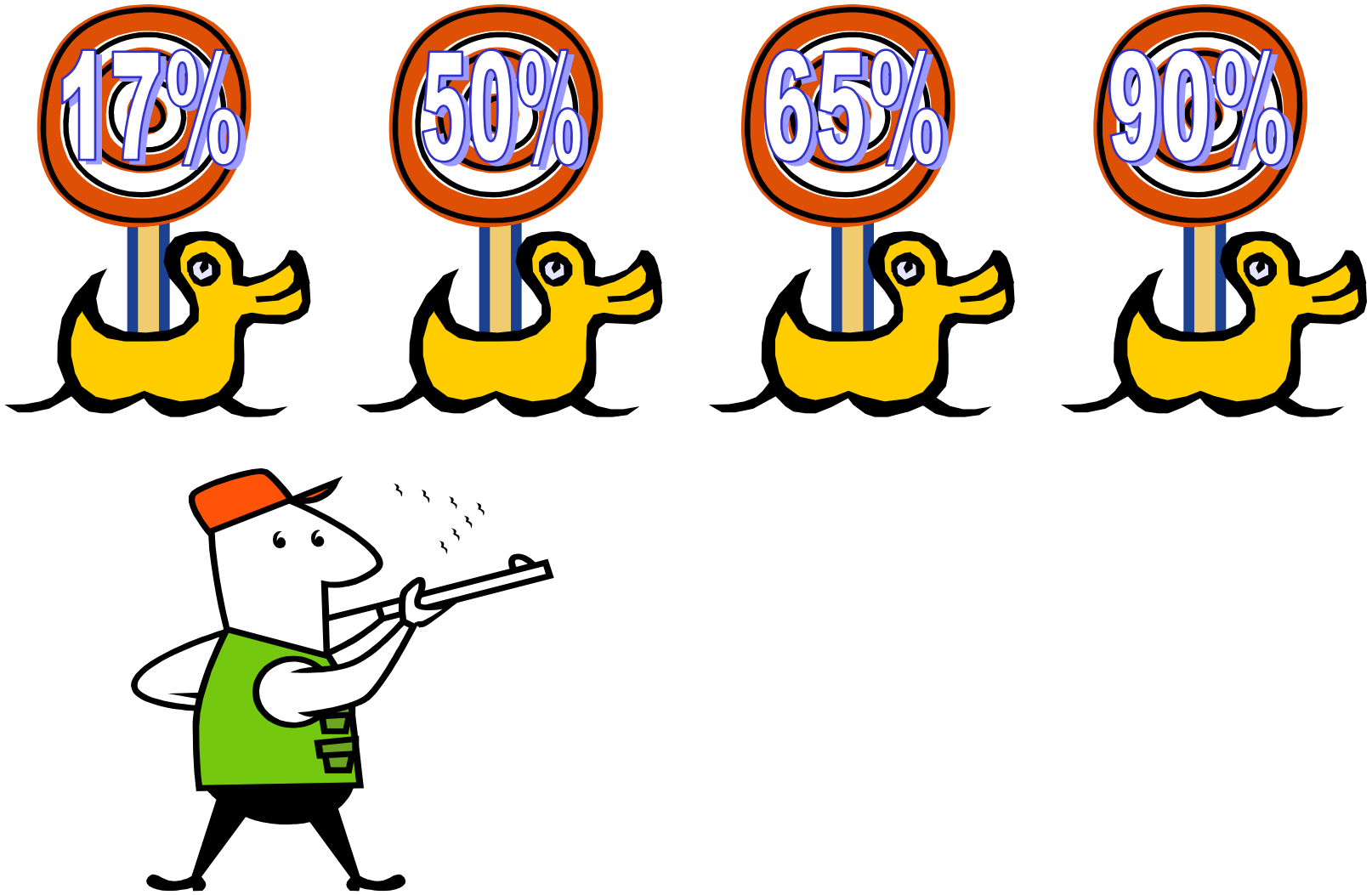
7FB-H2

Reference Plant Carbon Capture-Ready Features

- AGR system already captures CO_2 for recycle
  - Expandable for future
- Design pressure suitable for CO_2 capture
- Slurry fed – reduced pre-shift steam requirement
- Does not require 7FB HGP modifications
- Plot space for AGR expansion, shift unit/s, CO_2 compression
- GE design allows for retrofit of carbon capture equipment
- No new technology "invention" necessary
- Requires life-of-plant storage options and strategy

Reference Plant Capture Plant Plot Space

What Capture Level to Target



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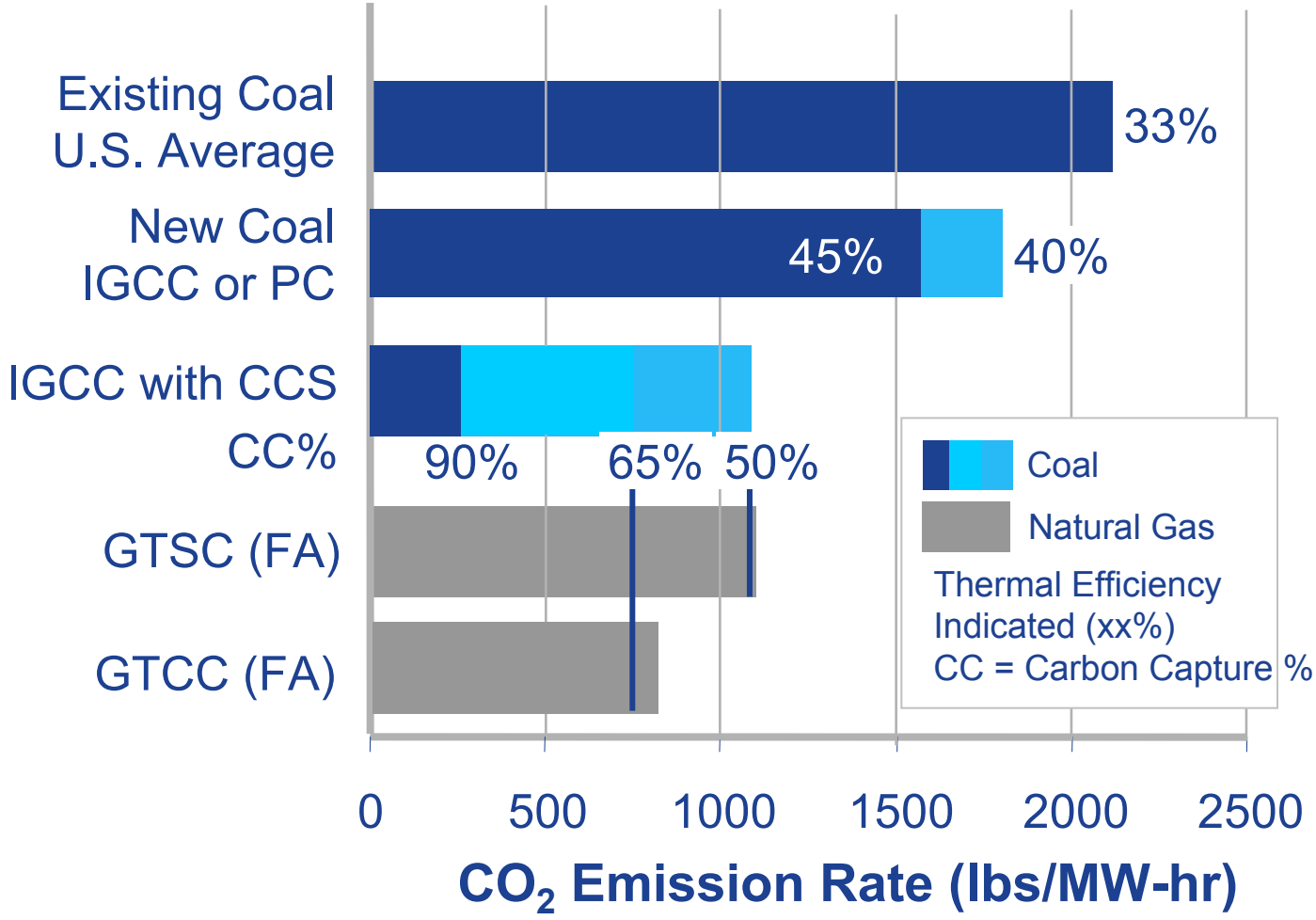
Carbon Footprints of Fossil Power



References: DOE NETL; EIA; IEA and GE Internal Data

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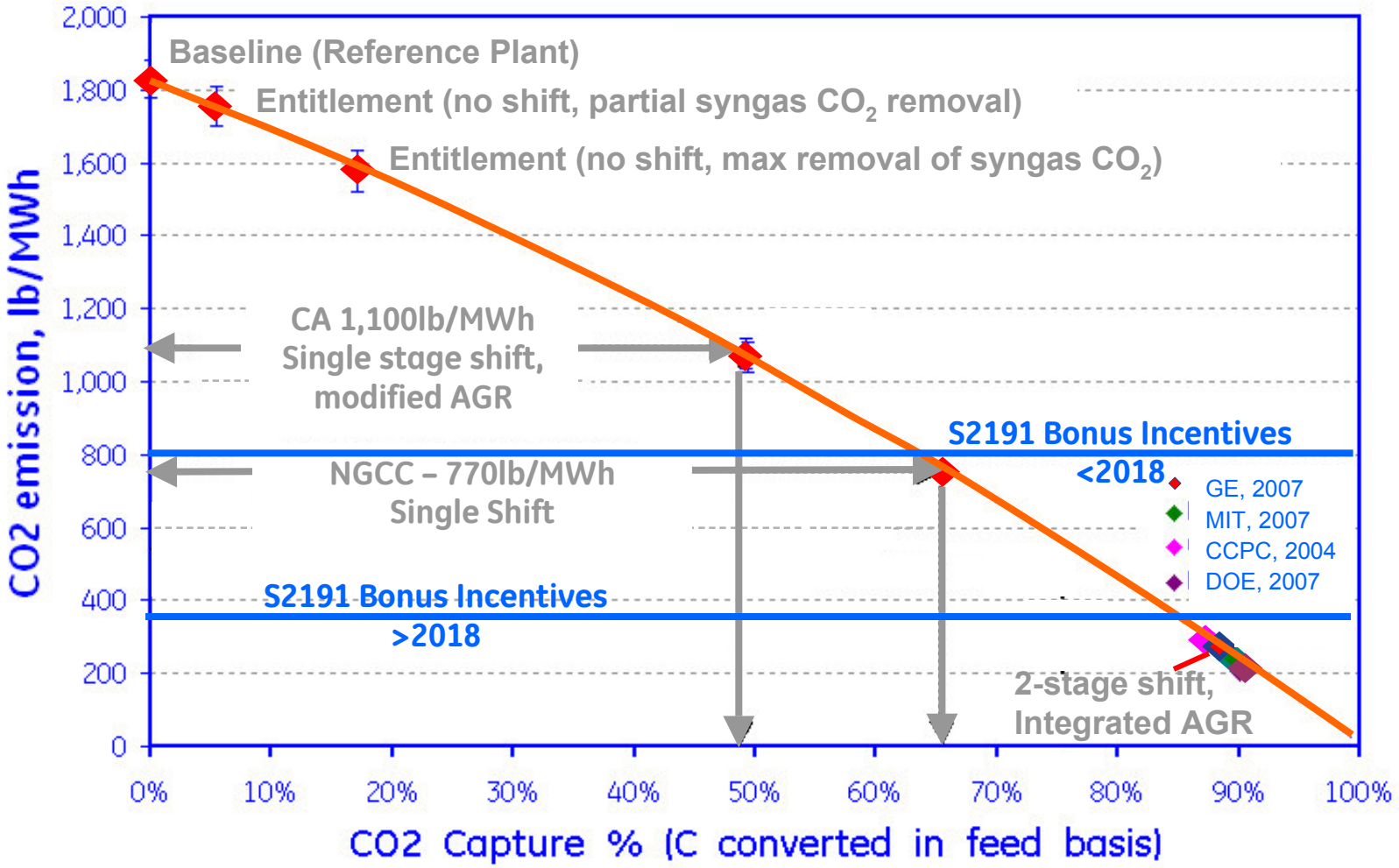
Criteria for Carbon Capture Levels



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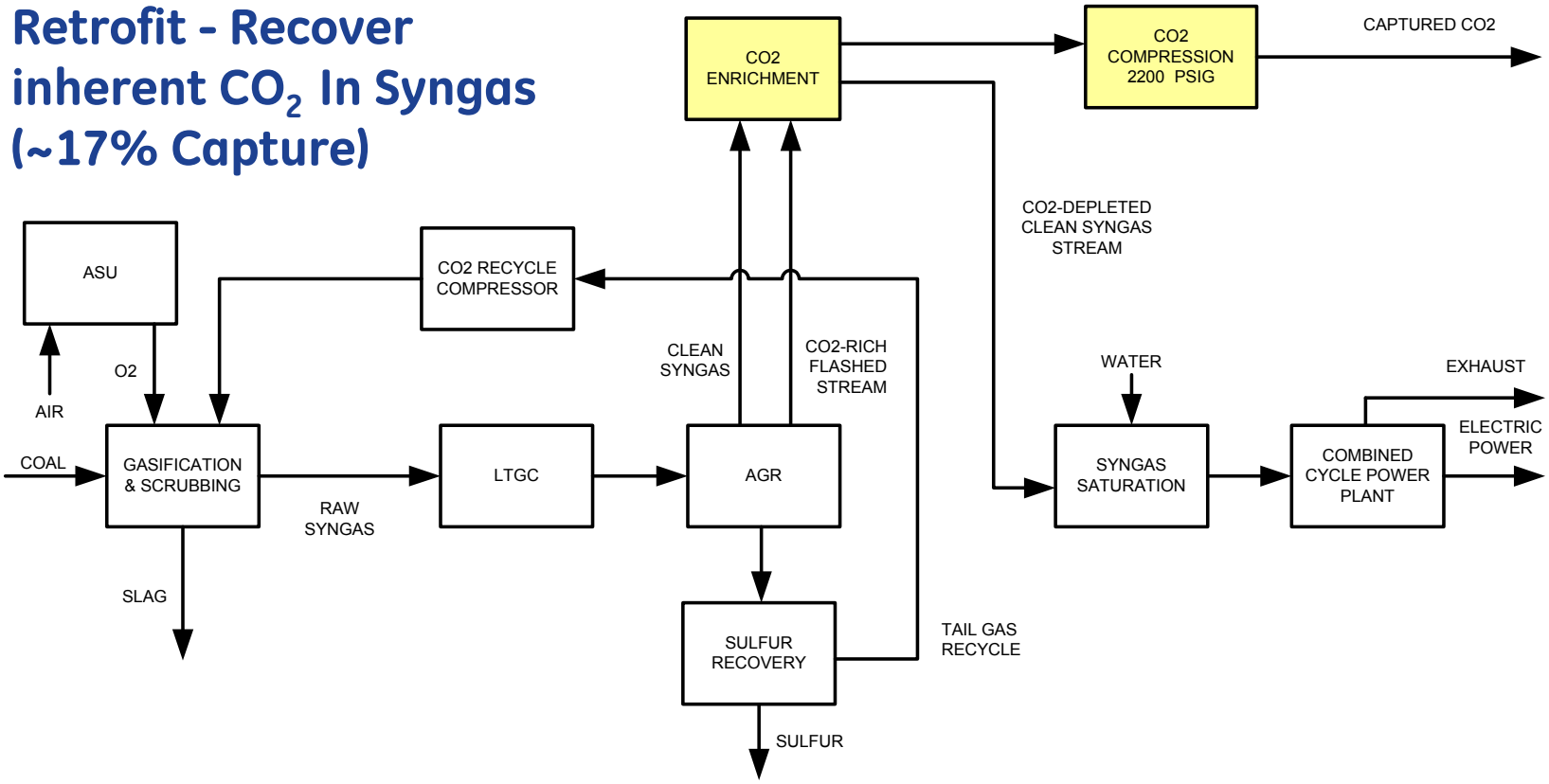
Configuration – Entitlement w/o Shift

Retrofit - Recover inherent CO_2 In Syngas (~17% Capture)



New or Modified

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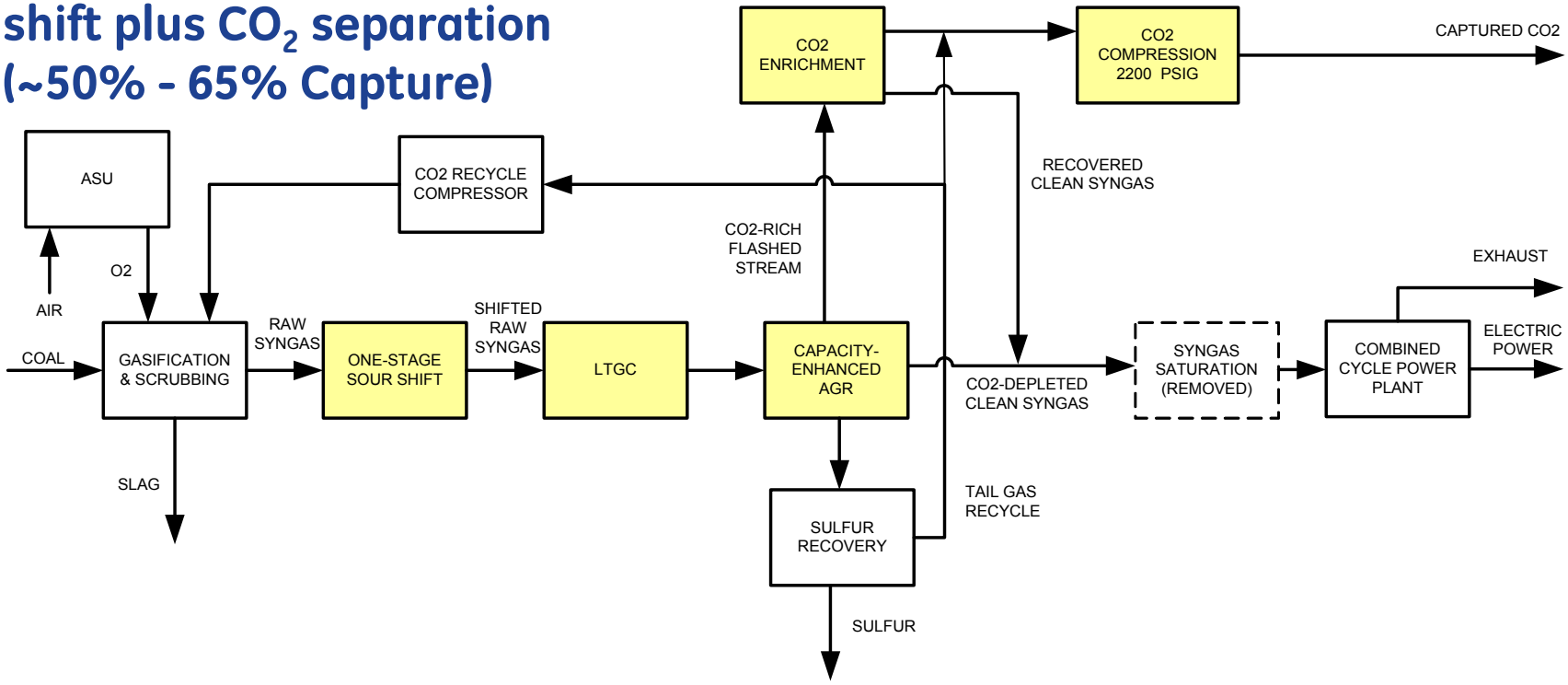
Configurations– Retrofit to NG Equivalent

Retrofit One-stage sour shift plus CO_2 separation (~50% - 65% Capture)



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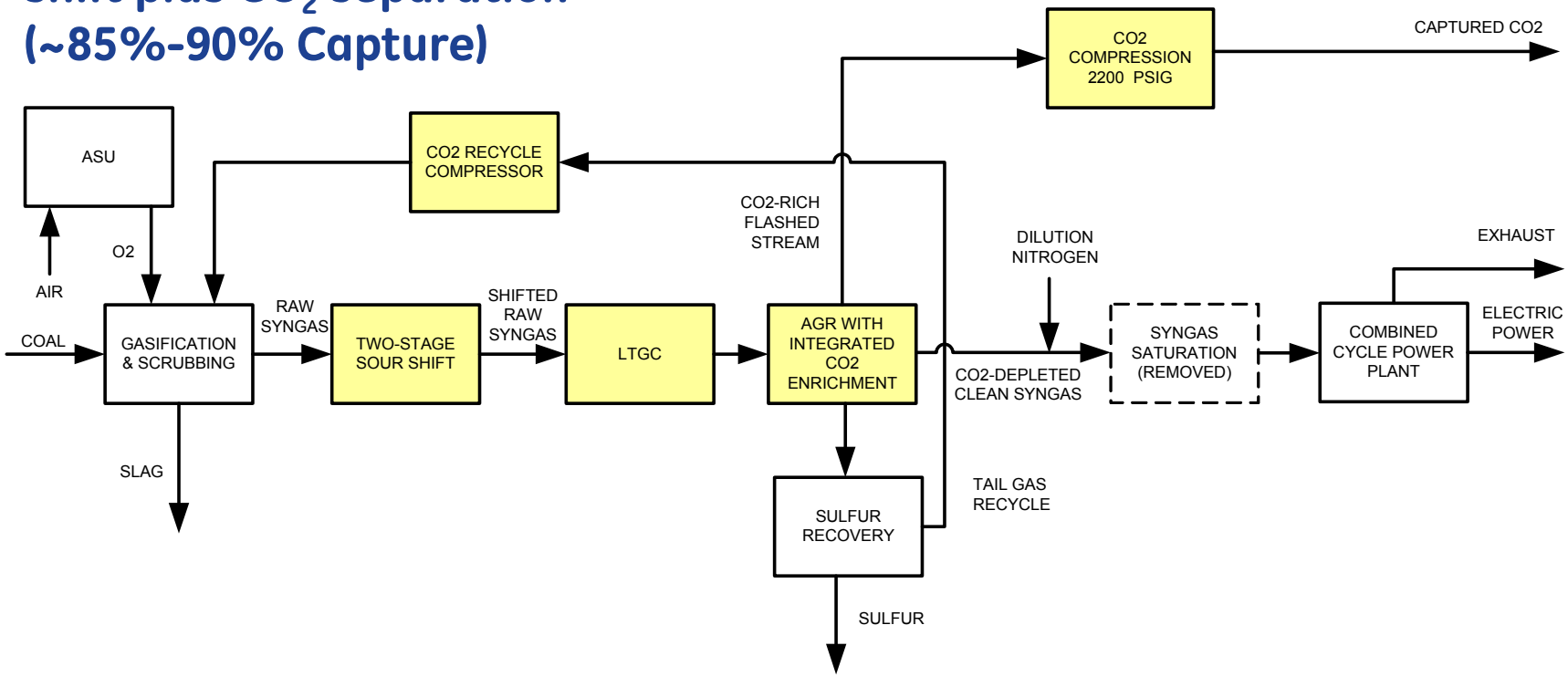
Configuration – Maximum Capture

Greenfield Two-stage sour shift plus CO_2 separation (~85%-90% Capture)



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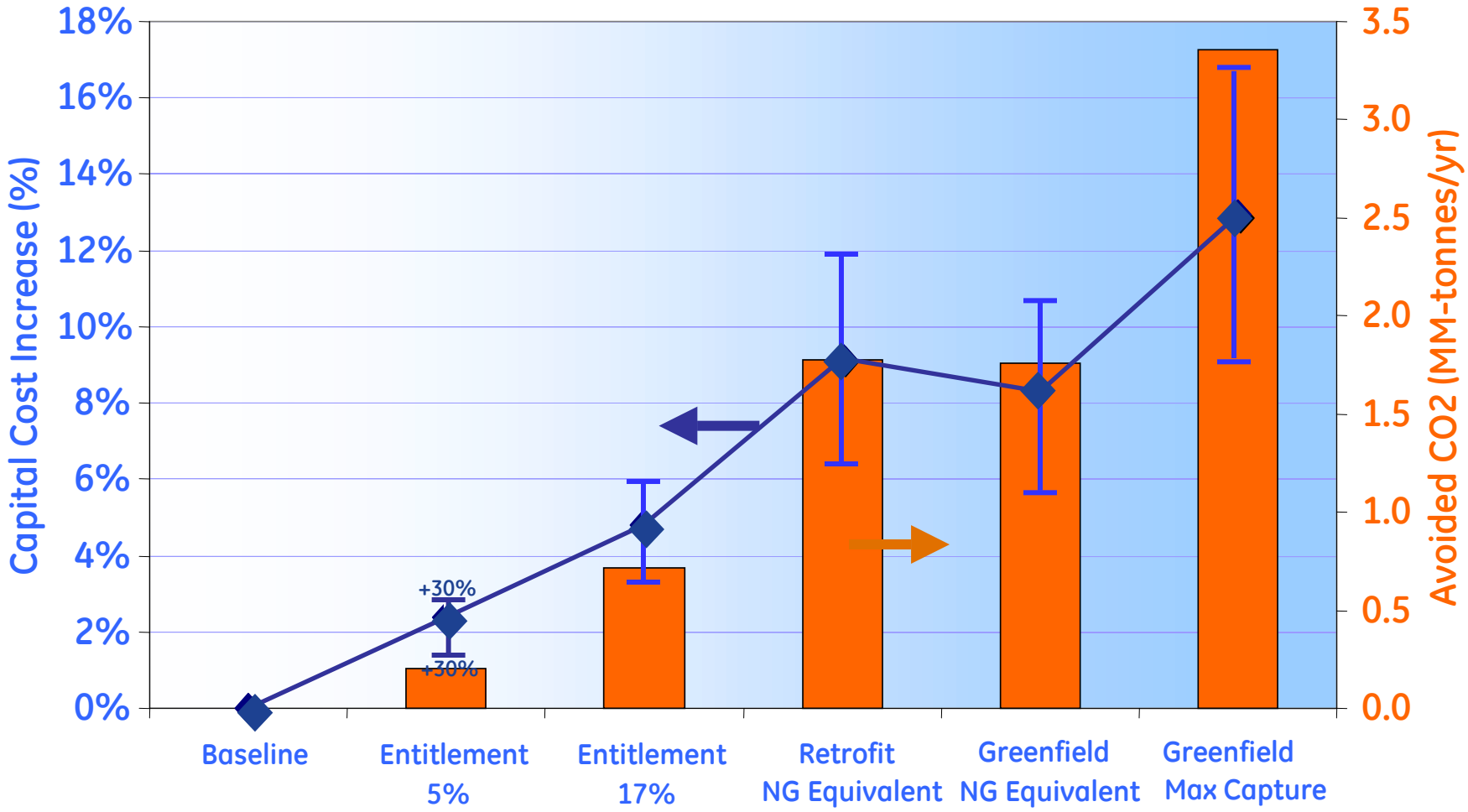
Tradeoff: Capital Cost vs. CO_2 Capture



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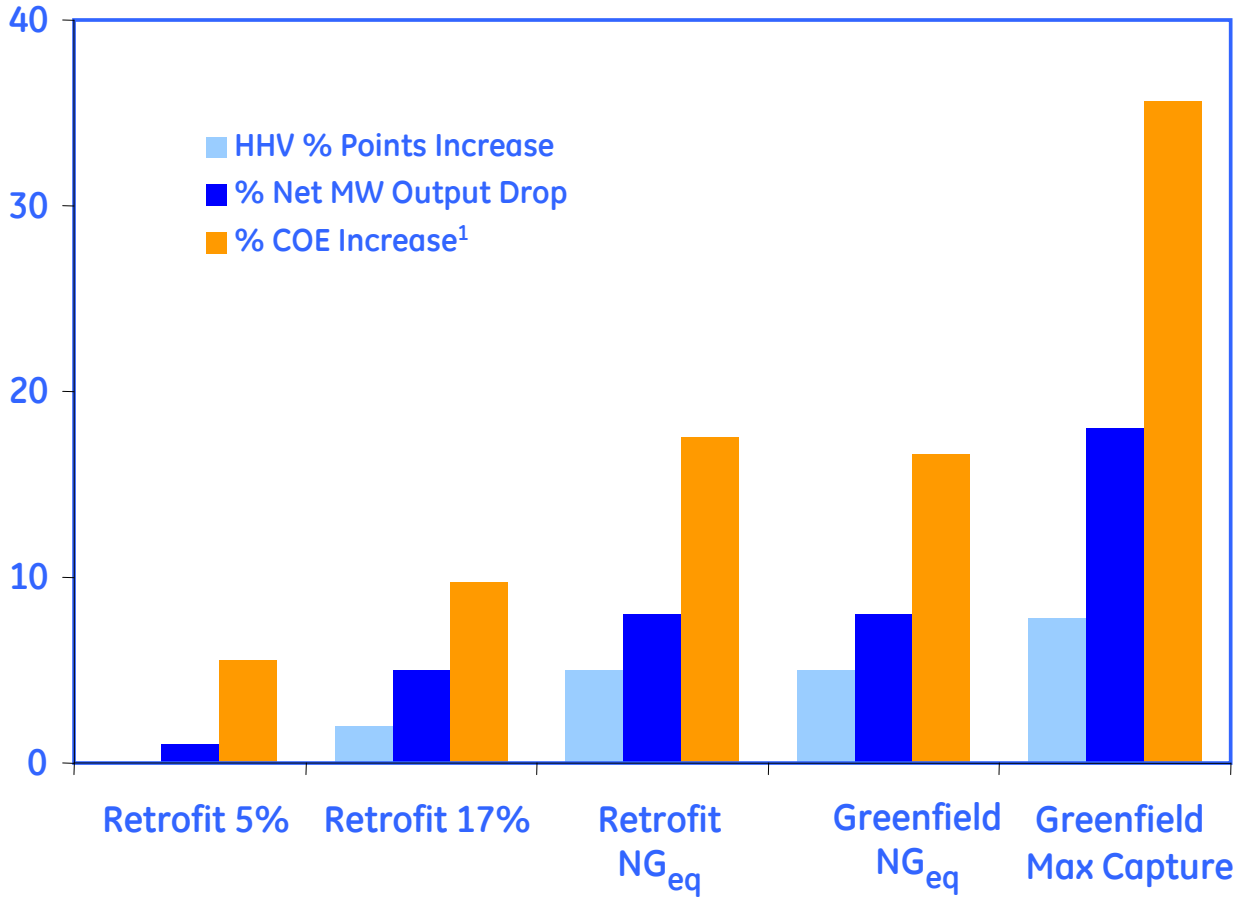
Performance Impact of Carbon Capture



[1] Excludes T&S

$$\text{Avoided Cost } (\$/\text{tonne}) = \frac{COE_{ccs}(\$/Mwh) - COE_{base}(\$/MWh)}{CO2_{base}(\text{tonne}/Mwh) - CO2_{ccs}(\text{tonne}/MWh)}$$

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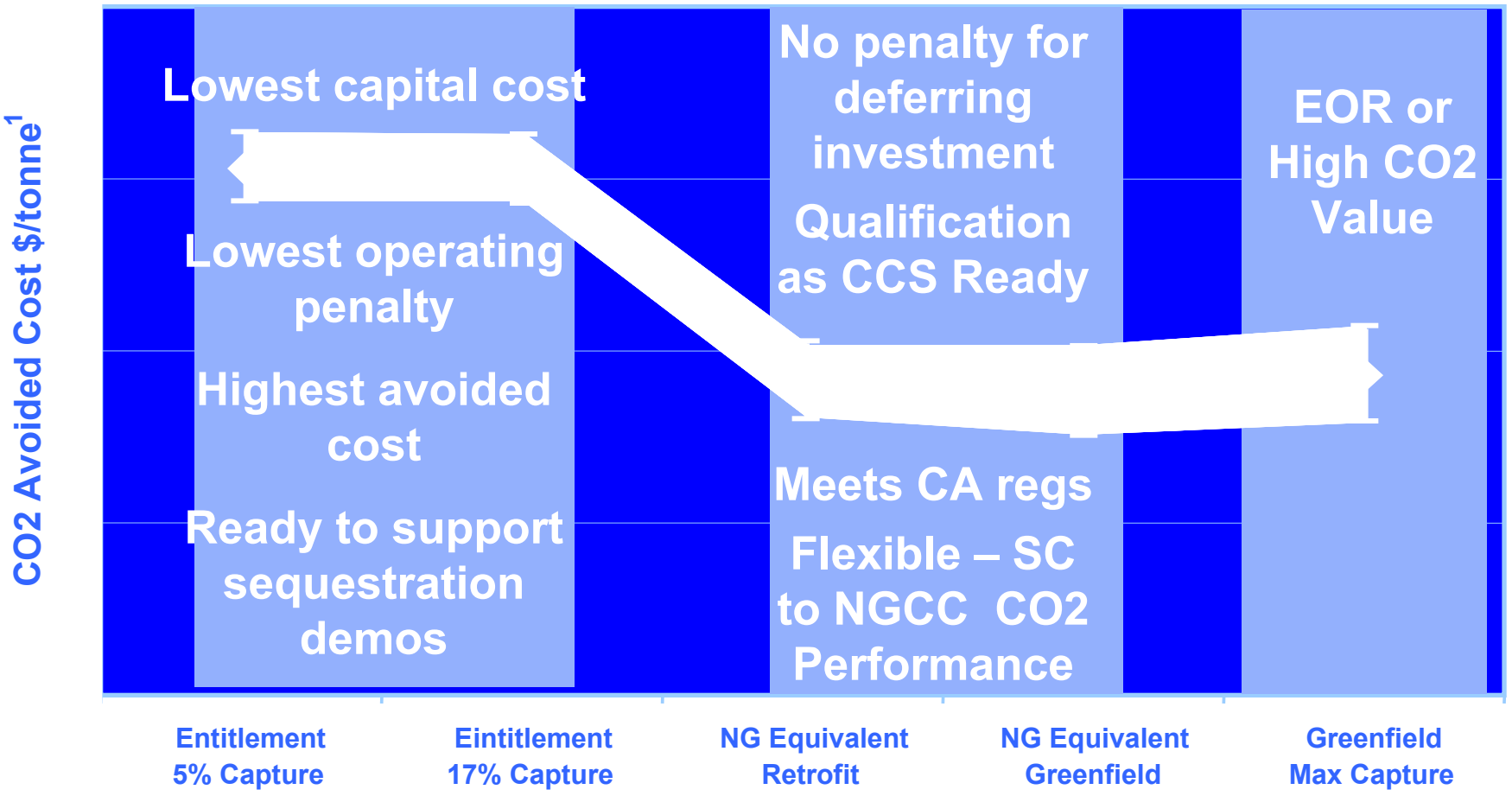
IGCC Flexibility for Carbon Value



[1] Capture with compression to 2,215psia, excludes T&S

IGCC Provides a Solution for Today's Carbon Uncertainty

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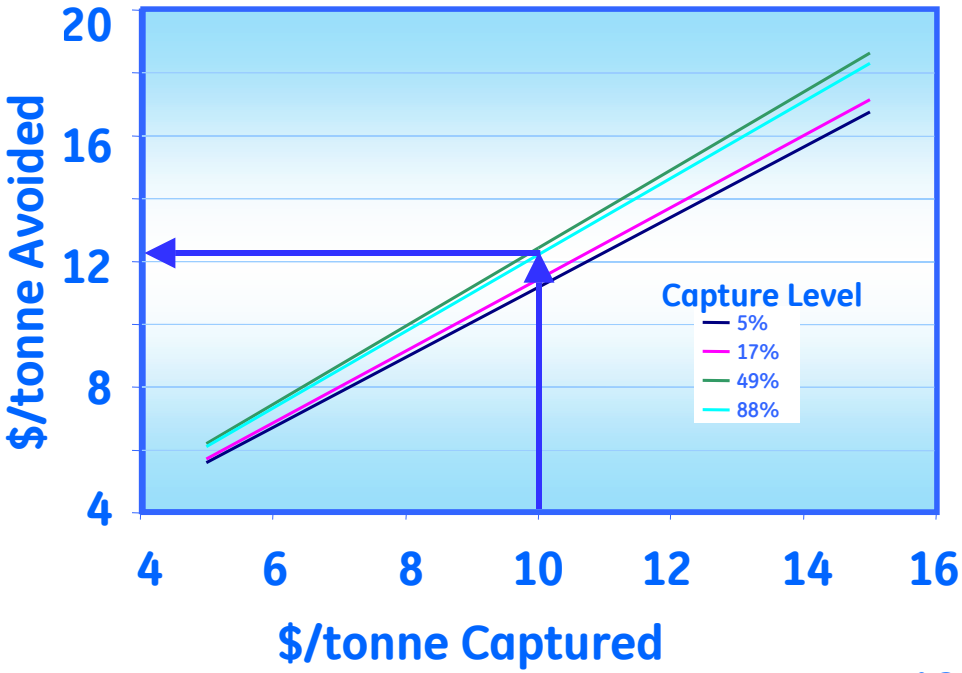
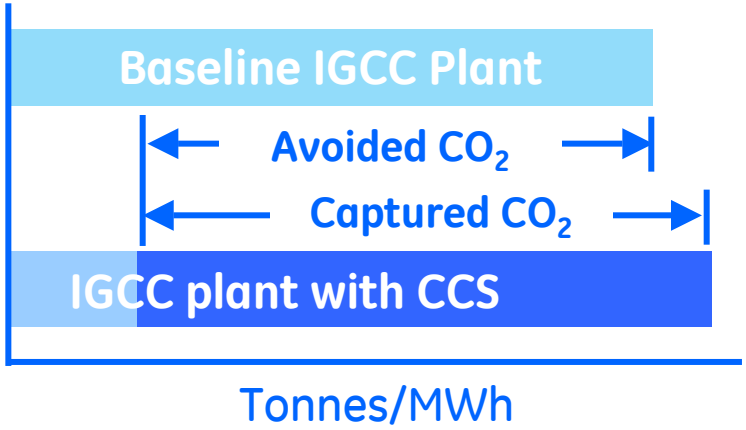
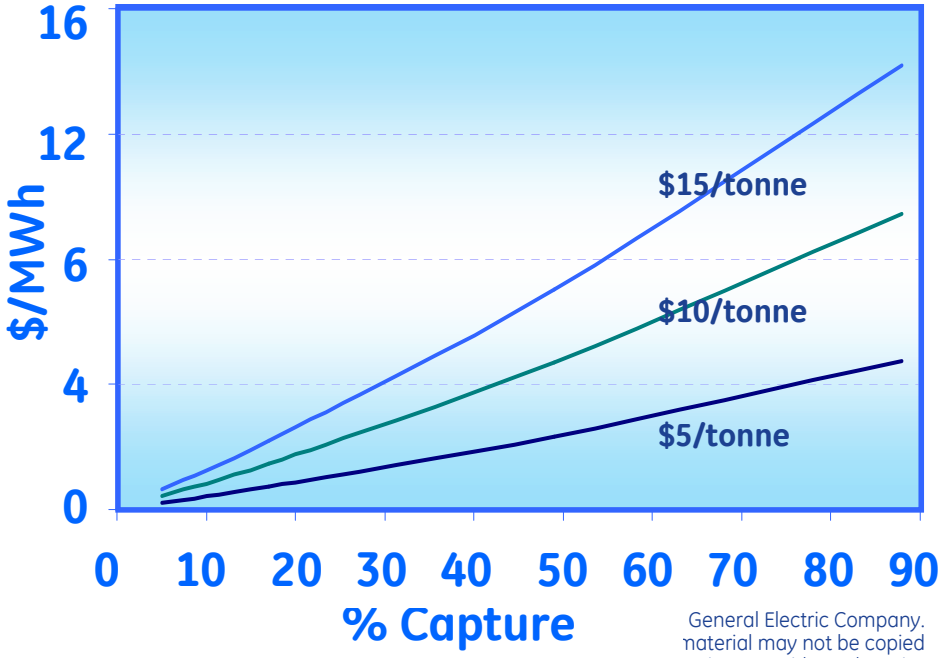
Impact of CO_2 T&S on COE





$$\text{\$/tonne Avoided} = \text{\$/tonne Captured} \times \frac{\text{Captured tonnes/MWh}}{\text{Avoided tonnes/MWh}}$$



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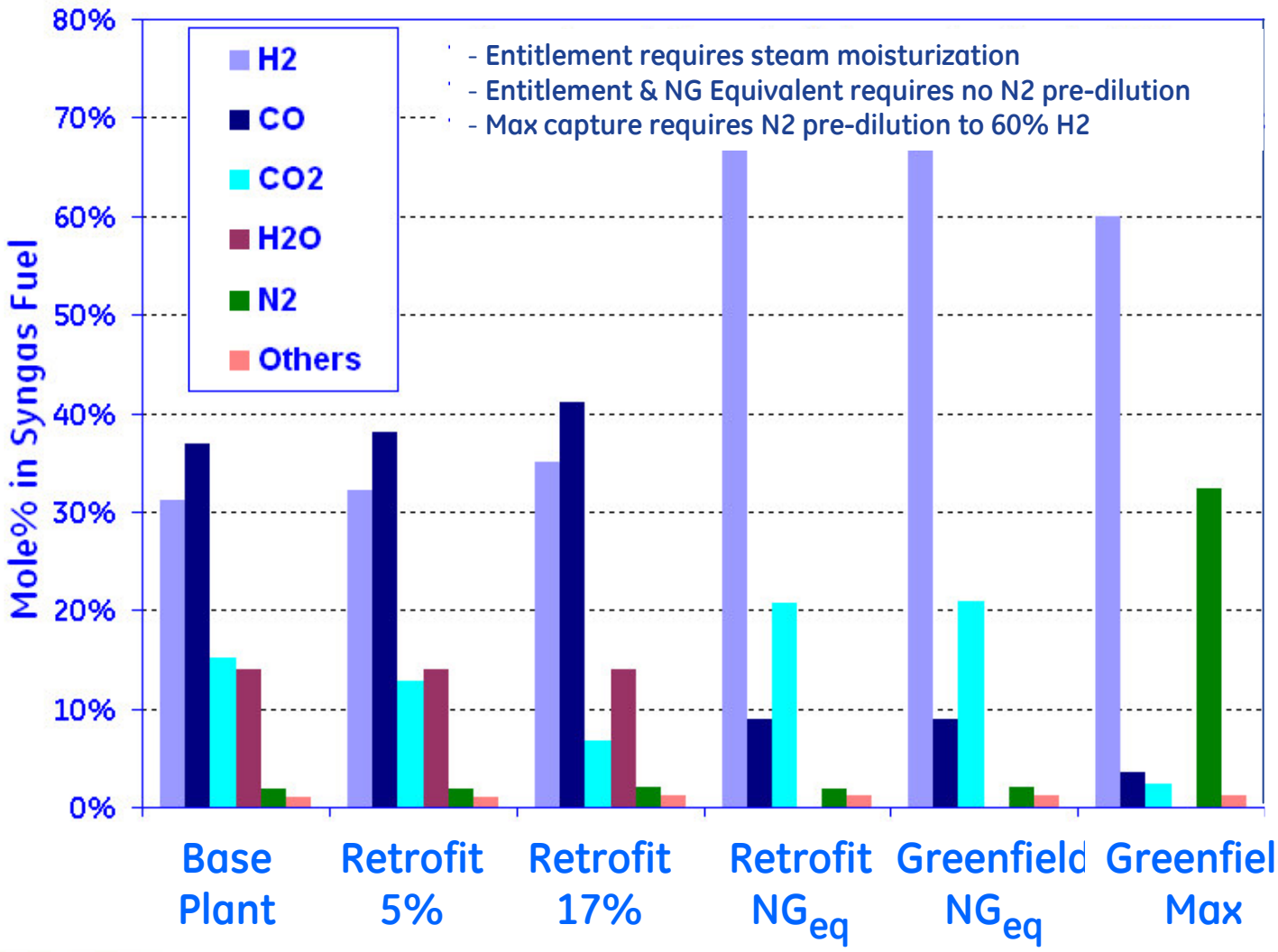
Turbine Fuel Impact



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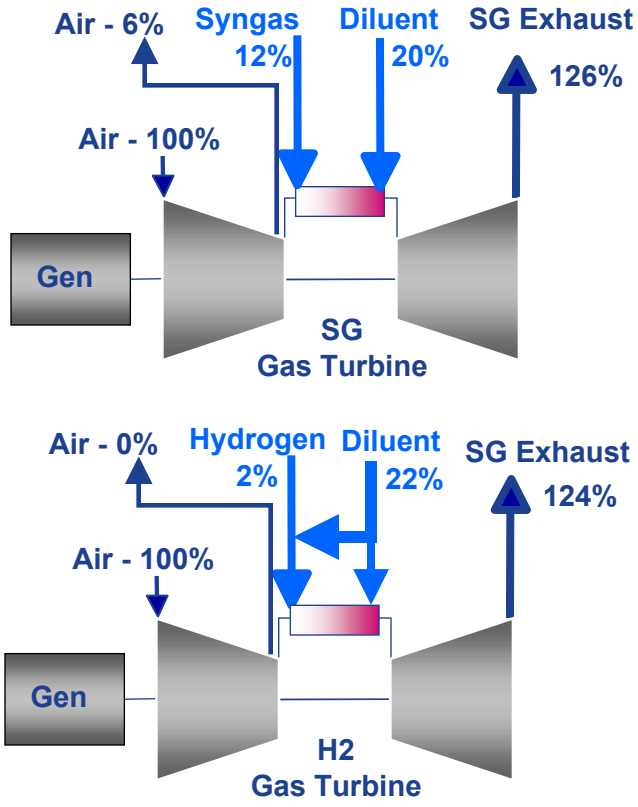
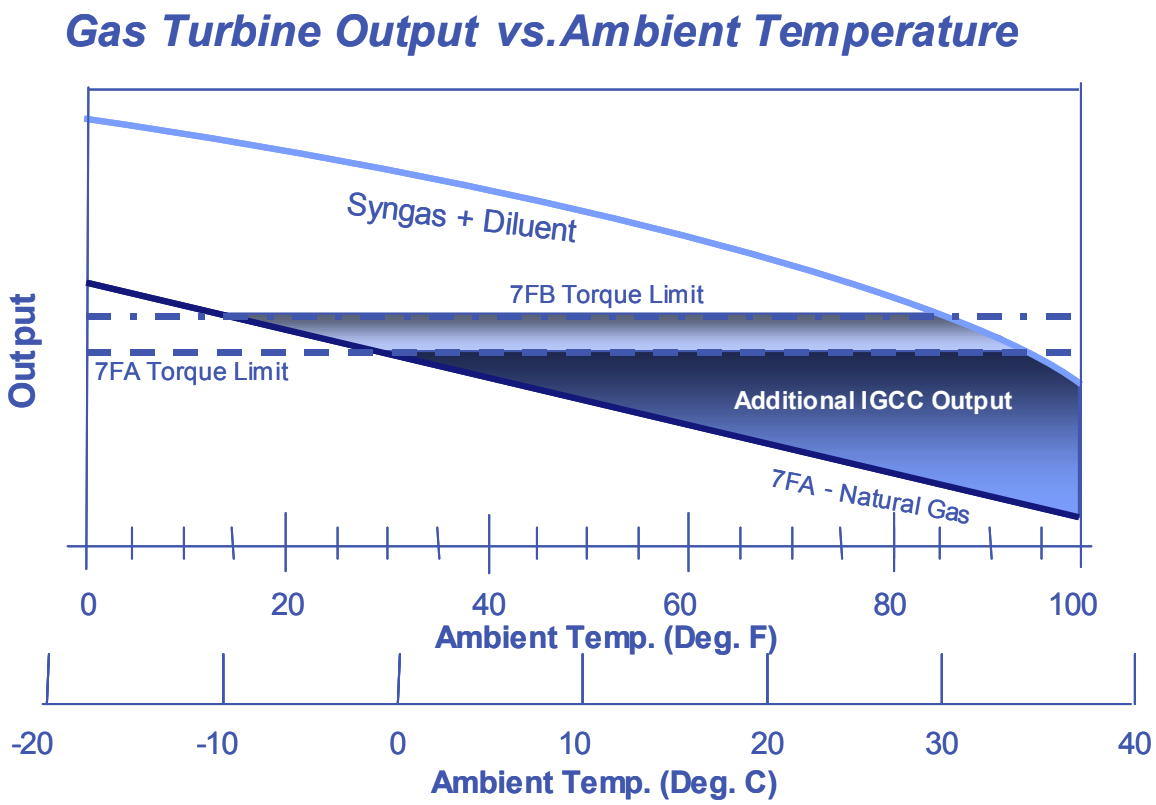
Maintaining GT Performance with H_2





N_2 Maintains GT Output at Torque Limit

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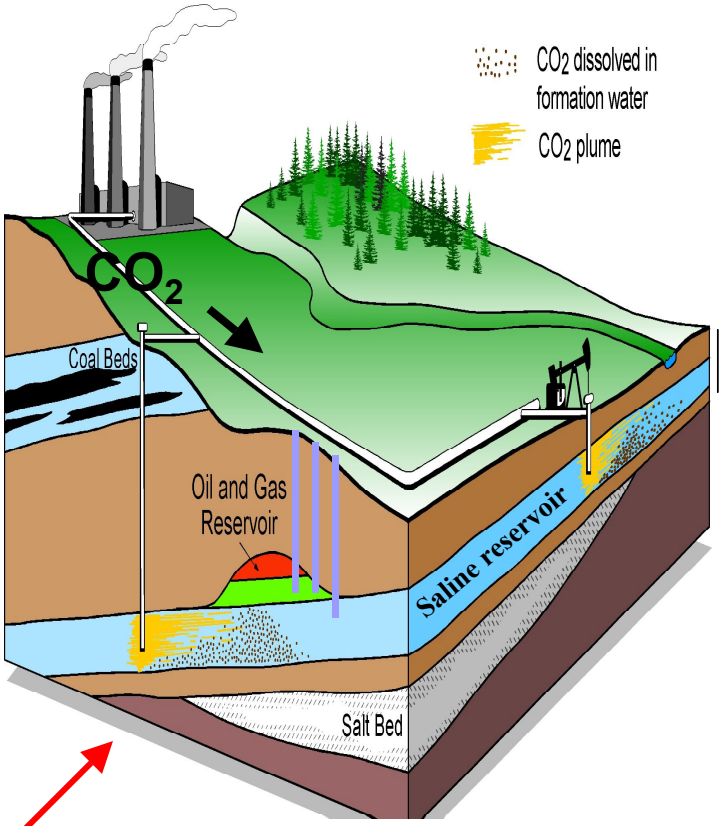
The Technology of CCS

Precombustion decarbonization

$H_2 + CO_2$

GE Energy
- Power
- Heat



- Underground storage
- Enhanced oil recovery (EOR)

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Comparison of CO_2 Storage Options

Characteristics	EOR	Saline Aquifers	Depleted Oil & Gas Reservoirs	Coal Beds
Experience Base	Permian Basin	Learning	Learning	To date, one failure
Storage Capacity	Moderate	Very high (10-100 x EOR)	Unknown	Low
Leakage Risk	Very low	Low	Very low	High
Accessibility to CO_2 Source	Limited	Extensive	Limited	Very limited
Likelihood of Success	100%	High	100%	Very low
Economics	Oil production could offset some of cost	Gov't incentive required	Gov't incentive required	Gov't incentive required
Overall Risk	Very low	Low	Very low	High
Other Comments	Most EOR projects do not have sufficient demand for CO_2 for 1 coal fired plant (30 yrs)	Largest storage capacity opportunity	CO_2 capacity needs to be quantified	Significant technical uncertainty

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Sample CO_2 Quality Specifications

Component	IPCC, 2005	IPCC, 2005; APGTF, 2002	Dakota Gas-ification Co.	Kinder Morgan, 2006; Elsam A/S et. Al 2003	Dixon Consulting ; EOR, 2001	Industry Working Group, 2005	Canyon Reef EOR, 2005
CO_2 (mole%)	> 95%	> 96%	> 96%	> 95%		> 95%	> 95%
N_2 (ppmv)	< 40,000	< 300	< 6,000	< 40,000	< 20,000	< 40,000	< 40,000
CH_4 (ppmv)	< 50,000	< 7,000	< 20,000	< 50,000	< 10,000	< 50,000	< 50,000
H_2S (ppmv)	< 1,061	< 9,000	< 20,000	< 200	< 100 (ppmw)	< 200	< 1,500
O_2 (ppmv)	< 7.5	< 50	< 100	< 10	< 2 (ppmw)	< 100	< 10
H_2O (ppmv)	< 641	< 20	< 2	< 480	<-5C DP at 300psia	< -40C DP	< 28lb/ MMCF

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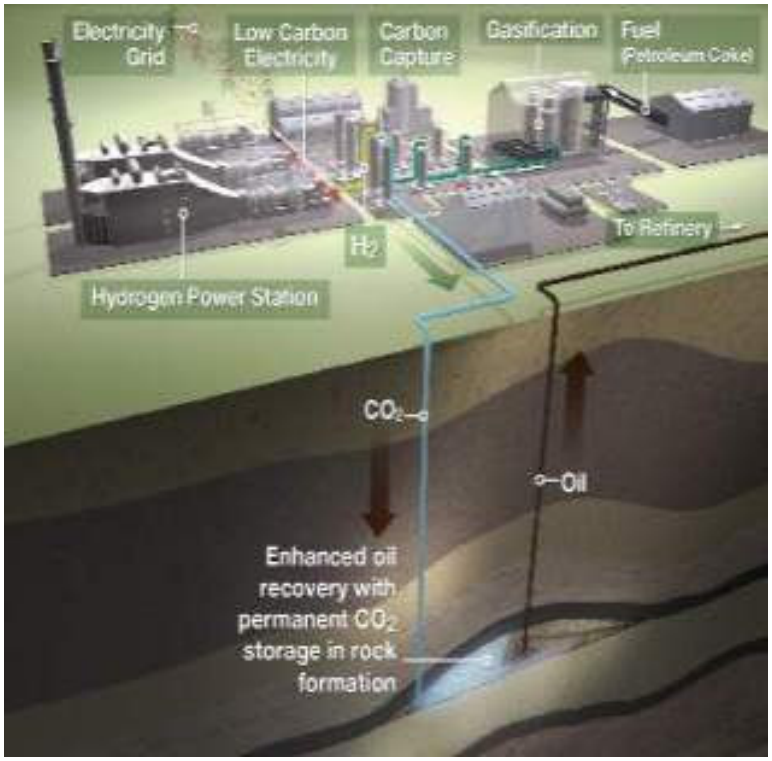
GE & BP H_2P Initiative

hydrogen energy



California Hydrogen Power Project

Collaborative Value of Two Industry Leaders

- Technology expertise
- Process expertise
- Committed resources
- Operations focused

Several Projects in Development Pipeline

- Feedstock: Utilize advantaged fossil fuels (coal, petcoke)
- Output: Produce high H2 fuel for gas turbines
- Avoid Carbon Emissions: Capture ~90% of CO2 & utilize for EOR or store in saline aquifers

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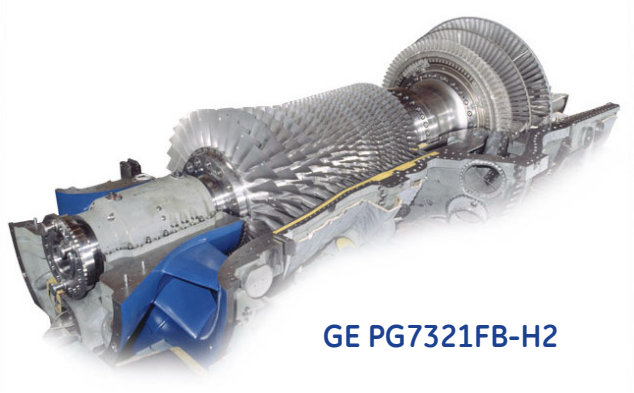
IGCC & CCS Combustion Landscape

Objective	Approach	Capability
Cleaner Energy from Coal	*Today* IGCC with Carbon Capture	• High-H_2 GT fleet • Successful operation • Diffusion flame • Diluent for NOx
	Future Advanced Separation & Gasification Technology	• Advanced pre-mix combustion • Membranes -- O_2, CO_2, H_2 • DOE program



GE PG7321FB-H2

Conceptual FutureGen plant courtesy US DOE

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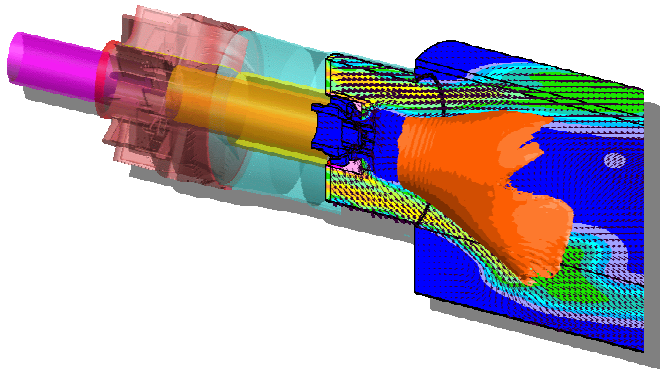
GE's DOE H_2/IGCC Turbines Program

Technology advancement for future gas turbines:

- IGCC - syngas fuel
- IGCC with carbon capture - H_2 fuel



Objectives:

- Lower NOx
- Higher efficiency
- Lower capital cost

Structure

- Phase 1: (2 yrs) - Technology Development (complete)
- Phase 2: (5 yrs) - Design and Component Validation
- Phase 3*: (4 yrs) - Build, install, validation testing

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Summary

- All systems required for IGCC carbon capture are commercially proven
- IGCC offers a flexible platform to capture CO_2 today for sequestration
- An IGCC plant is ready for retrofit to meet natural gas performance levels without penalty for deferral of decision
- IGCC carbon capture can be provided today as a base plant feature or as a future retrofit
- CO_2 sequestration validation with a clear regulatory environment need to catch up to capture

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