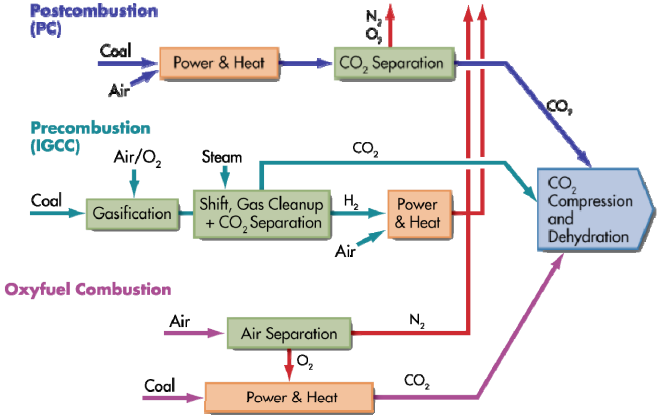

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CO_2 Capture – Technology Overview

George Offen

Sr. Technical Executive

Emissions/CCP Use

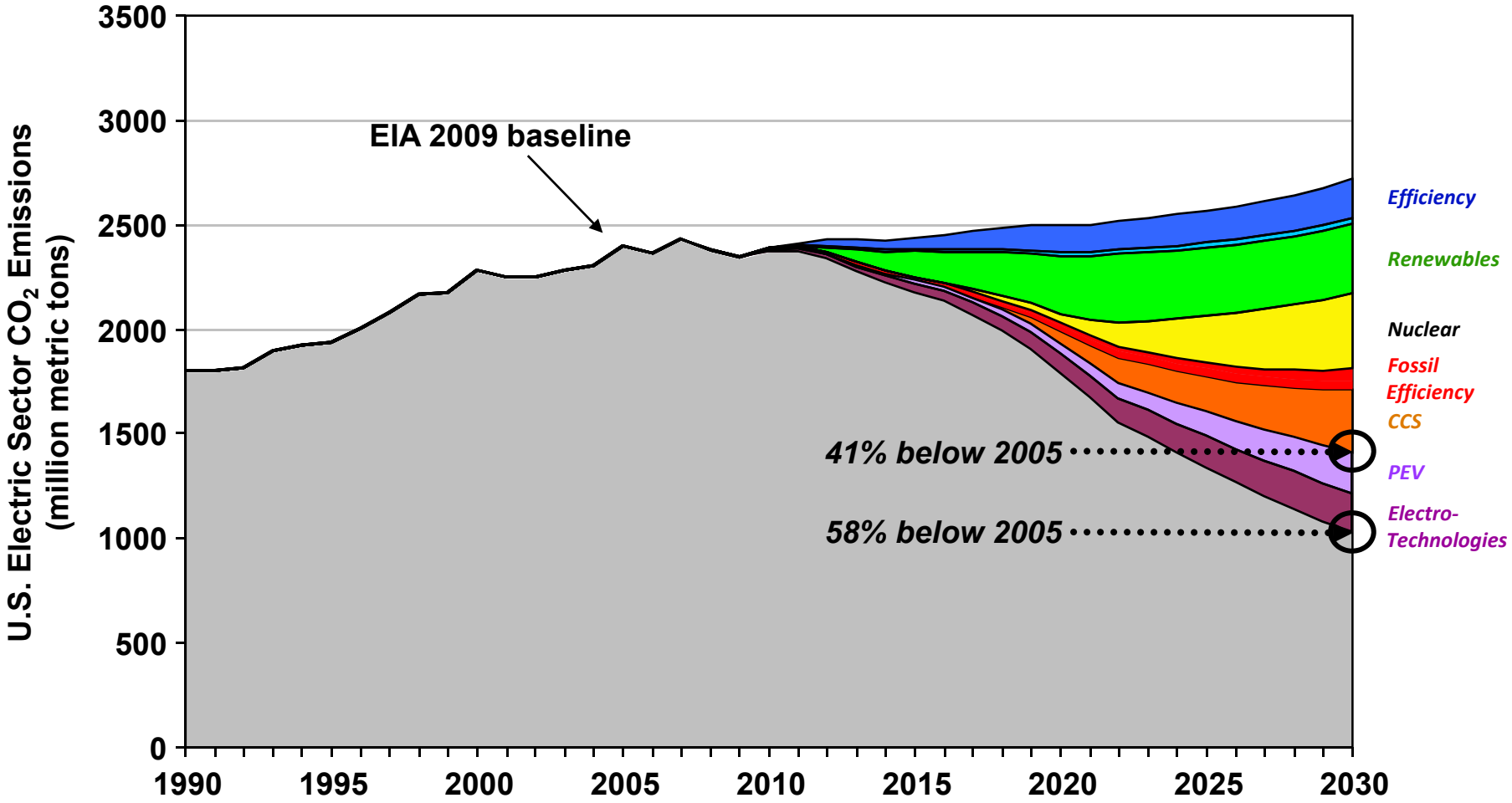
California Carbon Capture and Storage Review Panel

Sacramento, CA

April 22, 2010

EPRI Analysis Shows Technical Potential to Achieve Substantial CO_2 Reductions

Achieving all targets is very aggressive, but potentially feasible



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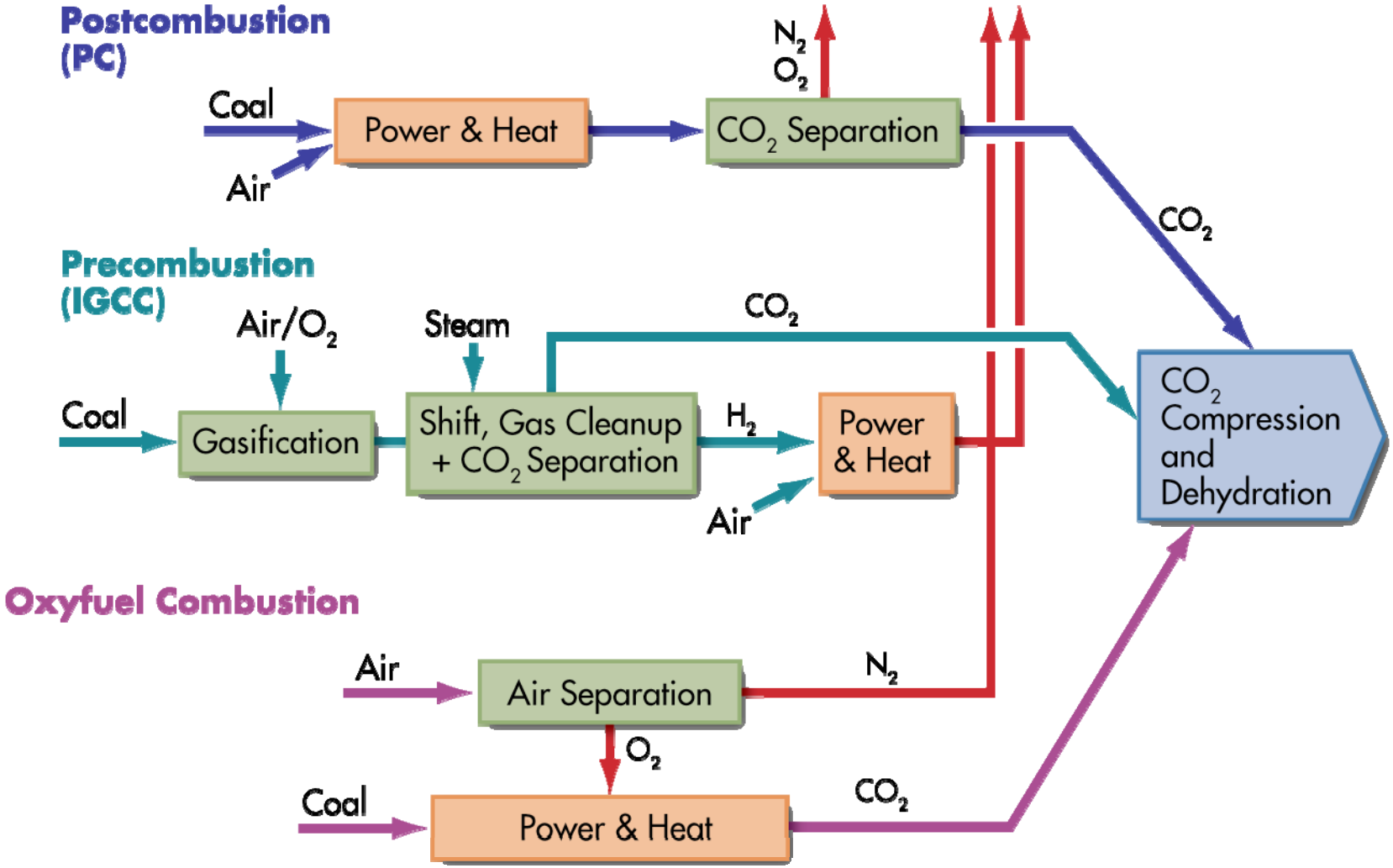
CO_2 Capture Technology Depends on Power Generation System



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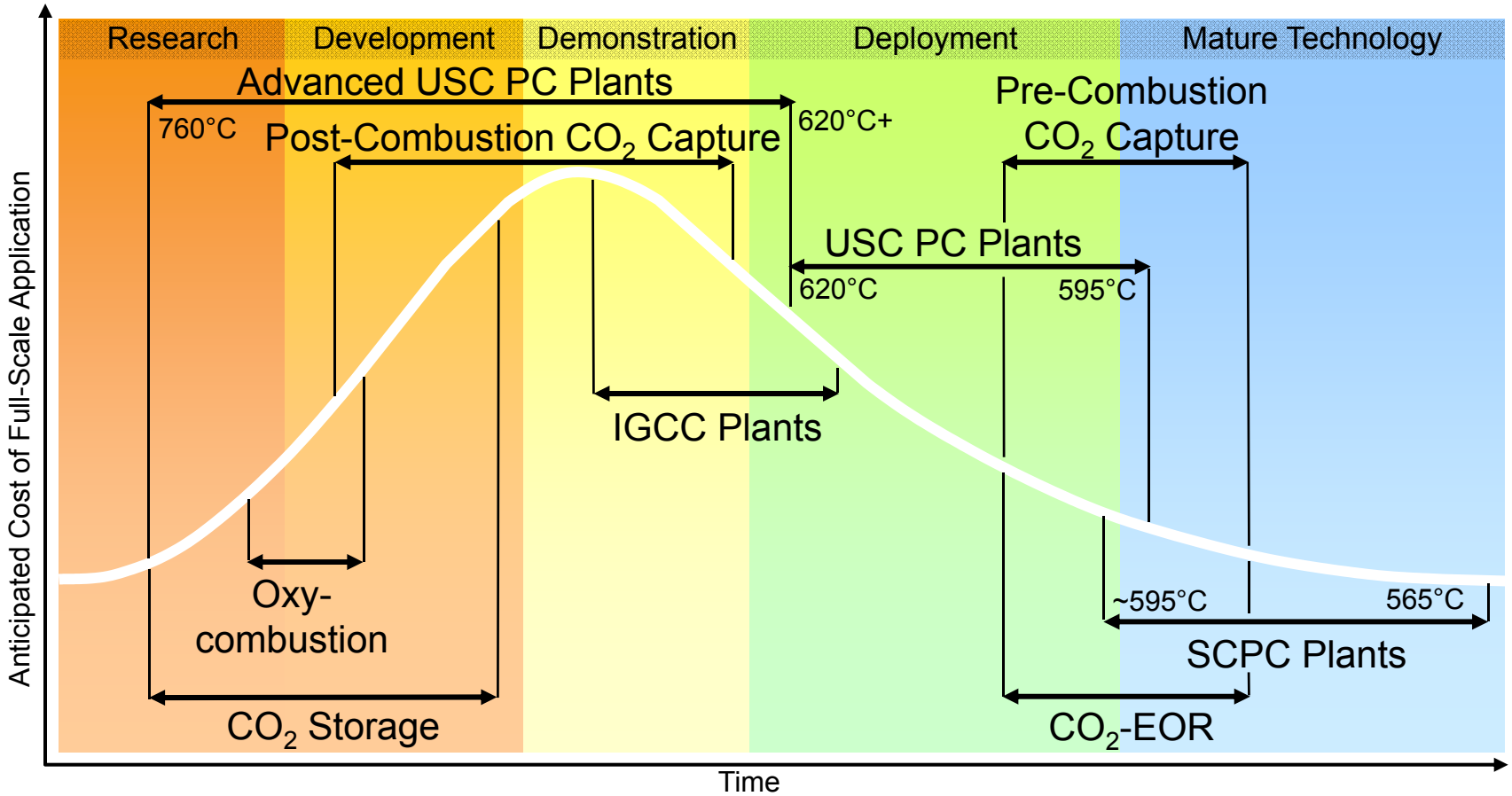
Where We Are Today—Different Maturity States for Advanced Coal and CCS Technologies



2020 Goal: Competitive advanced coal power systems with high efficiency, near-zero emissions, and 90% CO_2 capture

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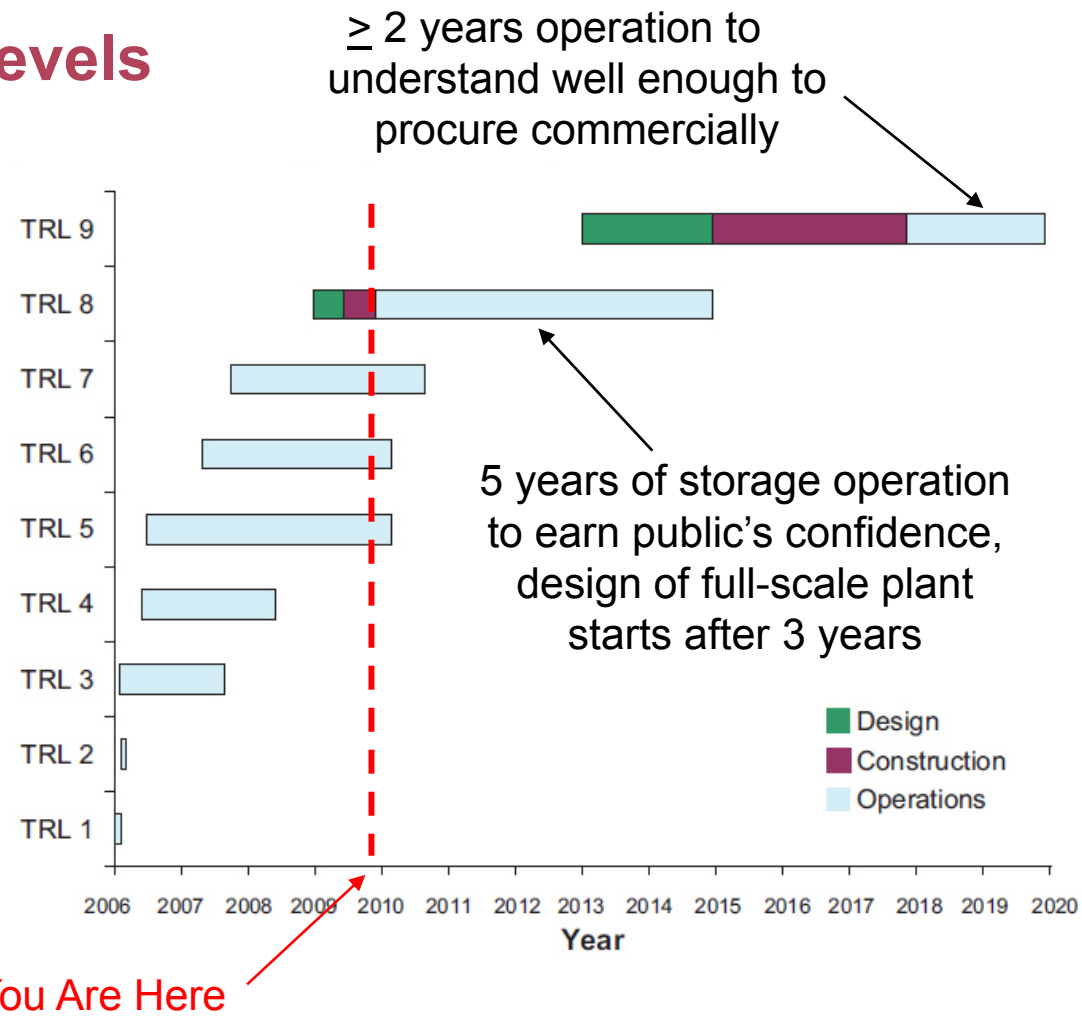
CCS Development Timeline Driven by Need for Multi-year Storage Demos, High Costs of Bypassing Learning-by-doing Phase on Capture

Technical Readiness Levels

TRL-9	Full-Scale Commercial Deployment
TRL-8	Sub-Scale Commercial Demonstration Plant
TRL-7	Pilot Plant
TRL-6	**Process Development Unit**
TRL-5	Component Prototype Development
TRL-4	Laboratory Component Testing
TRL-3	Analytical, "Proof of Concept"
TRL-2	Application Formulated
TRL-1	Basic Principles Observed



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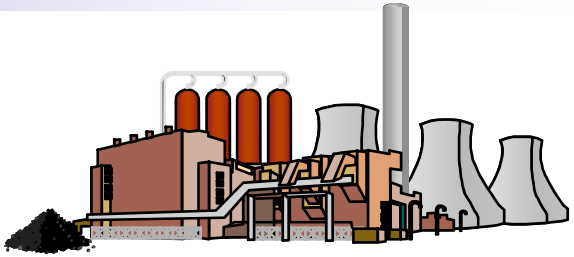
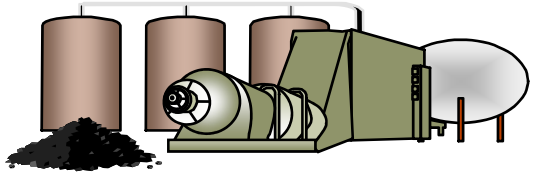
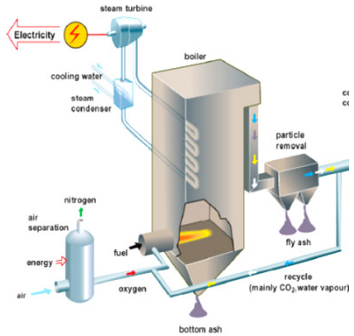
RD&D Is Addressing Key Advanced Coal Technology Challenges



- **New pulverized coal (PC)**
  - Increase plant efficiency
  - Reduce energy penalty of CO_2 capture
- **Existing PC**
  - Retrofit CCS in existing plants
- **Integrated gasification combined cycle**
  - Reduce water gas shift and O_2 costs
  - Integrate CCS in optimized plant design
- **Oxy-firing**
  - Demonstrate technology
  - Reduce O_2 costs
  - Determine co-sequestration opportunities





Goals: Reduce costs and demonstrate technologies, storage

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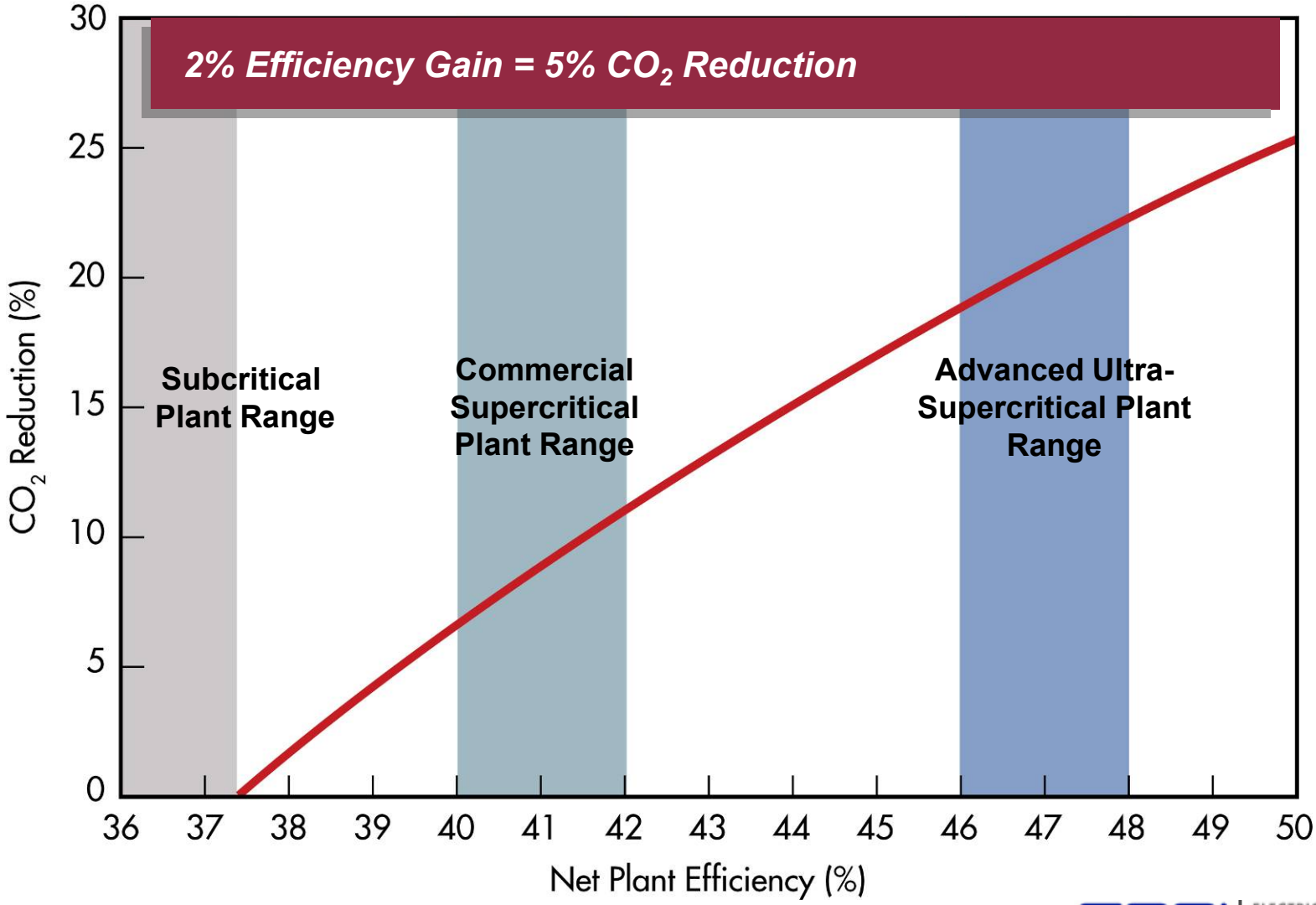
Lowest-cost CO_2 Reduction = Increased Plant Efficiency



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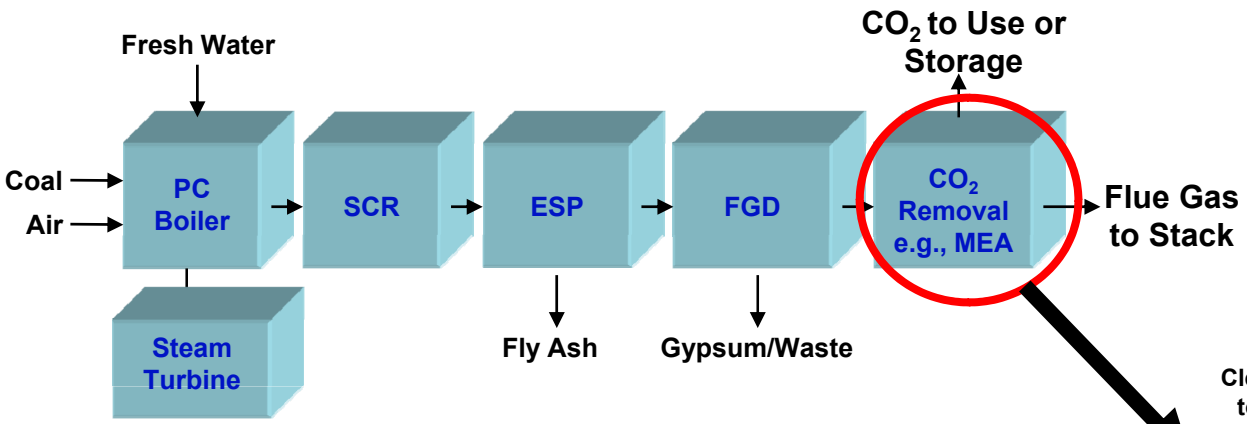
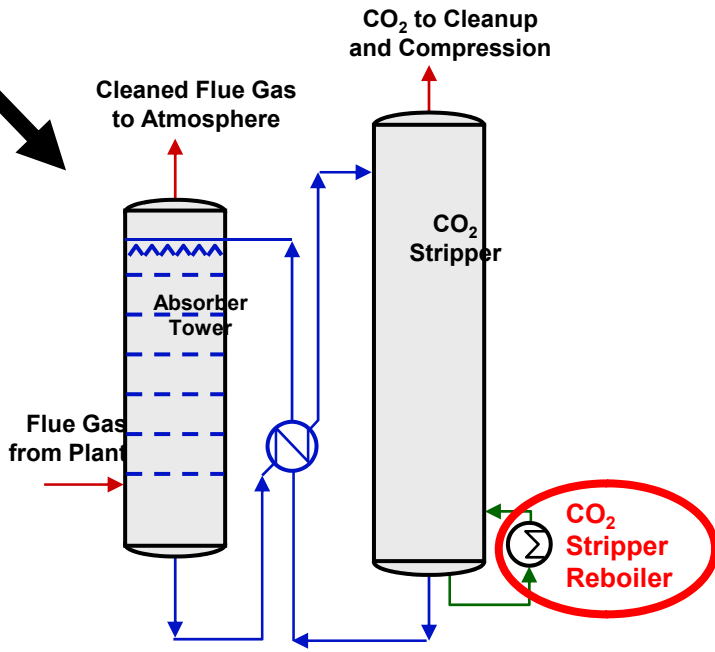
Pulverized Coal (PC) with CCS Needs Overcome Newness, Energy Penalty



Output Penalty: Up to 30+% *Today*



- Three small U.S. industrial post-combustion CO_2 capture plants operating today
  - Largest equivalent to 15 MWe
- CO_2 capture needs low SO_2, NO_2, PM, large amounts of energy, lots of space
- Maximizing efficiency requires optimal thermal integration

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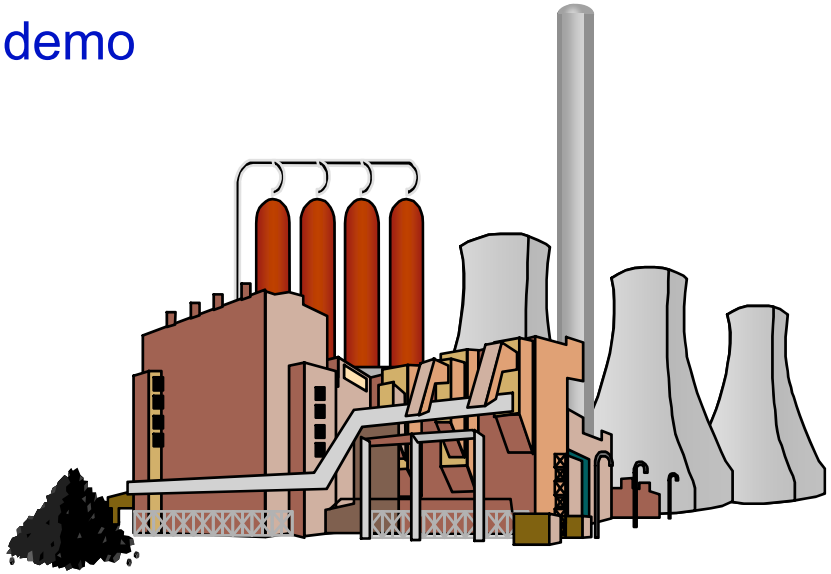
Solvent-based Processes Are Most Developed Post-combustion Technologies on Coal

- Amine (all < 1 MW pilots)
  - Fluor Econamine FG Plus^{sm}
  - MHI KM-CDR™
  - Aker
  - HTC Purenergy
  - Cansolv

Selected for large slipstream demos

Selected for ~125 MW demo

- Ammonia
  - Alstom Chilled Ammonia (1.7 & 20 MW, USA)
  - Powerspan ECO_2 (1 MW, USA)



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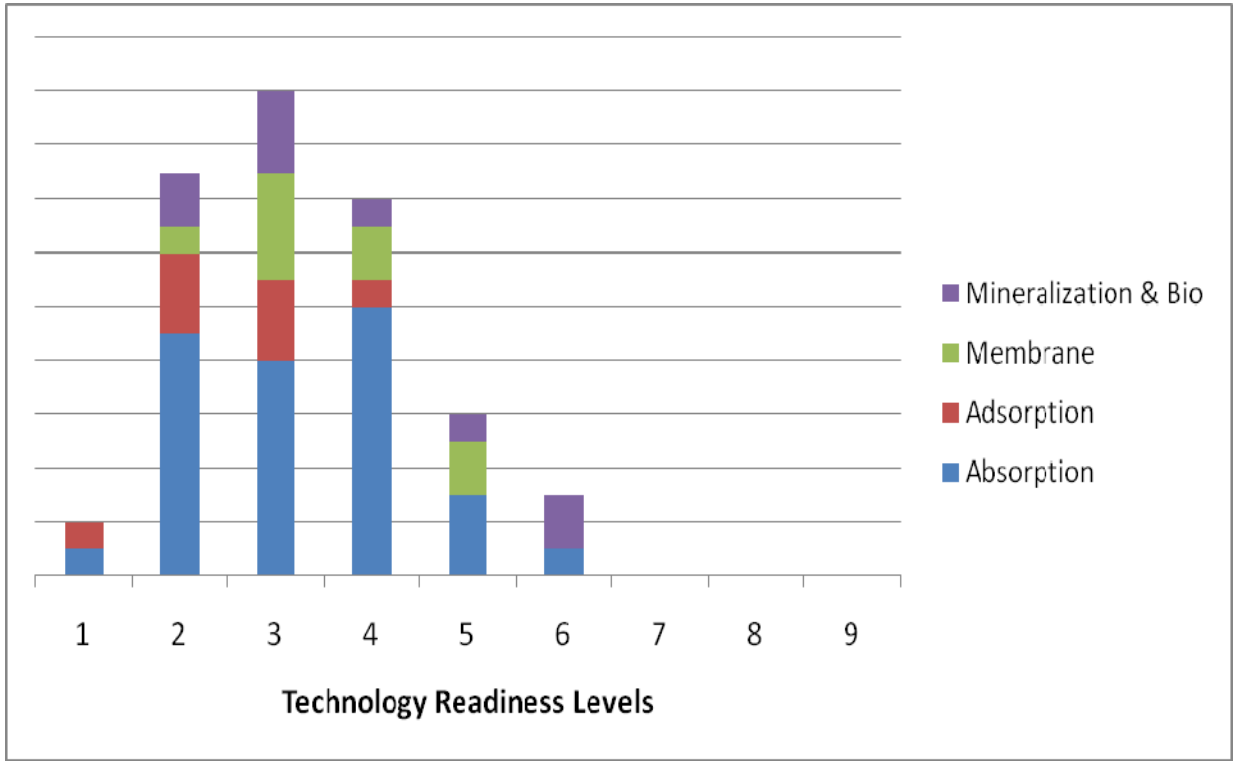
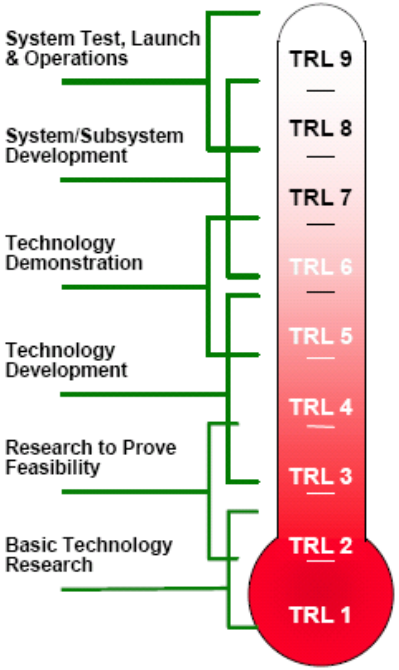
Capture Technologies: Technical Readiness Level (TRL)

- Majority of processes are absorption based
- Most are at TRL 2 -4 (preliminary design to laboratory validation)





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Identify Processes

Proactive search

Scale-Up (0.25–5 MW)

Verify operability, energy consumption, CO_2 capture rates of complete process

Capture and Storage Demo (~20 MW)

- Integrated capture and storage

Integrated Demo (~150 MW)

- Integrated power production with capture and storage
- Pre-commercial

Economics and Engineering for Full Plant Integration (>150 MW)

- Fully integrated power production with CCS
- Commercial

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Post-combustion Capture Development with EPRI Involvement*

Internal

Review and Evaluations (> 70 Processes)

Modeling

Absorption

Alstom's Chilled Ammonia
MHI's KM-CDR®
VMI/Univ. of Illinois-Chicago
Center of Applied Energy. Res. (U. KY)
Ion Engineering (ionic liquids)
Univ. of Texas
3H

Adsorption

Univ. of WY
ADA-ES
UC Berkeley & LBNL (informal)
Nat'l Univ. Singapore (informal)

Membranes

Membrane Technology & Research
Center Membrane Applied Science & Tech.
University Colorado
Stanford University (informal)

All Process Types

National Carbon Capture Center

Biological / Mineralization / Other

Calera
Univ. of Colorado
CMU

* Several with DOE

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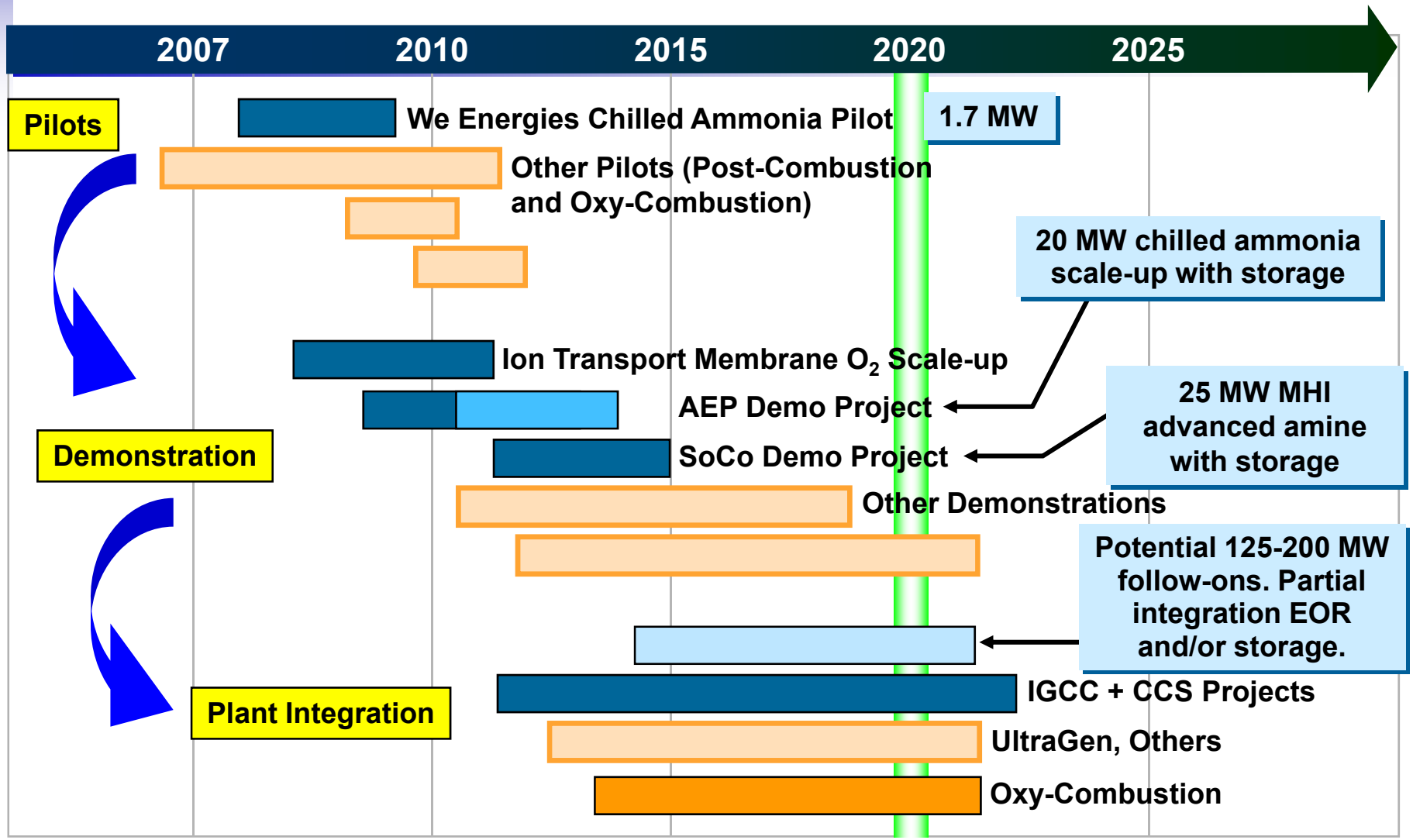
Need Multiple: Capture Demos – Risk Management, Competition
Storage Demos – Understanding thru Different Geologies



Goals – Affordable, Energy Efficient, Accepted

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Coal Gasification Plants w/CO_2 Capture (Today)

- IGCC and CO_2 removal offered commercially:
  - Have not operated in an integrated manner
- Three U.S. non-power facilities capture CO_2
  - Coffeyville
  - Eastman
  - Great Plains
- Many coal gasification plants in China recover CO_2
- Great Plains CO_2 recovered for EOR
  - 2.7 million tons CO_2 per year
  - ~340 MWe if it were an IGCC

No coal <u>IGCC</u> currently recovers CO_2

The Great Plains Synfuels Plant
http://www.dakotagas.com/Companyinfo/index.html

Weyburn Pipeline
http://www.ptrc.ca/access/DesktopDefault.aspx

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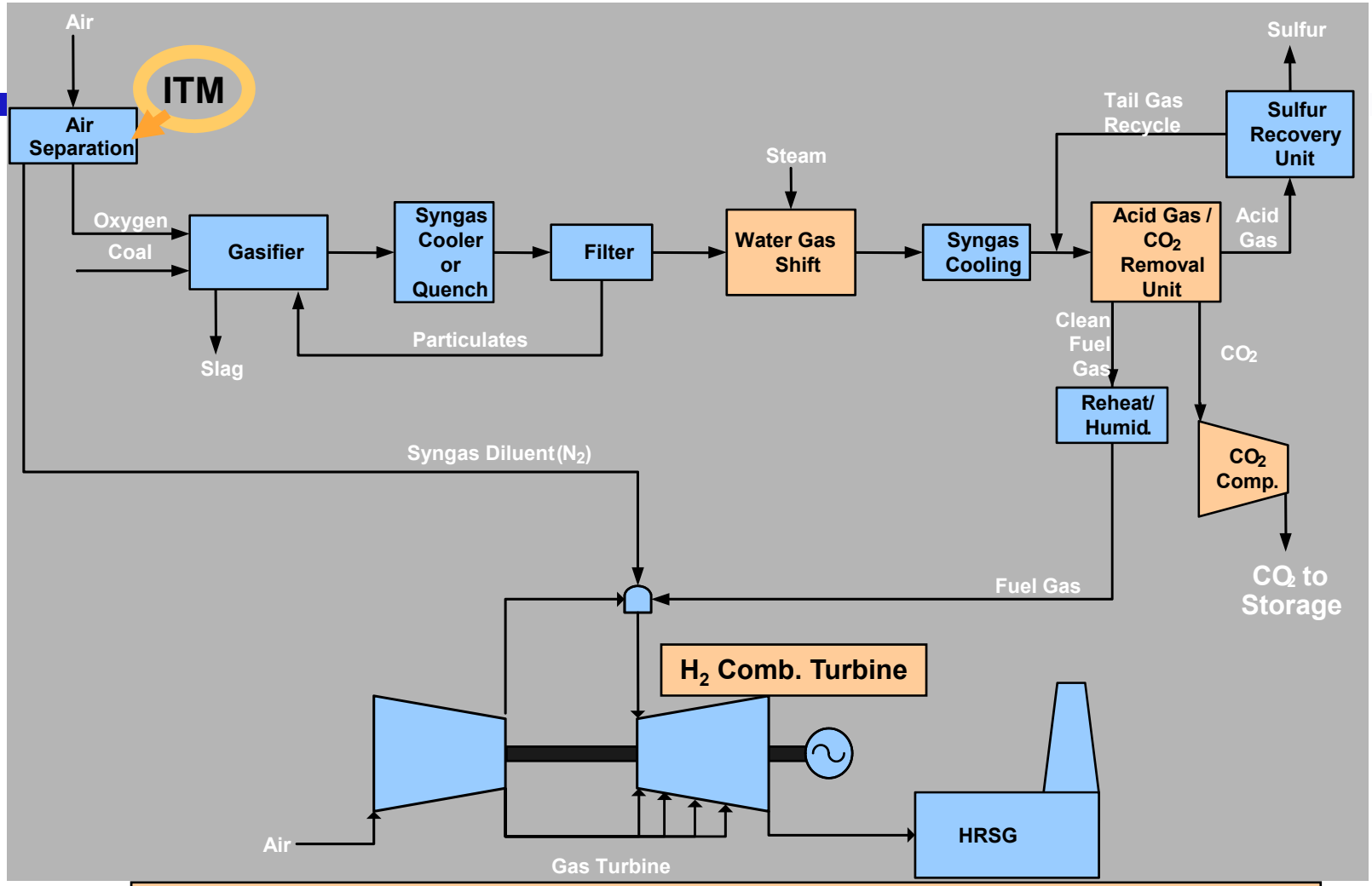
IGCC Additions for CO_2 Capture



1. Additions all demonstrated; integrated operation not
2. Seeking process, technology improvements

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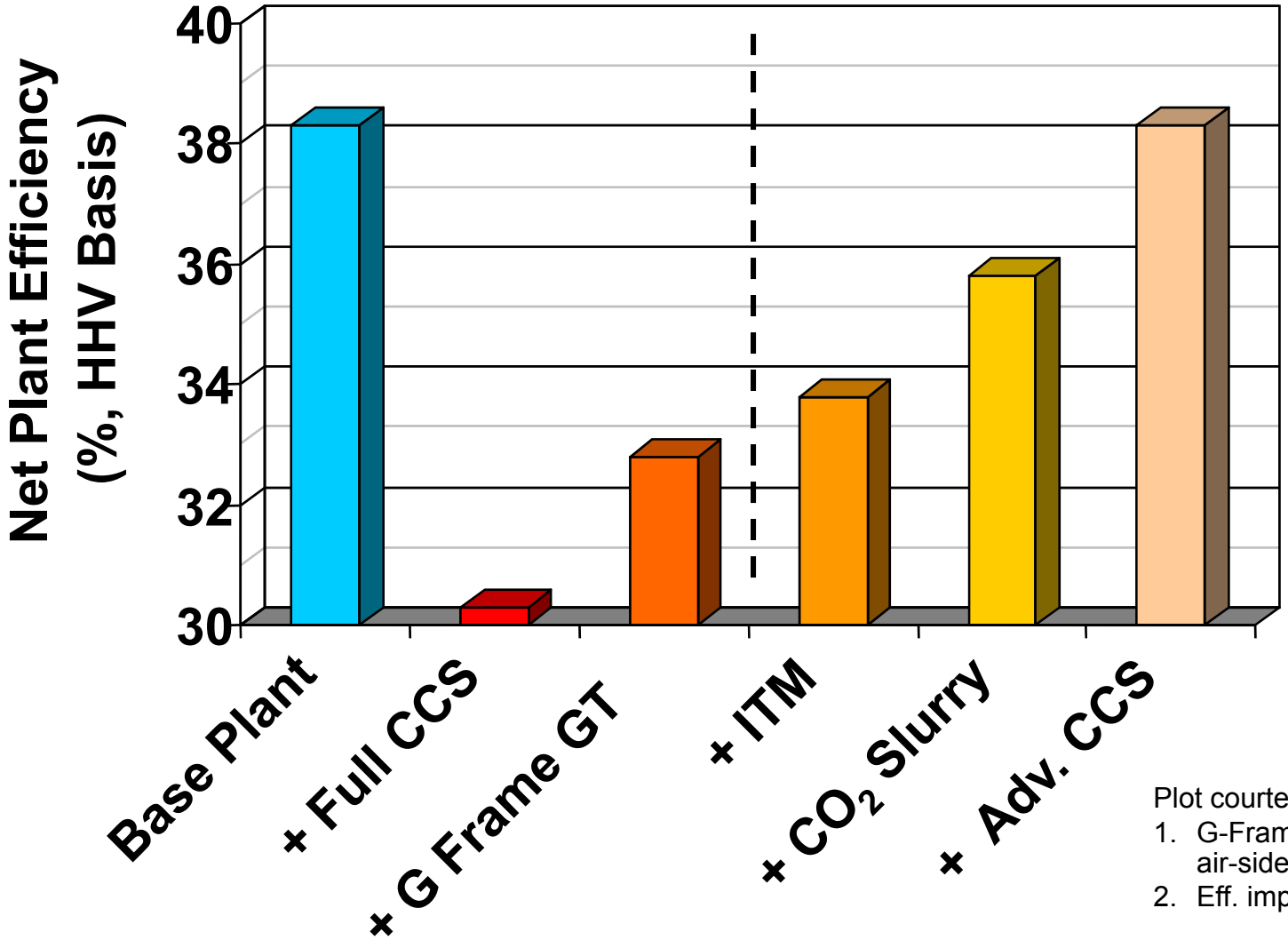
EPRI-Supported Demos and Long-term R&D Seek to Recover Pre-CCS Efficiency



Plot courtesy Air Products

1. G-Frame GT case includes full air-side GT-ASU integration
2. Eff. improvements cumulative

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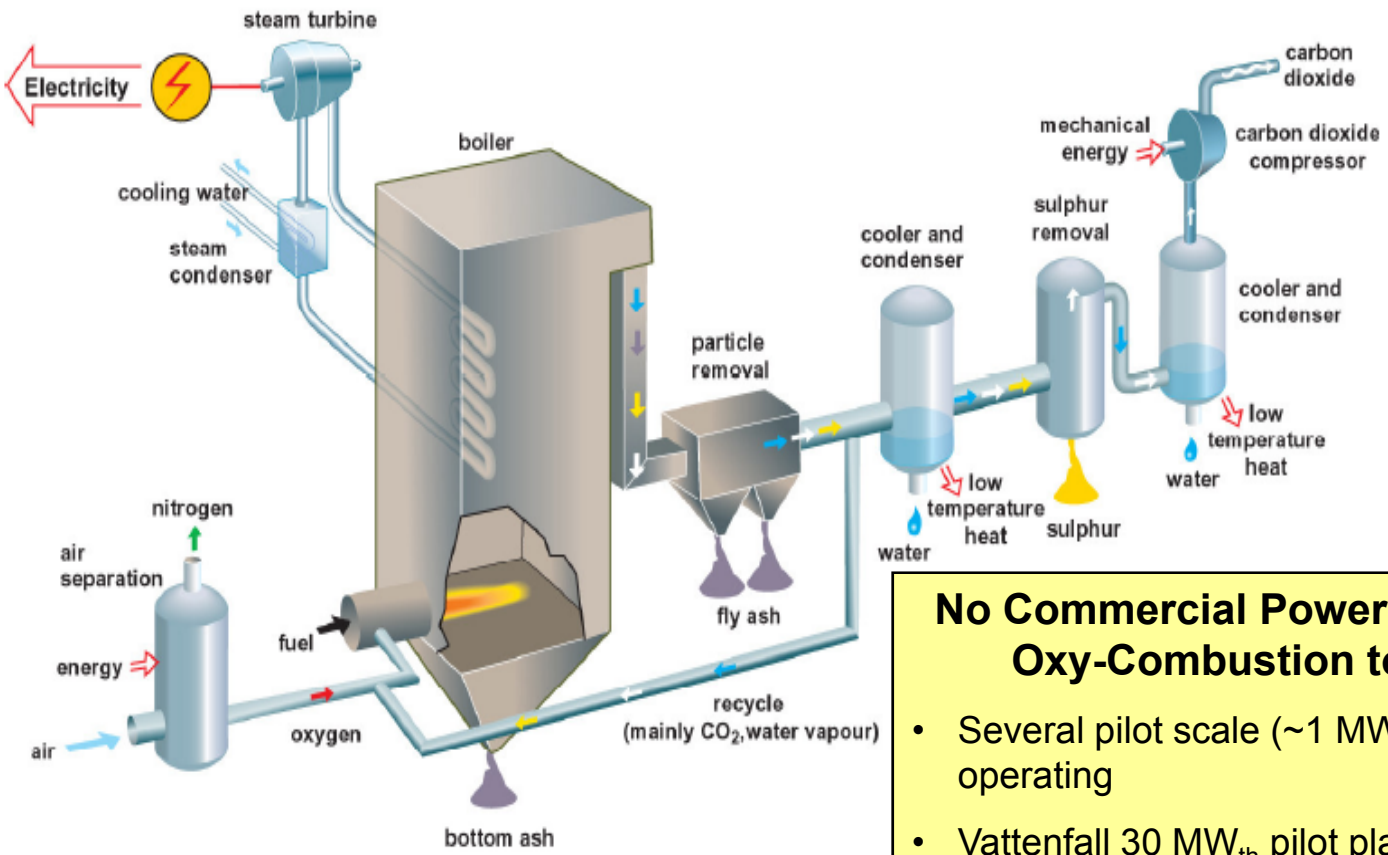
Oxy-Combustion Capture Status

O_2/CO_2 recycle (oxyfuel) combustion capture

Source: Vattenfall



No Commercial Power Plants use Oxy-Combustion today, but:

- Several pilot scale (~1 MW) test units operating
- Vattenfall 30 MW_{th} pilot plant operating
- B&W 30 MW_{th} test facility in Ohio

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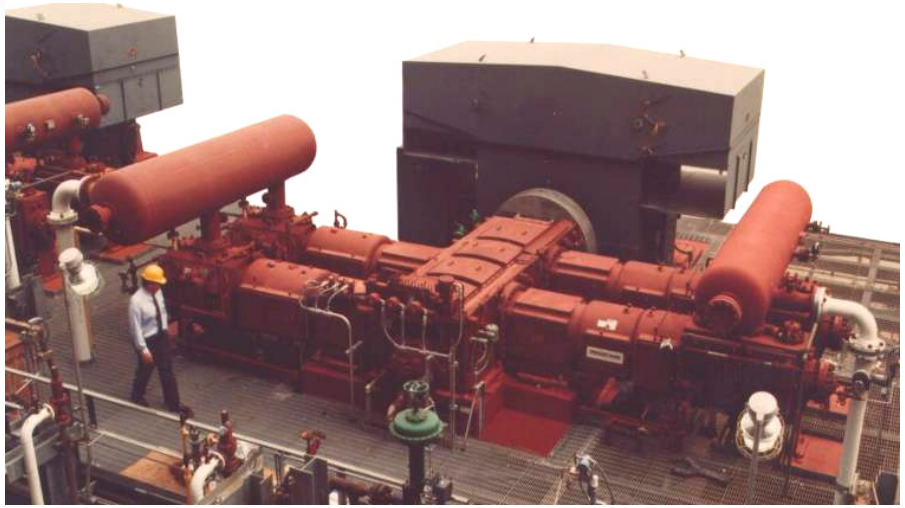
Compression and Transport



- Well established -- Multiple Proven Products
- R&D needed for CO_2 mixtures with impurities
- Novel Approaches
  - Isothermal compression + thermal integration into power plant
  - Combination of compression, liquefaction and pumping

- Postcombustion
  - Solvent slip, H_2O
- Gasification
  - May need added separation for H_2S
- Oxy-combustion
  - O_2, H_2O, SO_2 limits may add to process costs

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CO_2 Chain – Capture, Compression, Transport , Injection, Monitor, Verify, Remediate

- Many firms have responsibility for CO_2 at some point
- Few take charge of the full chain and look at how one link affects the next one up or down the line
  - Operation/design impact on constituents, conditions?
  - Impact of composition/condition on compression, phases, energy use?
  - Impact on transport design or meeting specifications?
  - Well design/ injection/ closure impacts?
  - Down hole chemistry, geology or use?
  - Liability /impacts of the material?

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No "Silver Bullet" "Silver Buckshot"

- No "**silver bullet**" technology for CO_2 capture for coal power plants.
  - Technology selection depends on location, coal, and application.
- IGCC/Shift often least cost for bituminous coals
- IGCC/Shift and PC plants with amine scrubbing usually ≈ COE for high-moisture subbituminous coals
- PC with amine scrubbing may be least cost for lignite
- Oxy-Combustion at developmental stage ➔ cost???
  - Overall COE probably ≈ PC + post combustion capture

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Questions

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