CURC

COAL UTILIZATION RESEARCH COUNCIL℠

Carbon Capture and Storage: A Technology Solution for Continued Coal Use in a Carbon Constrained World

Congressional Briefing
May 22, 2008
562 Dirksen Senate Office Building

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National Research Center for Coal and Energy

West Virginia University

CCS Technology Development Needs

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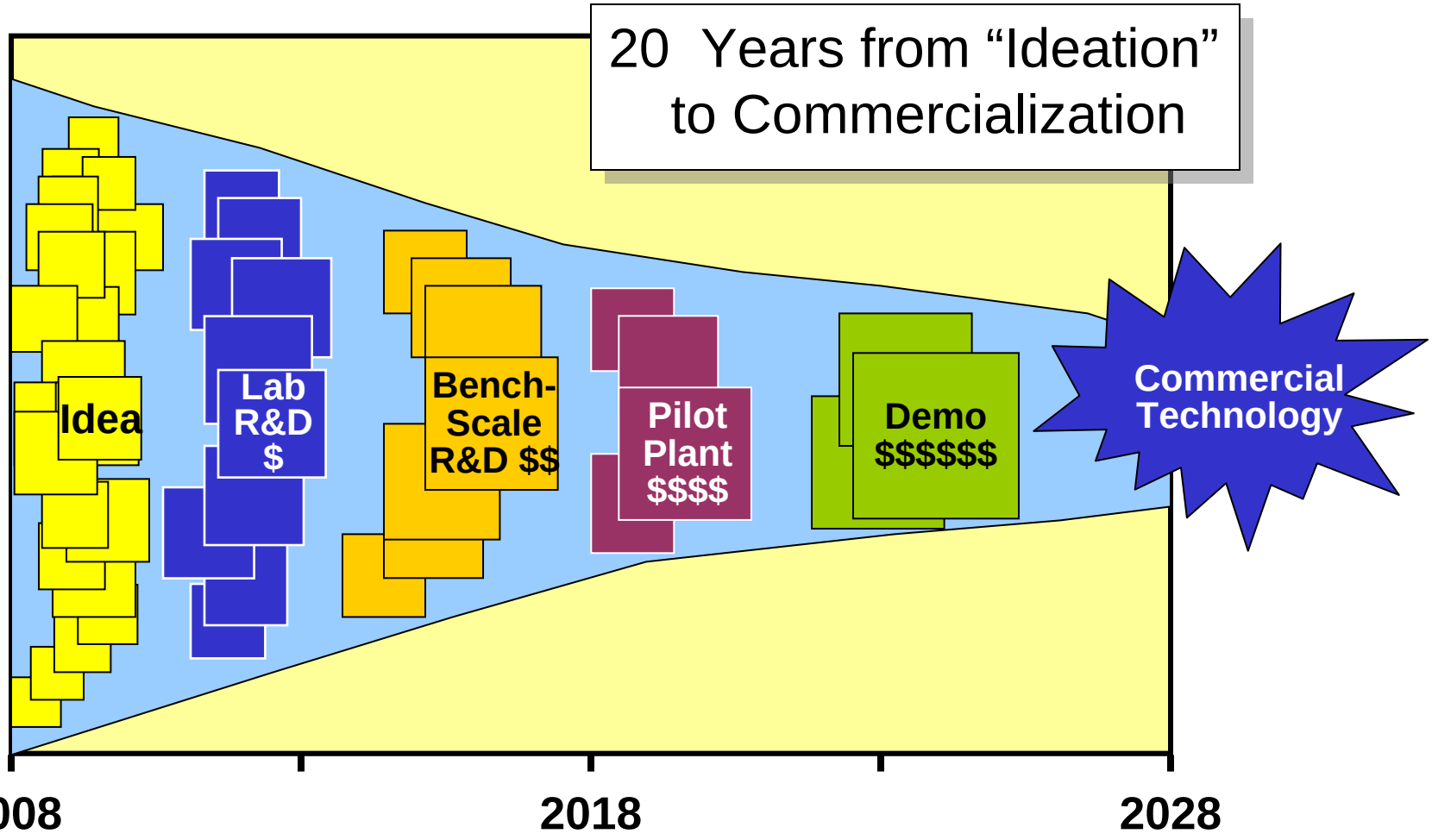
CURC Congressional Briefing on Carbon Capture and Storage
May 22, 2008
Washington, DC
File: Bajura-Briefing-05-22-08

Outline

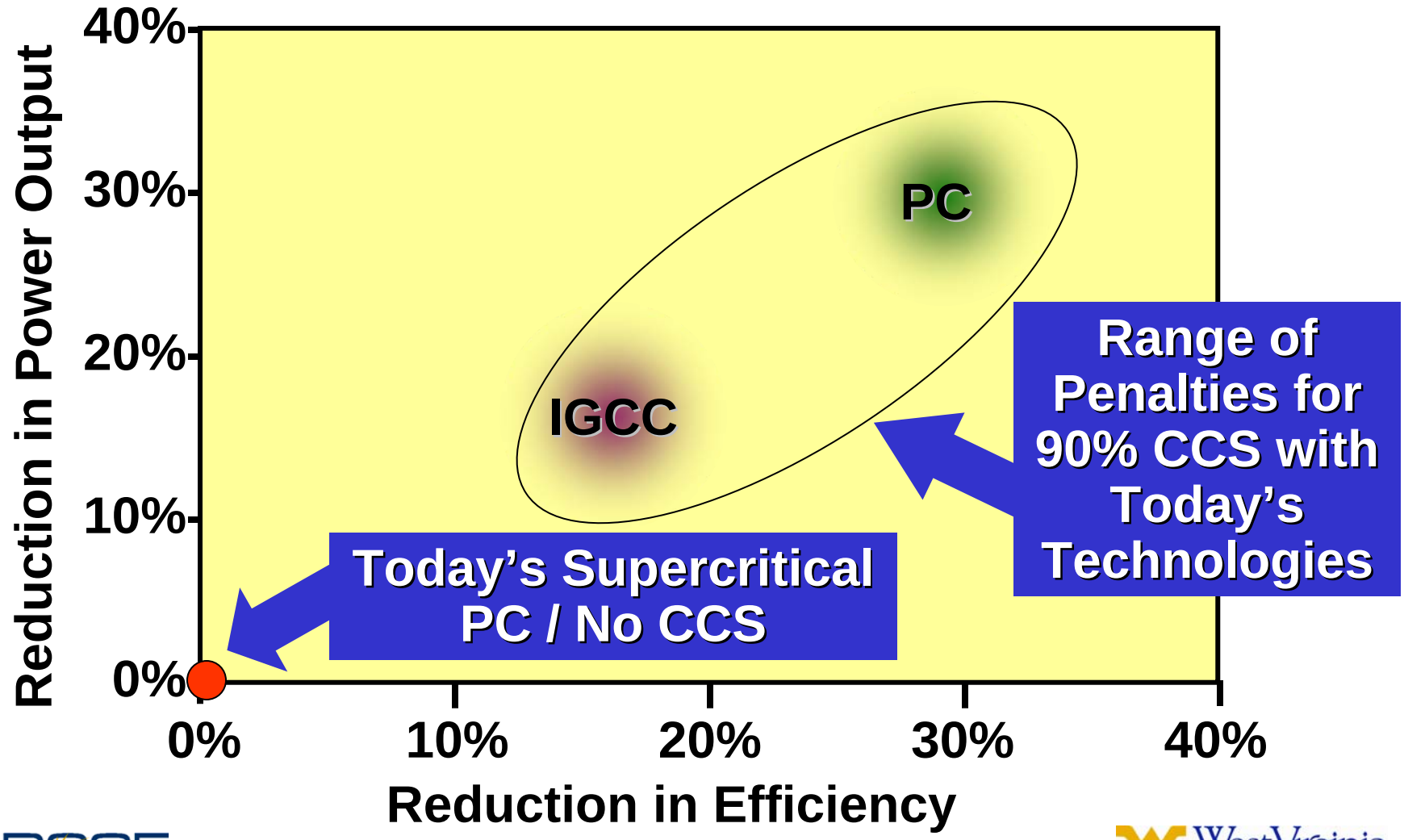
- RD&D context
- R&D needs
  - Combustion systems
  - Gasification systems
- Crosscutting R&D issues
  - Water
  - Carbon storage
- Benefits of RD&D

Timeline for RD&D on Power Generation Technologies



Performance Penalties for CCS

New Plant Applications



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Based on Cost and Performance Baseline for Fossil Energy Plants, NETL 2007

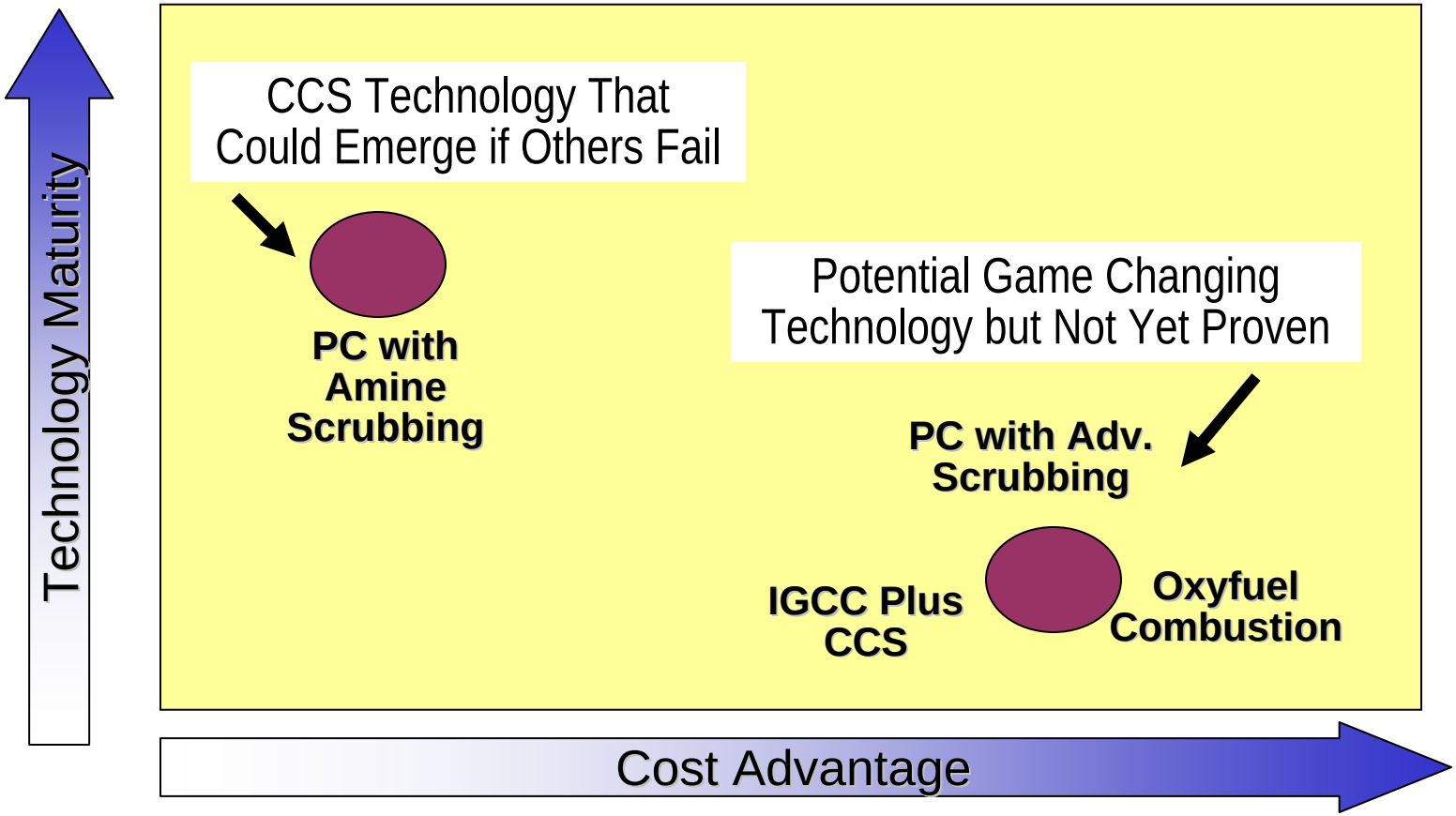
Role of RD&D

- If we had to use today's technology for 90% CCS:
  - Less power output, lower efficiency and higher capital cost
  - COE increases 60-80%* a.c.w. a new supercritical PC without capture
- New technologies show promise to reduce the incremental COE cost increase to 30%

Public & private investments in RD&D are needed to develop and deploy advanced technologies

** Cost and Performance Baseline for Fossil Energy Plants, NETL 2007*

Risk Profile of Emerging CCS Technologies



- Multiple technologies need to be developed

*Based on Emerging Energy Research report July 2007

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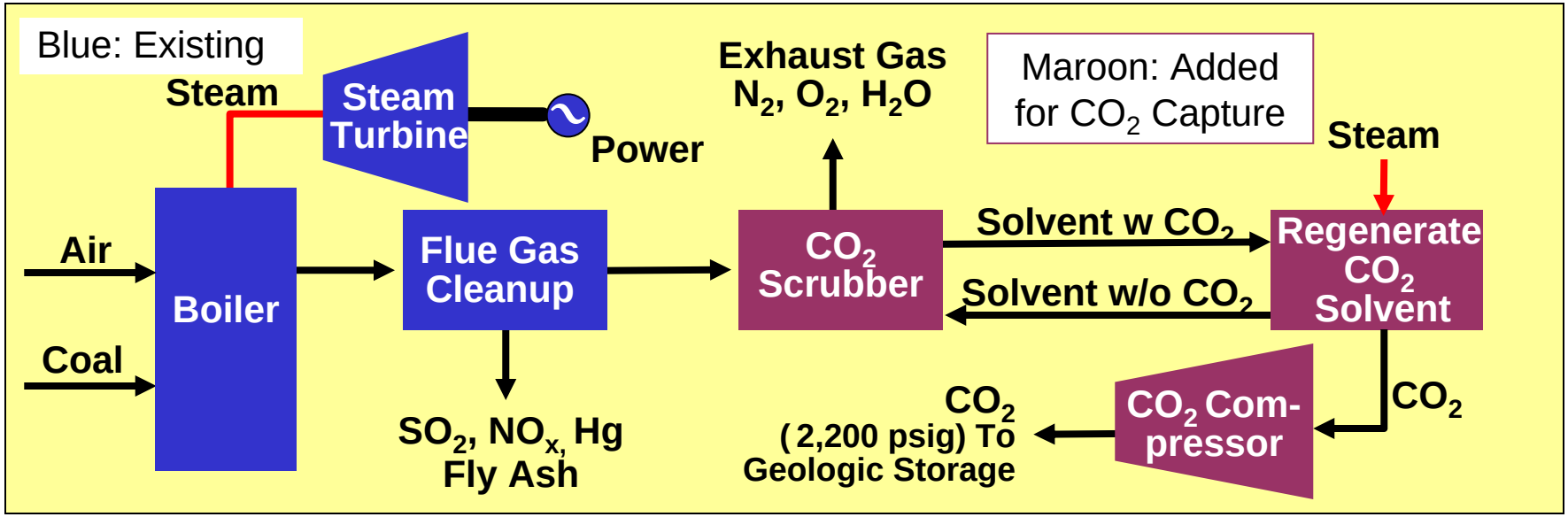
Pulverized Coal Plant (PC) with CO_2 Capture



R&D Challenges

- CO_2 capture
  - Large volume of flue gas containing low levels of SO_2, NOx, ash
  - High steam consumption to regenerate current CO_2 solvents
- Efficiency improvement

Post-Combustion CO_2 Capture

Current technology

- Monoethanolamine (MEA) scrubbers
- Small scale units at 3 U.S. coal plants

RD&D Needs

- Less energy intensive systems to remove CO_2 from flue gas

AES Warrior Run in MD
- Captures 10% CO_2
- 205 MWe CFB

AES Shady Point in OK
- Captures 2-3% CO_2
- 320 MWe CFB

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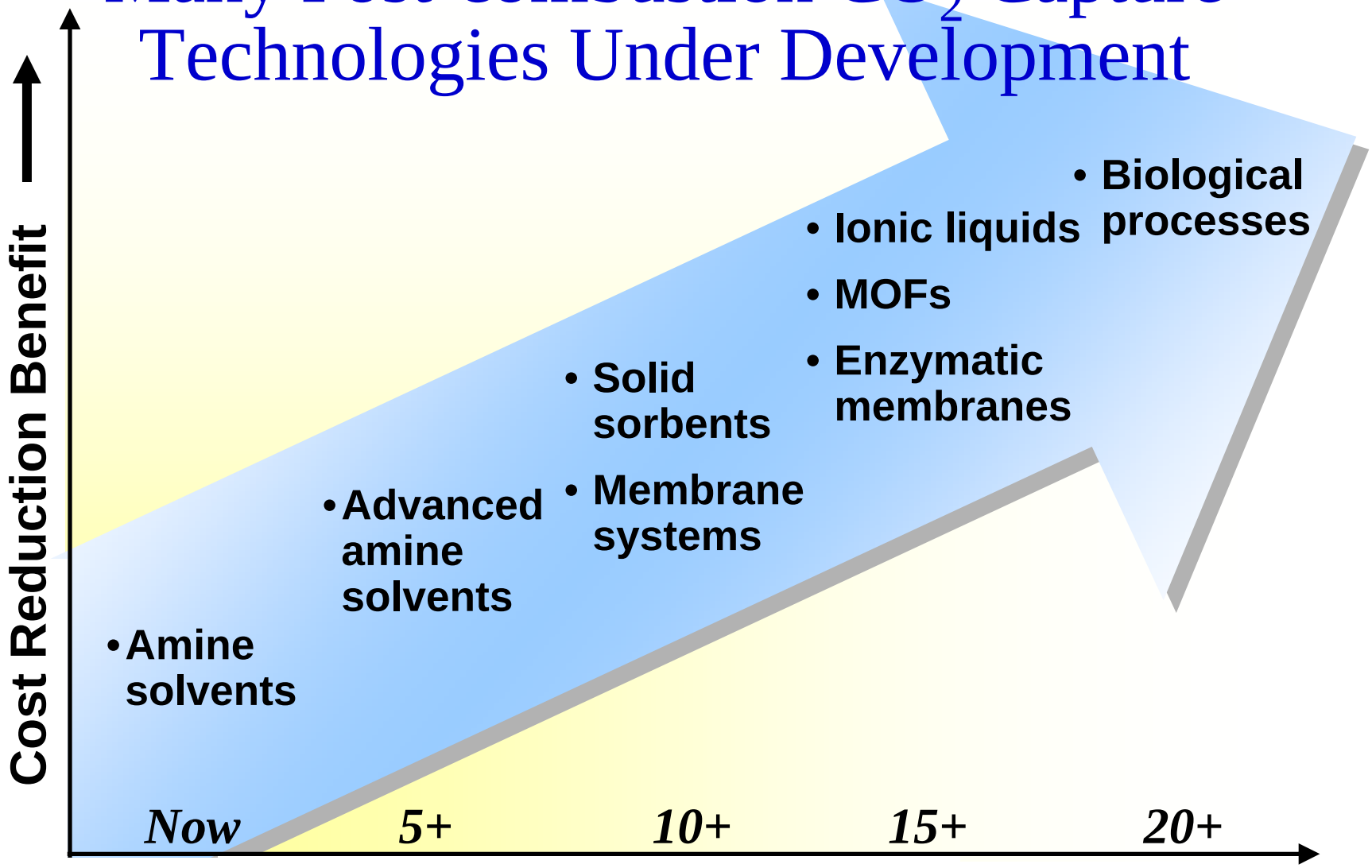
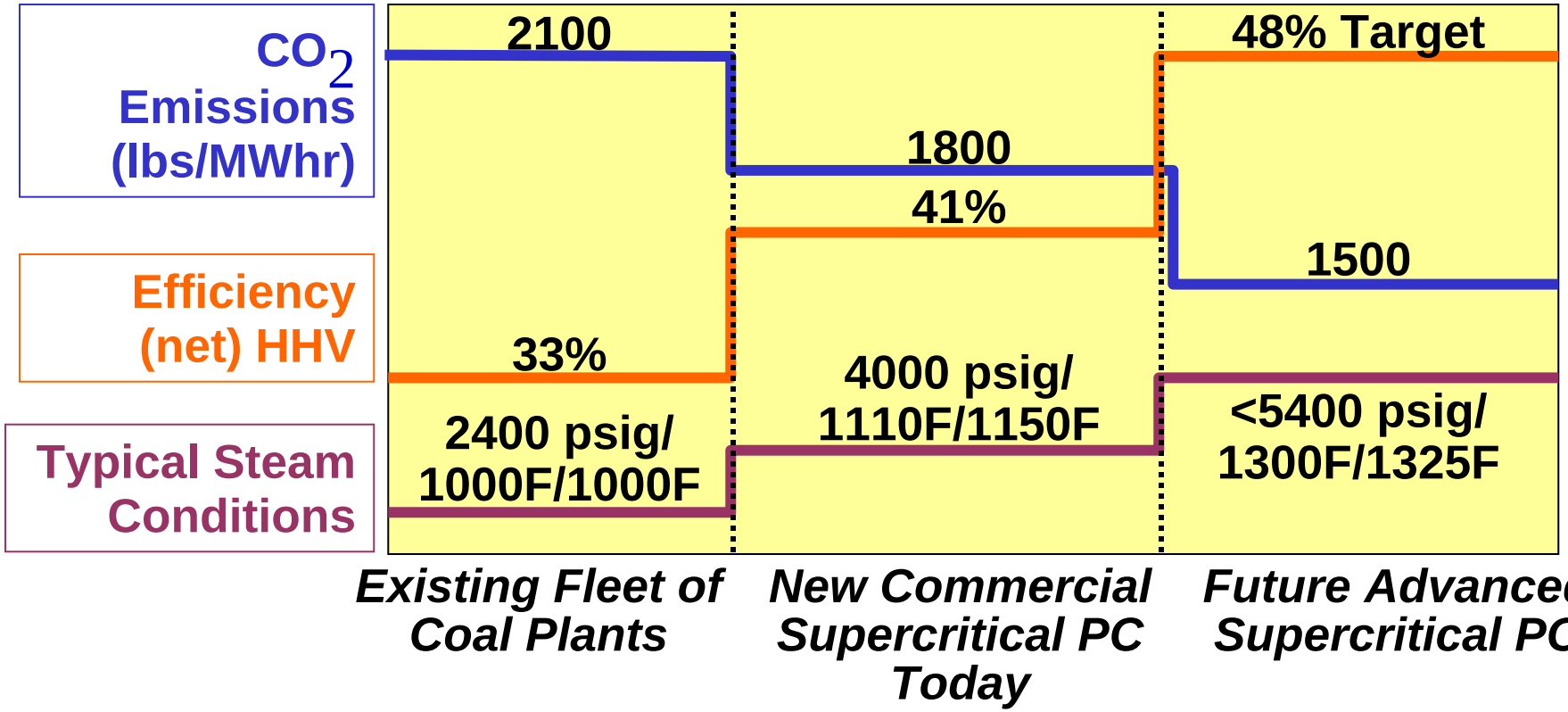
Photos: J. Strakey who cited AES and E.S. Rubin, Carnegie Mellon as sources

Many Post-combustion CO_2 Capture Technologies Under Development



Higher PC Efficiency ➡ Lower CO_2 Emissions



R&D Needs for High Efficiency PC Plants

- Advanced materials for boilers & turbines
- New boiler and turbine designs
- Plant optimization

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Based on Alstom graphic

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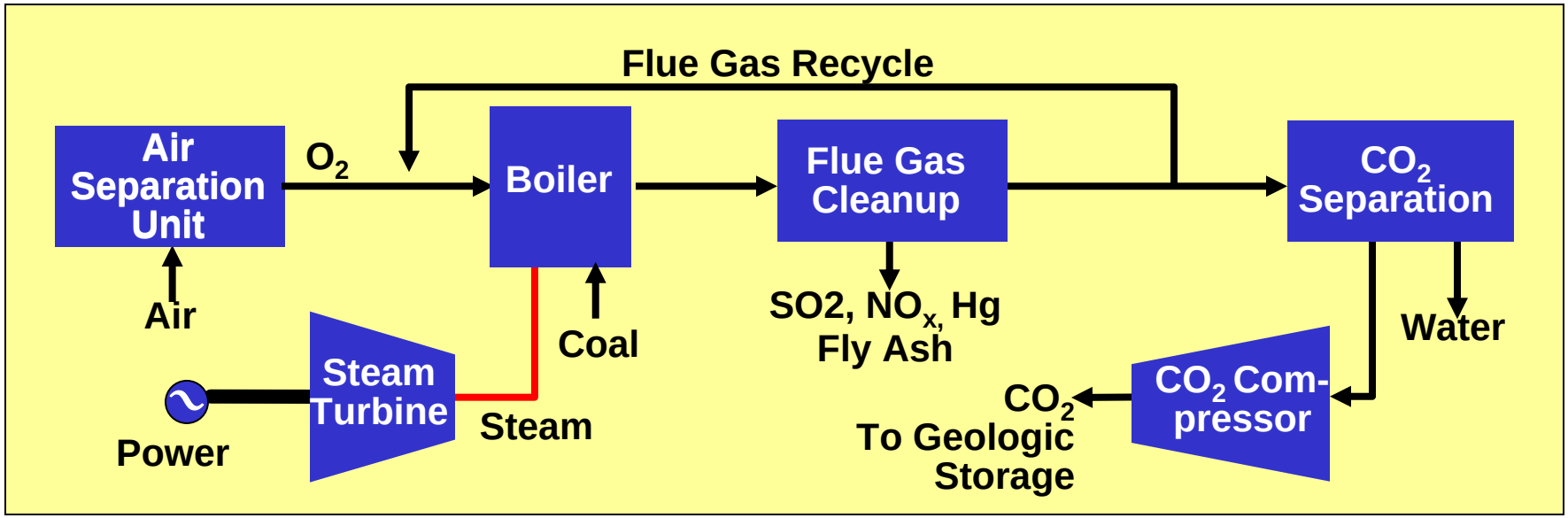
Oxyfuel Combustion with CO_2 Capture



R&D Challenges

- Optimize CO_2 recycle rate and oxygen purity requirements
- Feasibility of co-sequestering CO_2/NOx/SOx (delete flue gas cleanup process)
- Retrofit designs

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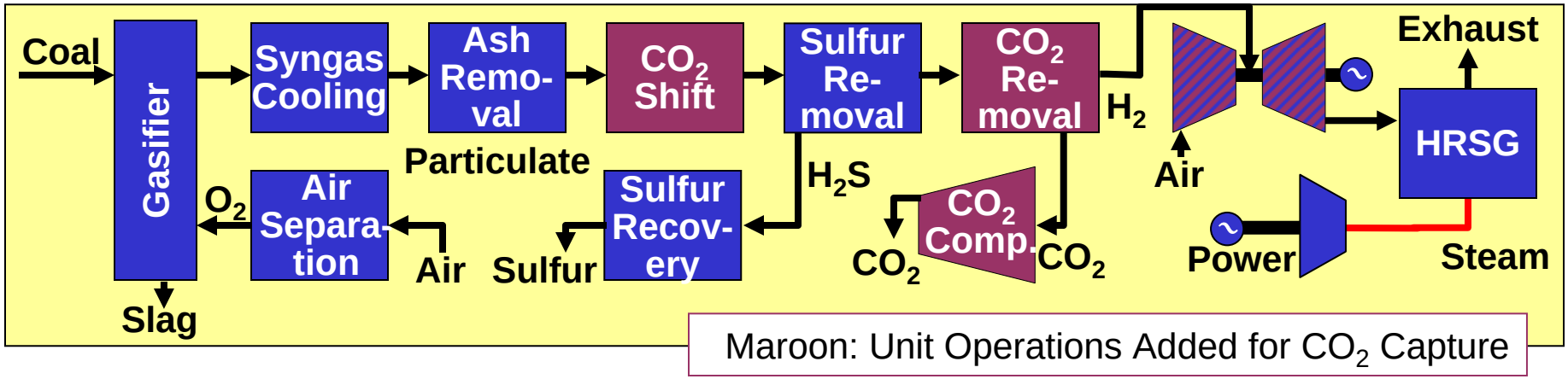
IGCC with CO_2 Capture



Today's IGCC technology w/o capture

- As efficient as supercritical PC
- Very clean

BUT . . .

- Lower availability of gasification block than PC system
- Capital cost 20-30% higher than PC
- Higher COE than PC

- IGCC is a less mature technology than PC
- Worldwide, four IGCC plants operating on coal
- Hundreds of gasifiers

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Benefits from RD&D for IGCC

- Potential least-cost option for low CO2 emissions coal power
  - With capture, IGCC COE is 10% less than PC* based on current IGCC and PC technologies
  - As an emerging technology, IGCC has much room for improvement in efficiency, reliability, cost
- Flexibility—provides a syngas with multiple uses
  - Fuels
  - Chemicals
  - Hydrogen

** Cost and Performance Baseline for Fossil Energy Plants, NETL 2007*

R&D Needs for IGCC

Lower-Cost O_2 Production
- Current cryogenic separation is reliable
- BUT it's 15% of capital cost
- Consumes 15% power

Better Gasification
- Improve reliability so spares not needed
- Advanced designs for low-rank coal
- Better refractory and syngas coolers

CO_2 Capture
- Technologies that use less auxiliary power

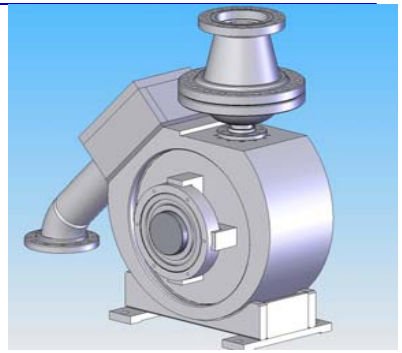
Fuel Gas Cleanup
- Warm gas cleaning could improve efficiency by ~3 % points over current cold cleanup

Fuel cells
- Decrease cost
- Increase size

Combustion Turbines
- Higher temperature operation
- Use of high-H_2 content fuel in large turbines
- Lower NOx w/o SCR

ITM Air Separation
5 TPD test at APCI's Sparrows Point gas plant

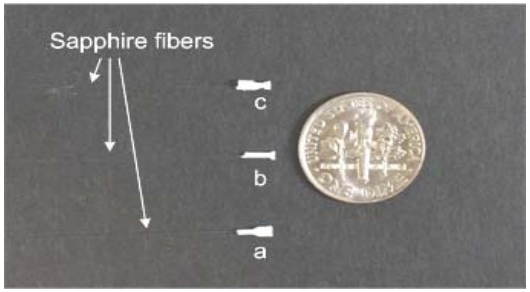
Advanced Refractories For Gasifiers
Target is refractory material that lasts years, rather than months



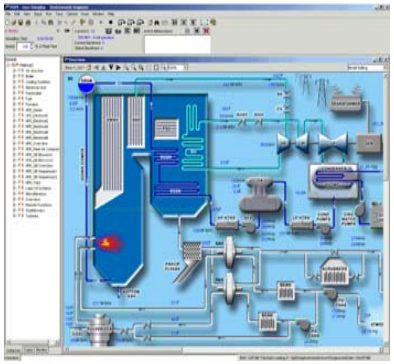
Dry Coal Feed System for Gasifiers
Reduces thermal losses with slurry feed and low-rank coals

Current R&D

Warm-gas Cleanup - Integrated testing at Tennessee Eastman's gasification plant



Temperature Sensor for Gasifier
VPI&SU developed single crystal high temp. sapphire sensor (up to 1600 C)



IGCC Simulator
Full-scope, high-fidelity, real-time generic IGCC plant with CCS

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Water & Electricity Inextricably Linked

- Coal technologies use water for:
  - Cooling
  - Emission control
  - Coal mining
  - Coal cleaning

R&D Needs

- Develop new materials & processes to treat & use nontraditional, brackish or produced water
  - Saline reservoirs or mine pools
- Reduce or eliminate water use
- Deliver water more efficiently

Goals of Water R&D

- Reduce fresh water consumption
- Both surface and ground water

Lake Lanier, Sept. 2007
Atlanta's Water Supply

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Technical Challenges for Carbon Storage

I - Pre-operation

- More sophisticated characterization than is now common

II - Site Operation

- Continual monitoring of entire injection field
- Surface surveillance and leak detection
- Criteria for identifying problems
- Strategies for addressing problems

III - Site Closure

- Criteria for establishing when closure is appropriate
- Procedures for closure
- Monitoring needs
- Remediation technology if needed

IV - Long-term Stewardship

- Criteria for acceptance into long-term stewardship
- Monitoring needs

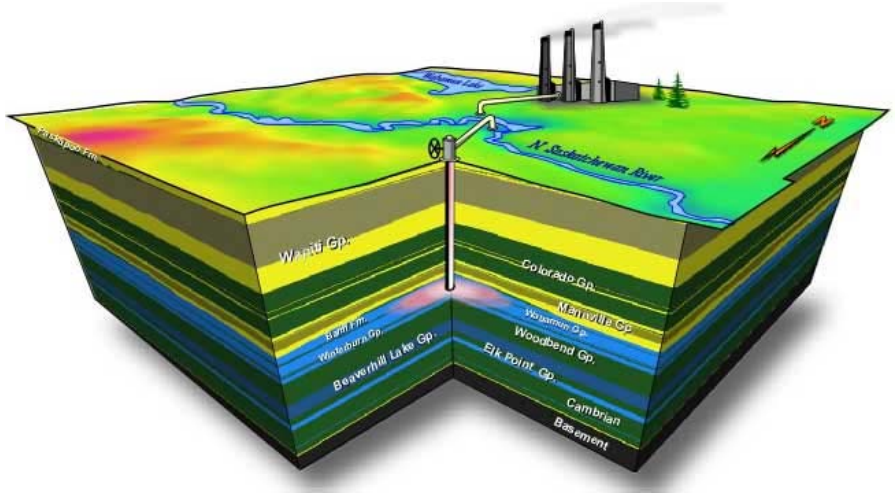
Four CO2 Storage Phases

Key Carbon Storage R&D Topics

- Trapping mechanisms/ optimization of injection
- Monitoring & verification
- Long-term interaction of CO_2 with formation

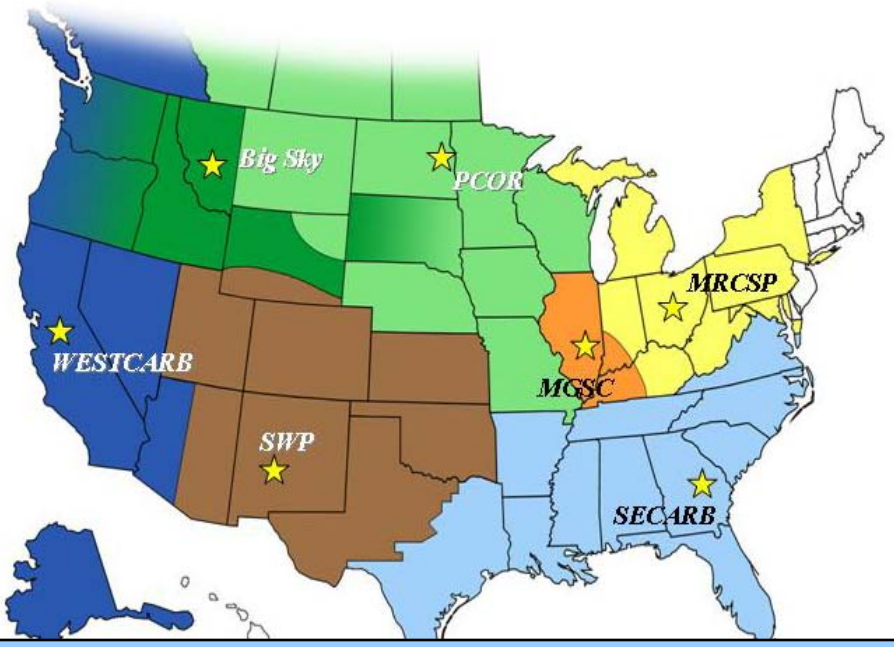
Address Societal Concerns

- Liability
- Health
- Public acceptance



Sketch from Alberta Geologic Survey website

Seven Regional Partnerships



Three Phases

Characterization (’03-’05)
- Completed

Validation (’05-’09)
- 24 field validation tests underway

Deployment (’08-’17)
- 7 large injection tests in different geologic formations (6 awards, 1 in procurement)

Partnership goals

- Engage regional, state, local governments
- Determine regional sequestration benefits
- Baseline region for sources & sinks
- Establish monitoring and verification protocols
- Address regulatory, environmental, & outreach issues
- Validate sequestration technology & infrastructure

- **>350 Organizations**
- **41 States**
- **4 Canadian Provinces**
- **3 Indian Nations**

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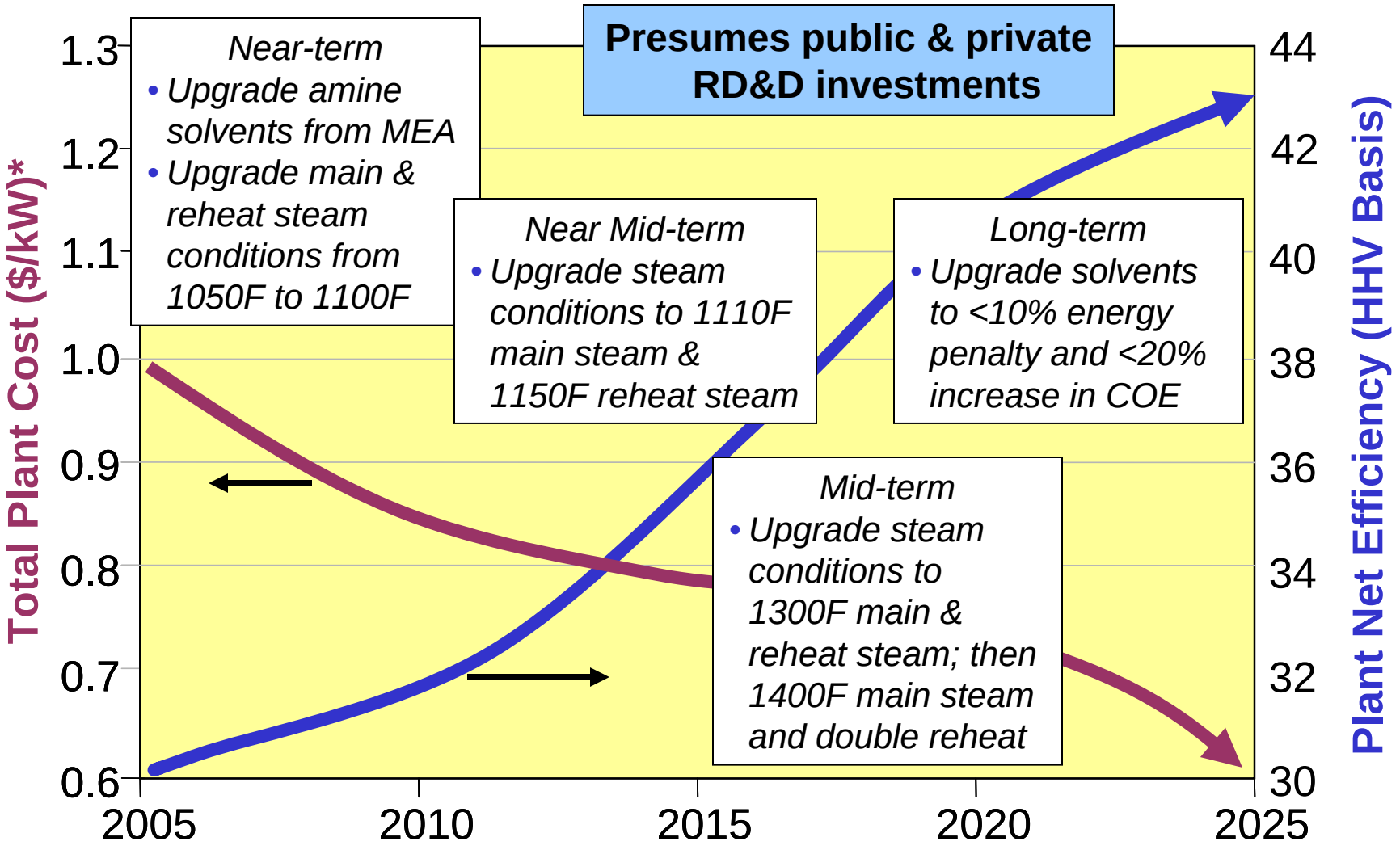
CURC-EPRI RD&D Roadmap

An industry written, long-term RD&D blueprint that identifies what needs to be done to develop & deploy technologies

- Enable industry to generate cost-effective electricity from coal with CO_2 capture
- Control emissions of SO_2, NOx, mercury, particulates and CO_2 to near zero levels

Road Map Proposed for RD&D in PC Systems



*Constant dollars normalized to 2005 plant cost

Estimates based on EPRI chart

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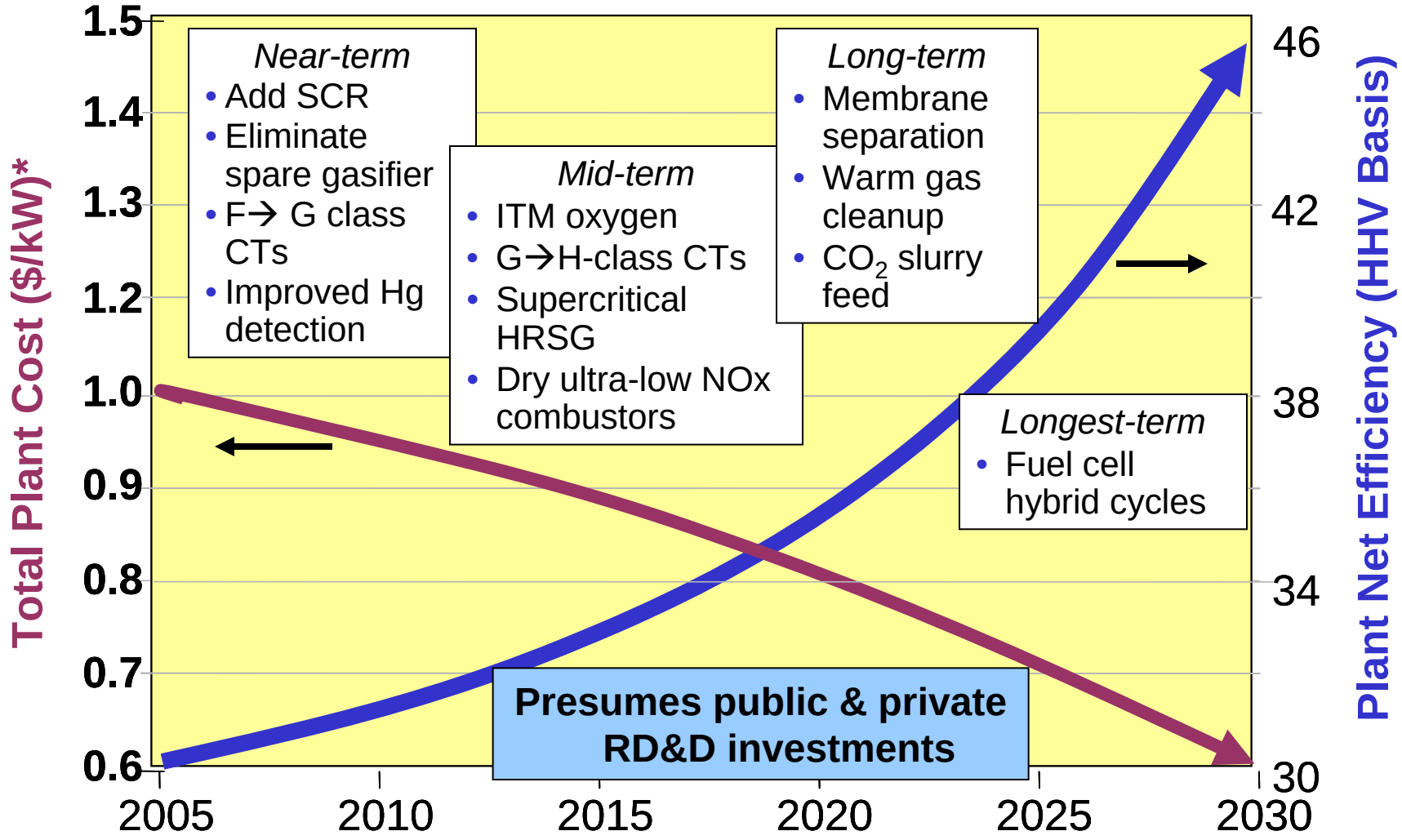
Road Map Proposed for RD&D in IGCC



*Constant dollars normalized to 2005 plant cost

Estimates based on EPRI chart

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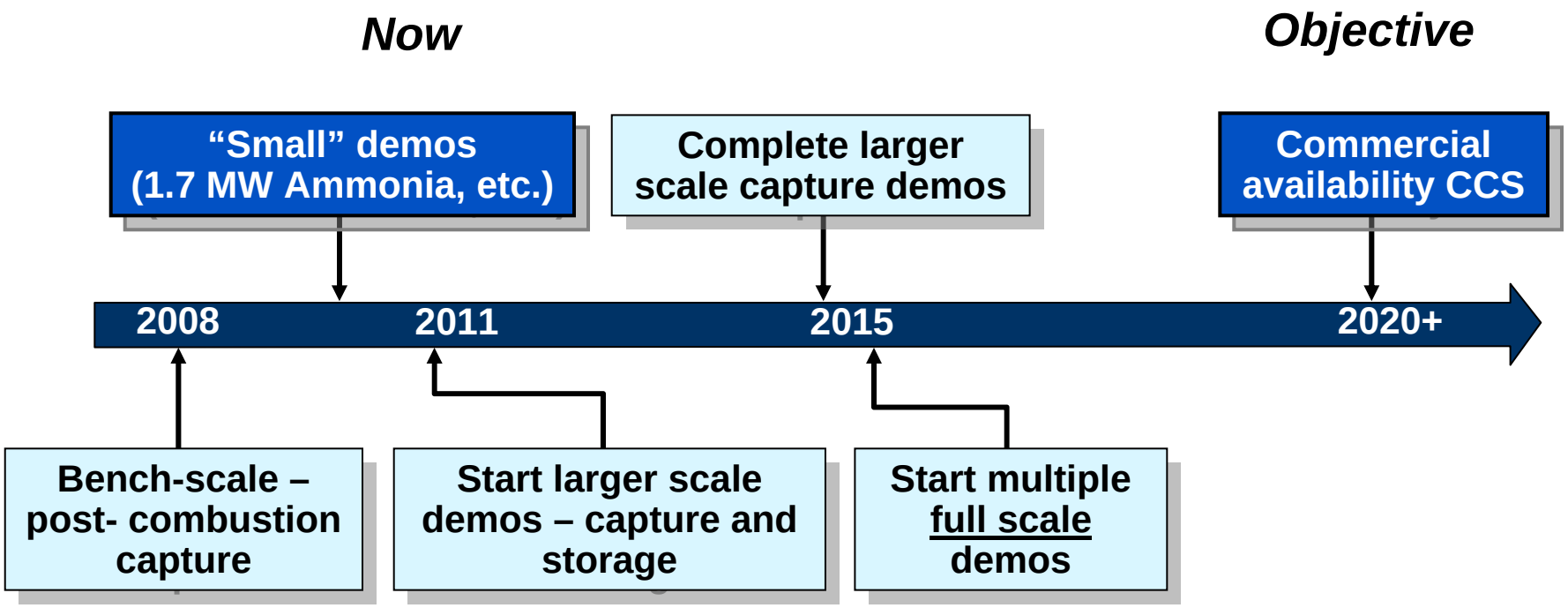
Roadmap for CO_2 Capture and Storage



Needs: Multiple large-scale CAPTURE and STORAGE demos

Timing: 2020 objective ➔ start today, parallel paths

Realistic? A challenge – need technical, policy, funding alignment

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Source: DOE-NETL Carbon Sequestration R&D Roadmap Modified by EPRI to add Chilled Ammonia example

Funding Needs – RD&D Roadmap ($B)

	R&D	Demos	TOTALS
FutureGen	1.5		1.5
IGCC	1.2	4.0	5.2
Combustion	0.6	4.6	5.2
IEP*	0.5	1.2	1.7
Carbon Storage	0.2	Low CO_2 - 1.1 High CO_2 - 1.5	Low CO_2 - 1.3 High CO_2 - 1.7
Fuel Cells	0.7	0.9	1.6
Turbines	0.5	0.4	0.9
TOTALS	5.1	12.2 - 12.6	17.3 - 17.7

~$17.5 Billion through 2025
Federal Share ~ $10.5 Billion
Industry Share ~ $7 Billion

*Innovations for Existing Plants

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