An Industry Perspective on Coal and CCS

Power

Industrial

Polygen

MIT-NESCAUM Symposium

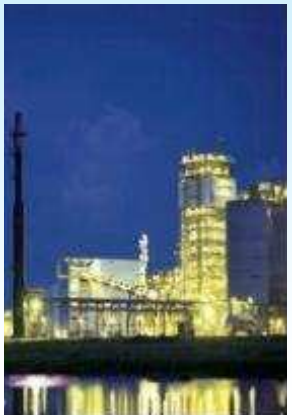
New Directions in Energy Policy and Impacts on Air Quality

imagination at work

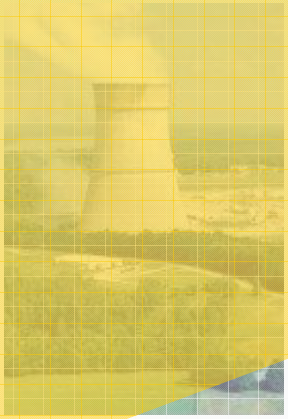
There is no "silver bullet"

Gas

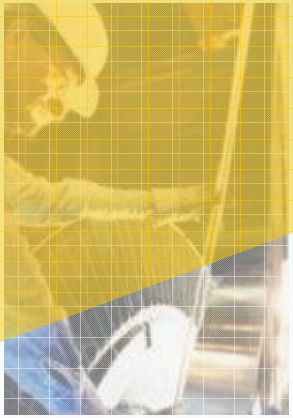
Bioma



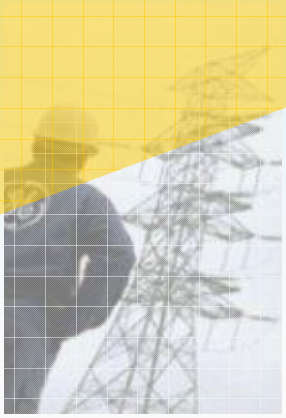
Cleaner Coal



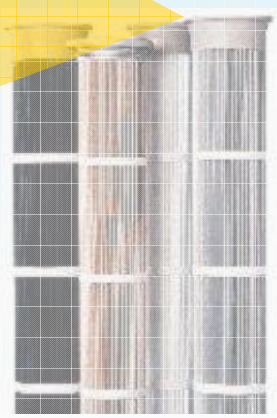
Nuclear



Asset Optimization



Network Reliability



Environmental Services

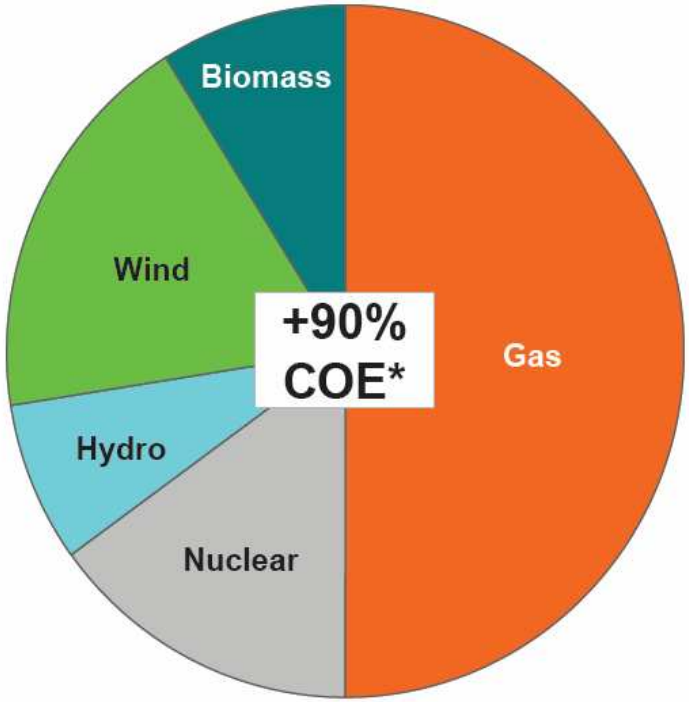
Coal technology focus

- CAPEX
- CO2
- Cycle time
- Fuel envelope

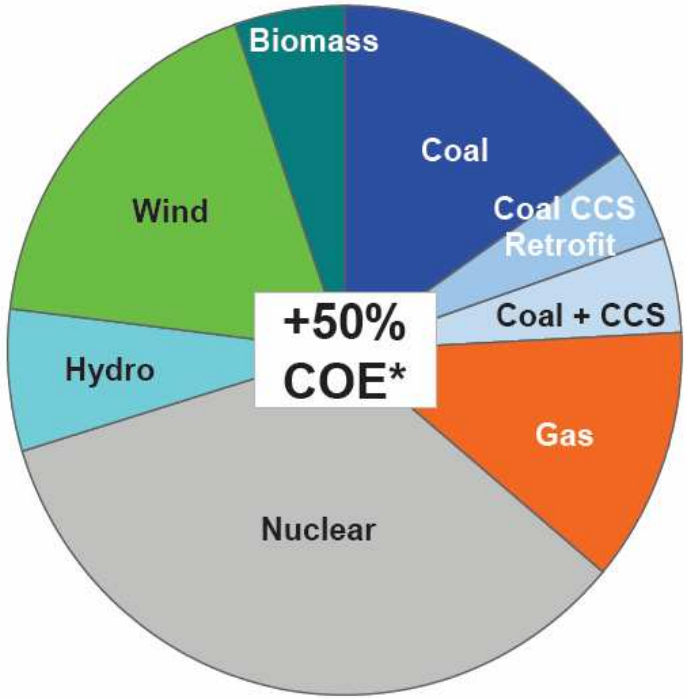
EPRI 2009 PRISM/MERGE Analysis -2030

Impact of limited carbon management technology portfolio at 2030

Remarkably different futures…and only 20 years away!



Limited Portfolio



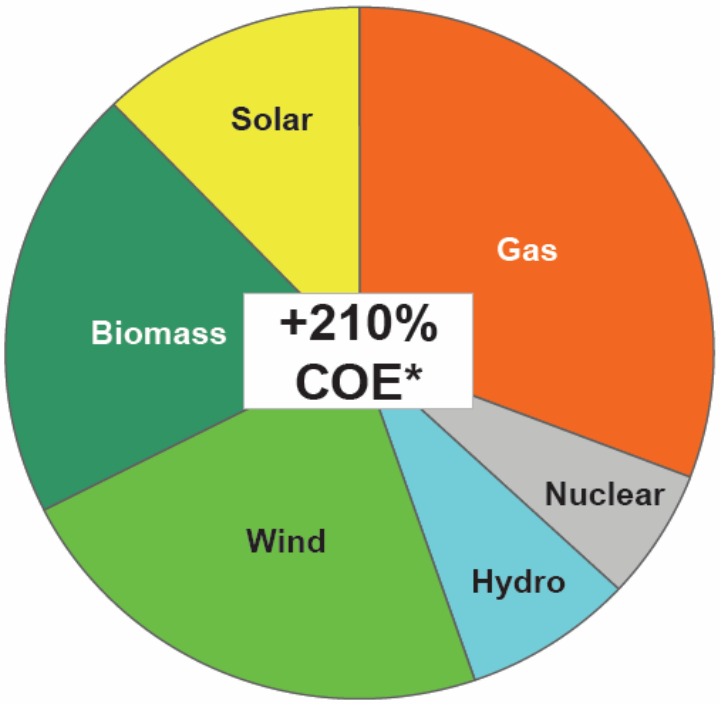
Full Portfolio

** Cost of electricity increase relative to 2007*

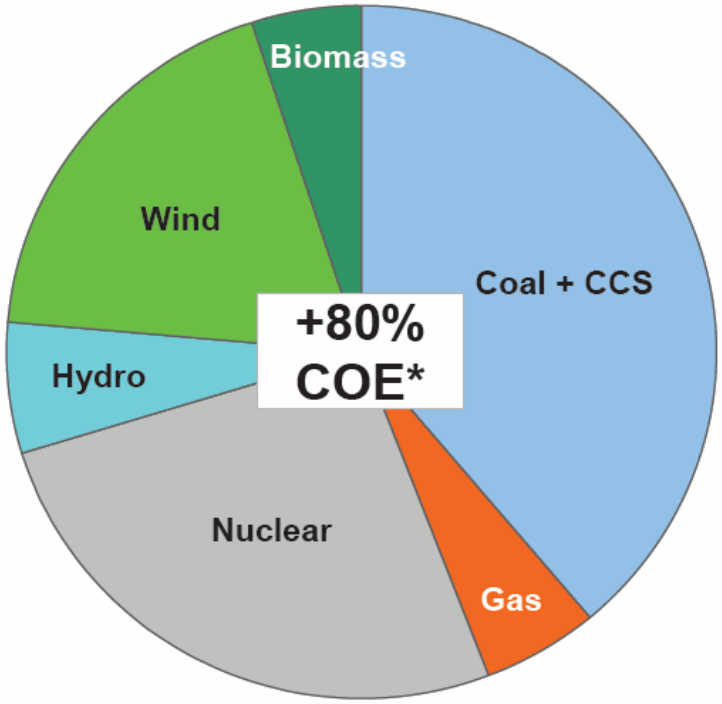
EPRI ELECTRIC POWER RESEARCH INSTITUTE

EPRI 2009 PRISM/MERGE Analysis - 2050

Totally different futures in 2050



Limited Portfolio



Full Portfolio

** Cost of electricity increase relative to 2007*

EPRI ELECTRIC POWER RESEARCH INSTIT

Coal: a critical but challenged resource

- "Coal is a national and globally abundant, low cost resource that is and will continue to be a predominant generation choice in developing nations."

John Krenicki, GE Vice Chairman

Testimony before the Environment & Public Works Cmte, U.S. Senate, July 16, 2009

- "Coal is an abundant, reliable, and a relatively inexpensive energy source. Using it is necessary for energy independence and US competitiveness."

John Rice, GE Vice Chairman

The utility's dilemma

Legislative & regulatory uncertainty

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

Political & enviro *"Give me carbon capture NOW"*

Carbon credit pricing, incentives & costs

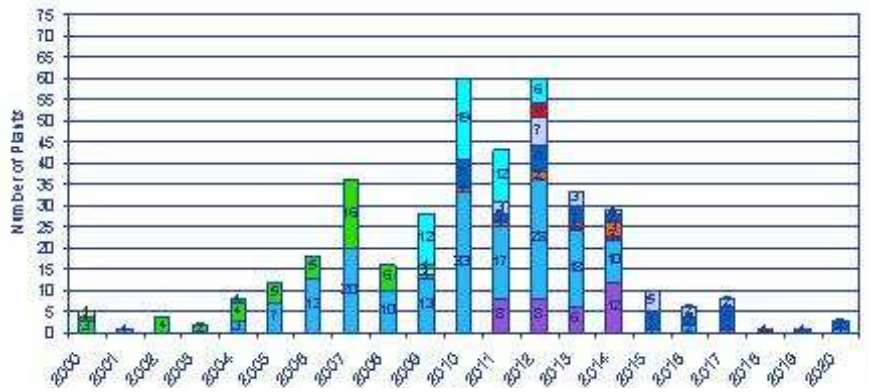
Return & safety for shareholders

Technology readiness

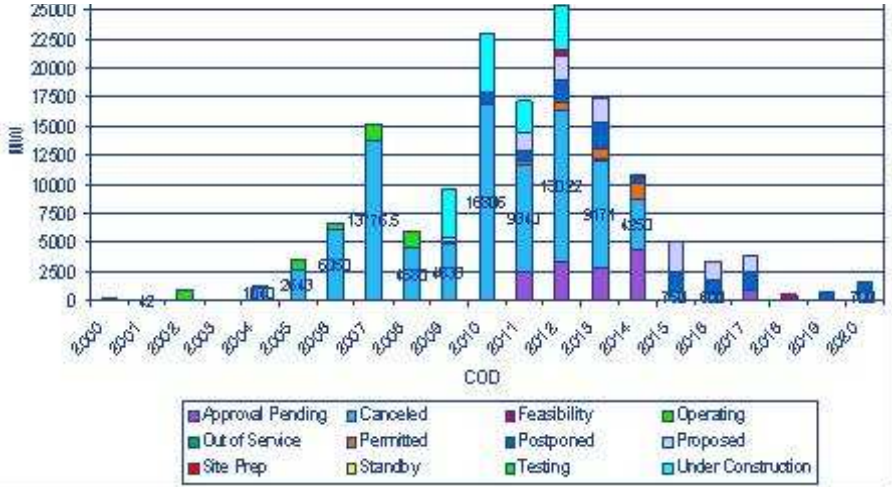
Reality –coal is disappearing as an option

- Since 2001 the coal industry has had 177 plants and a total of 87GW cancelled
- Aging coal fleet – 32% average efficiency
- New coal plants required to develop CO2 BACT analyses
- NSR fines and even shutdowns of existing plants

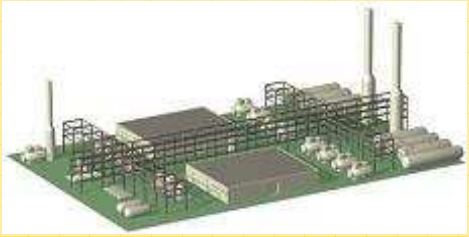
Numbers of Plant Cancellations



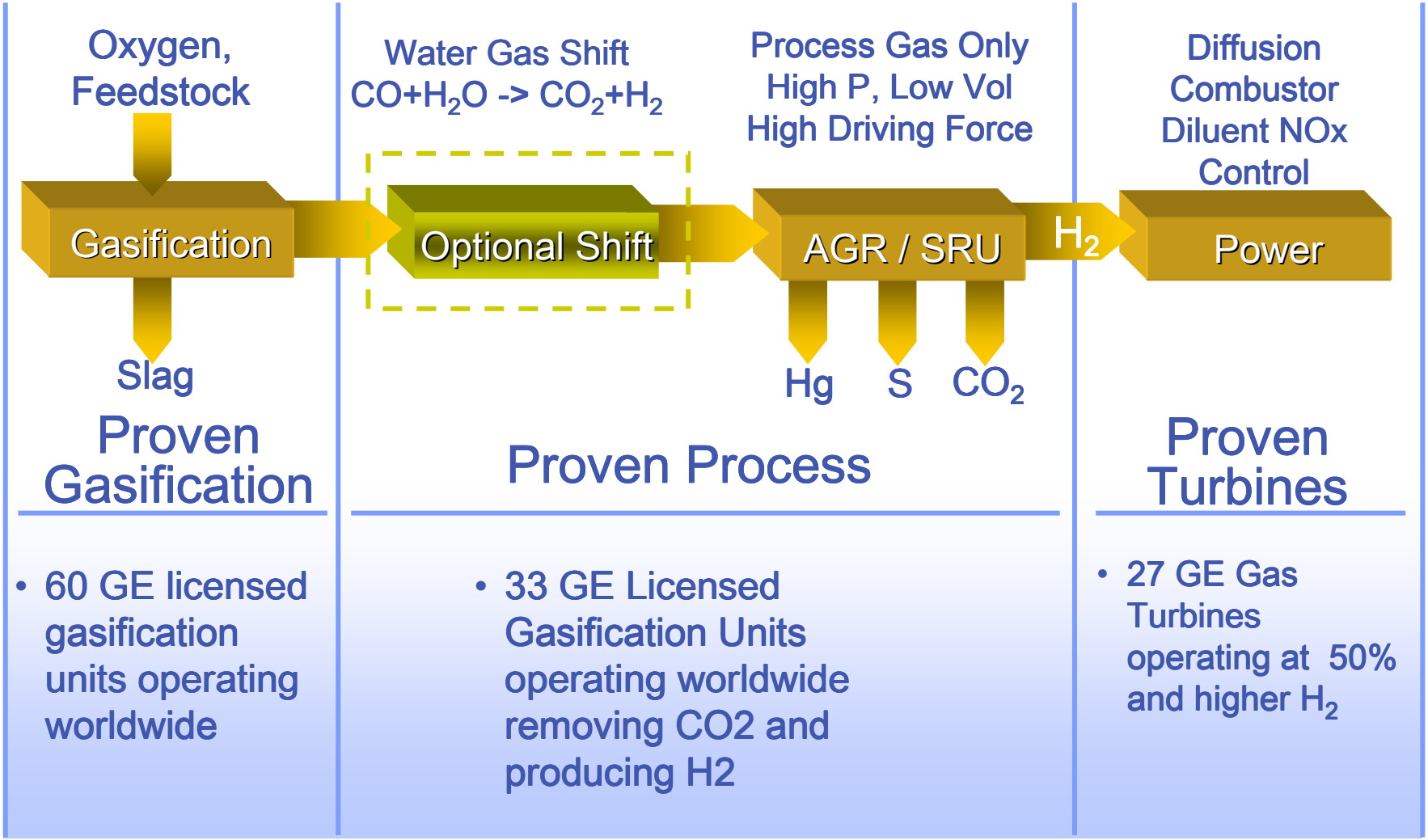
MW of Plant Cancellations



Investing and Delivering for Coal Growth

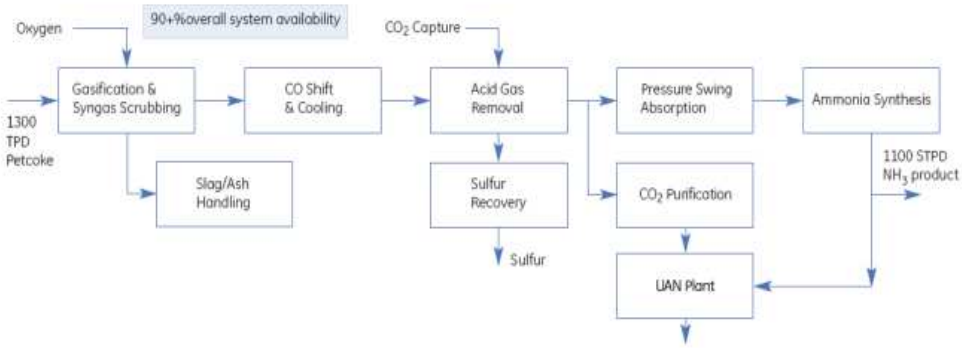
IGCC 630 MW Plant	630MW net 38.5% HHV Carbon capture ready In construction at Edwardsport	
GE Carbon Island ™	Carbon capture retrofit Natural gas equivalency Alliance with Schlumberger	
High Plains Technology Center	Expand IGCC fuel envelope Joint with U of Wyoming $100MM invest – 2012 COD	
207FB IGCC Power Block	Syngas 234MW GT 4 Flow G-33 ST CC Hydrogen capability	

IGCC CO_2 Capture Readiness



Example: Proxy for Power Carbon Capture

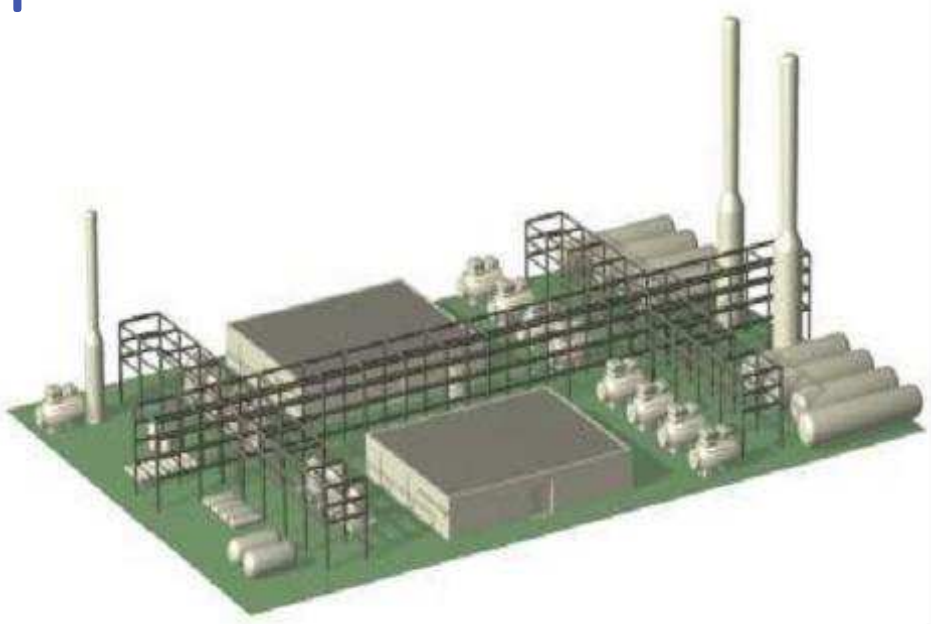
- **Coffeyville Resources (CVR)**
  - Nitrogen fertilizer
  - Licensed 1997; Start-Up 2000
  - Feedstock: Petroleum Coke
  - Design Capacity: 1,300 STPD
  - >90%+ system availability
- **Similar to IGCC with CO_2 capture:**
  - Selexol™ solvent
  - Gasifiers: 2 x 900 ft3 Quench
  - Operating Pressure: 620 psig (43 bar)
- **CO_2 Capture**
  - >90% capture (from shift effluent)
  - CO_2 meets Kinder-Morgan pipeline specification (EPRI analysis)
  - 30% of the CO_2 is compressed to 2,200 psia for fertilizer production



GE's Carbon Island™

- Commercially offered
- Greenfield or retrofit
  - Low cost/performance impact
  - Integrated with existing Acid Gas Removal (AGR)
  - Installed during turbine maintenance
- Flexible carbon capture options
- 585 MW output[1]
- 33% HHV Eff[2]
- Tie-ins matched GT outages

[1] From 630MW base
[2] From 38.5% base

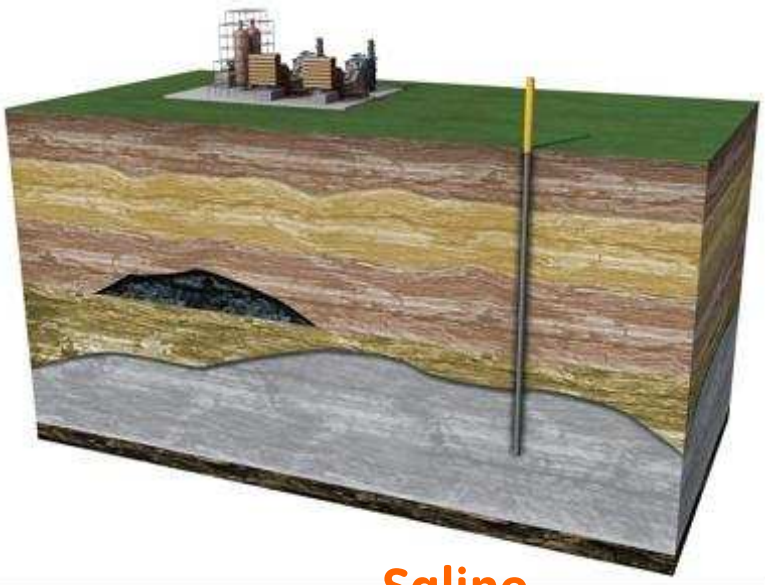


NG Eq. CO_2 Footprints

- Simple Cycle:
  50% carbon capture
  (~1,100 lb/MWh)
- Combined Cycle:
  65% carbon capture
  (~770 lb/MWh)

GE & Schlumberger Alliance

IGCC Plant



Saline Reservoir

Total Carbon Solution

- Schlumberger: site selection, characterization, design & construction, monitoring, decommissioning
- GE: IGCC & carbon capture

Alliance Benefits

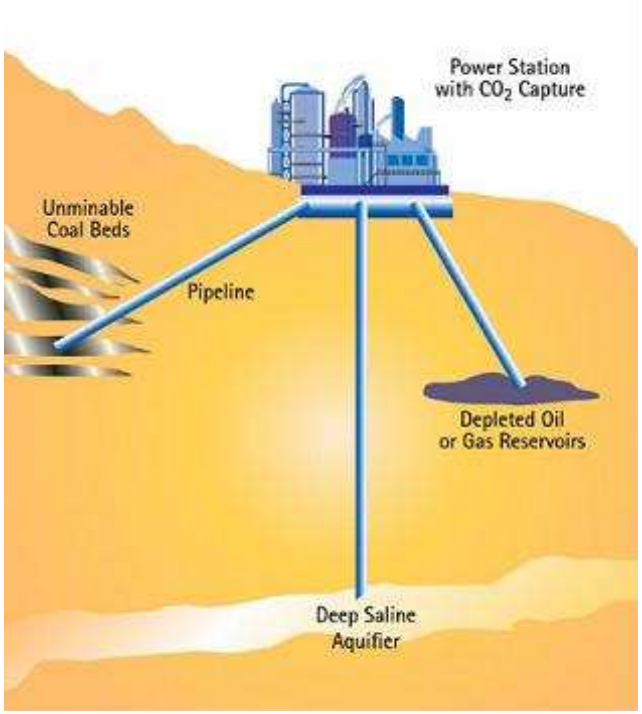
- Aligns buying cycle
- Coordinates engineering & construction of storage & facility
- Integrates operations/maintenance profile
- Develops CO_2 specs based on specific projects and geologic formation

Purpose

- Accelerate the use of IGCC with CCS technology
- Technical & commercial certainty for coal-based power generation

The future of CCS

Will Carbon Capture and Storage Become Mainstream?

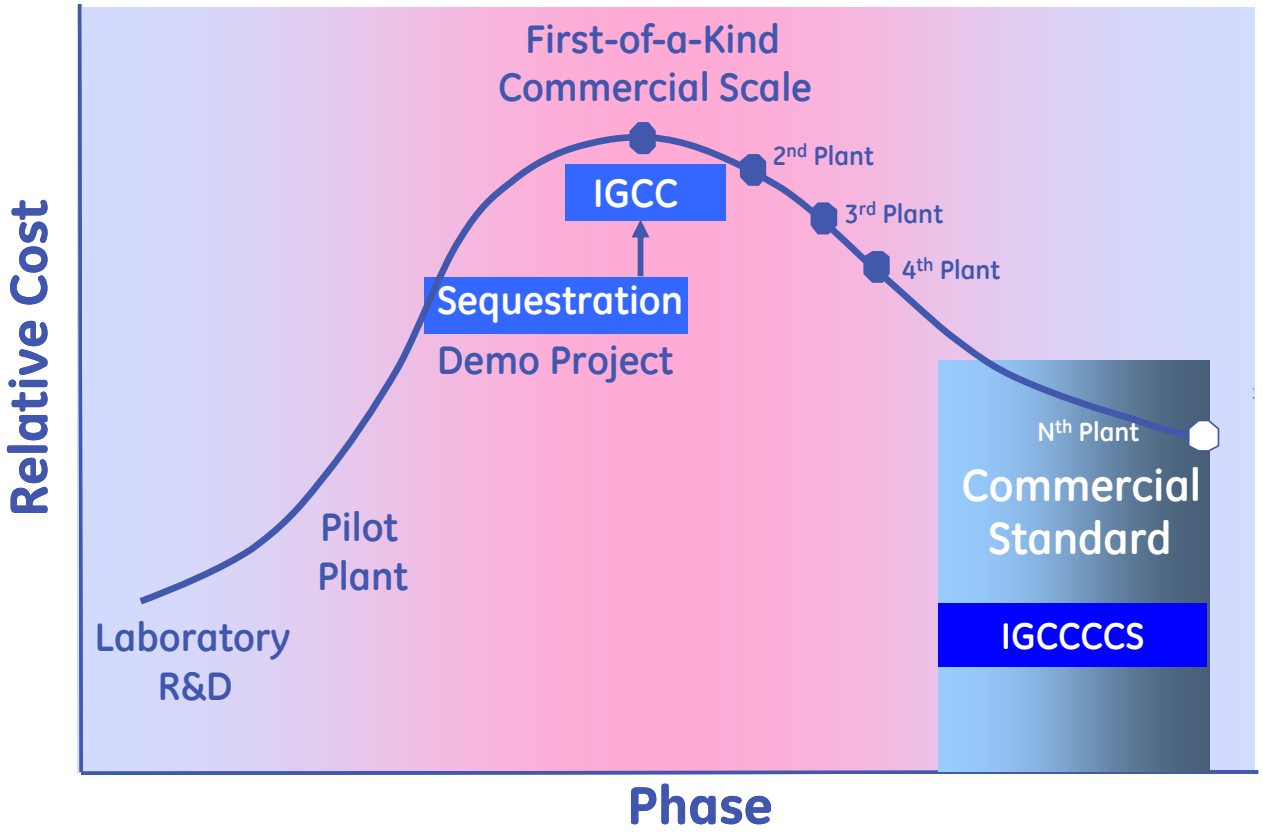


Issue	Challenge
Price Incentives	Private sector players need strong and stable price to ensure that they will earn a reasonable return
Legal Risk	Tort and contractual liability remain too high for utilities to pipe or store CO2 near urban centers
Cost	Higher than expected infrastructure costs associated with CO2 pipeline network and large injection plumes for each coal plant
Public Perception	NUMBY -- Widespread public protests against CCS projects in their communities.
R&D and Demo Funding	Government funding inadequate to prove that CCS is commercially viable and poses acceptable risks





Crossing the "Peak of Despair"



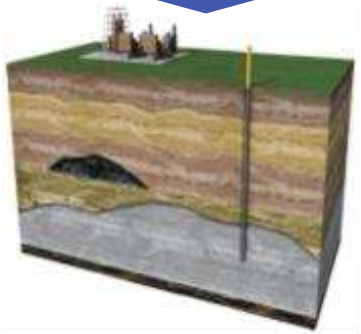
Path to Reducing Cost

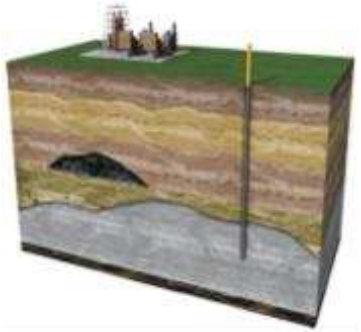
- Mature core technology
- Standard design
- Cycle reduction
- Simplification
- Sourcing pipeline
- Material substitution
- Margin validation/reduction
- Performance/RAM optimization

Carrots and sticks

Regulations/Mandates
Supply Information
Consumer Tax Incentives
Consumer Price Subsidies

Demand PULL



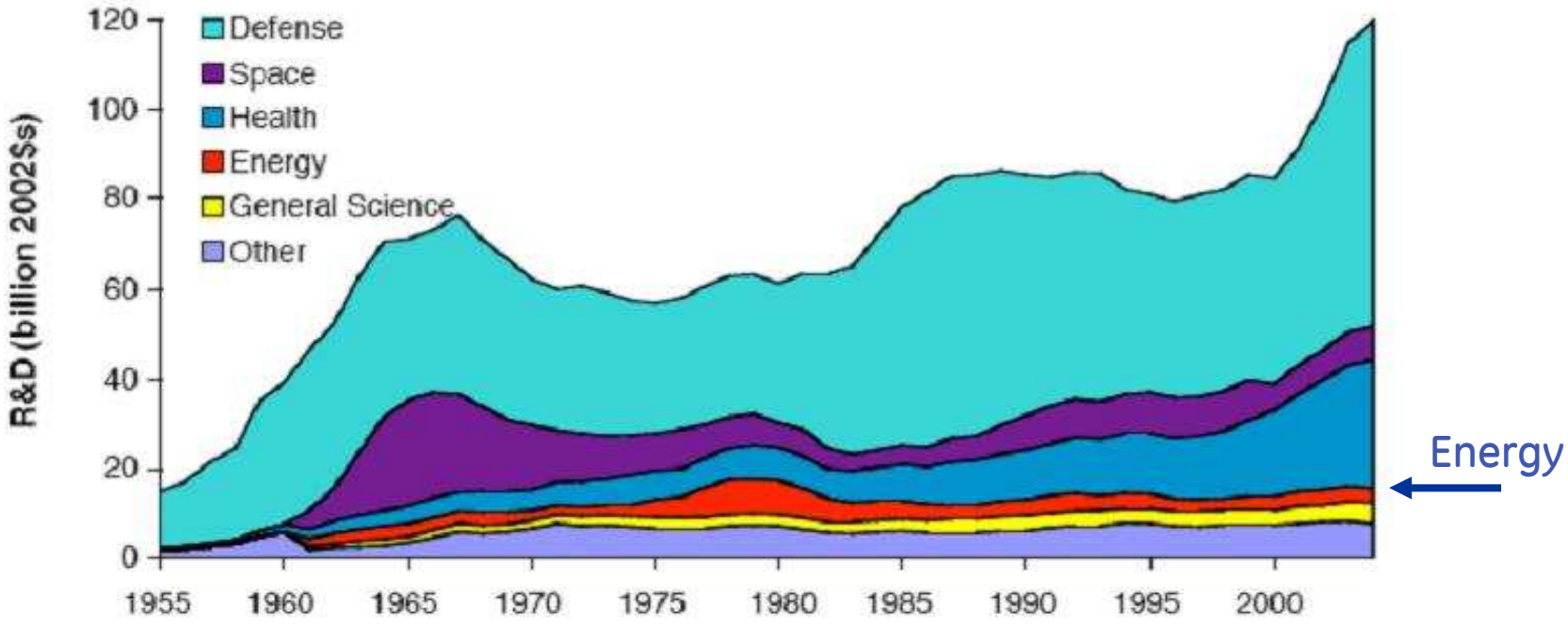


Supply PUSH

Supportive Legal Regime
Supply Information
Deployment Incentives
OEM R&D Subsidies

US funding history has not been kind to Energy

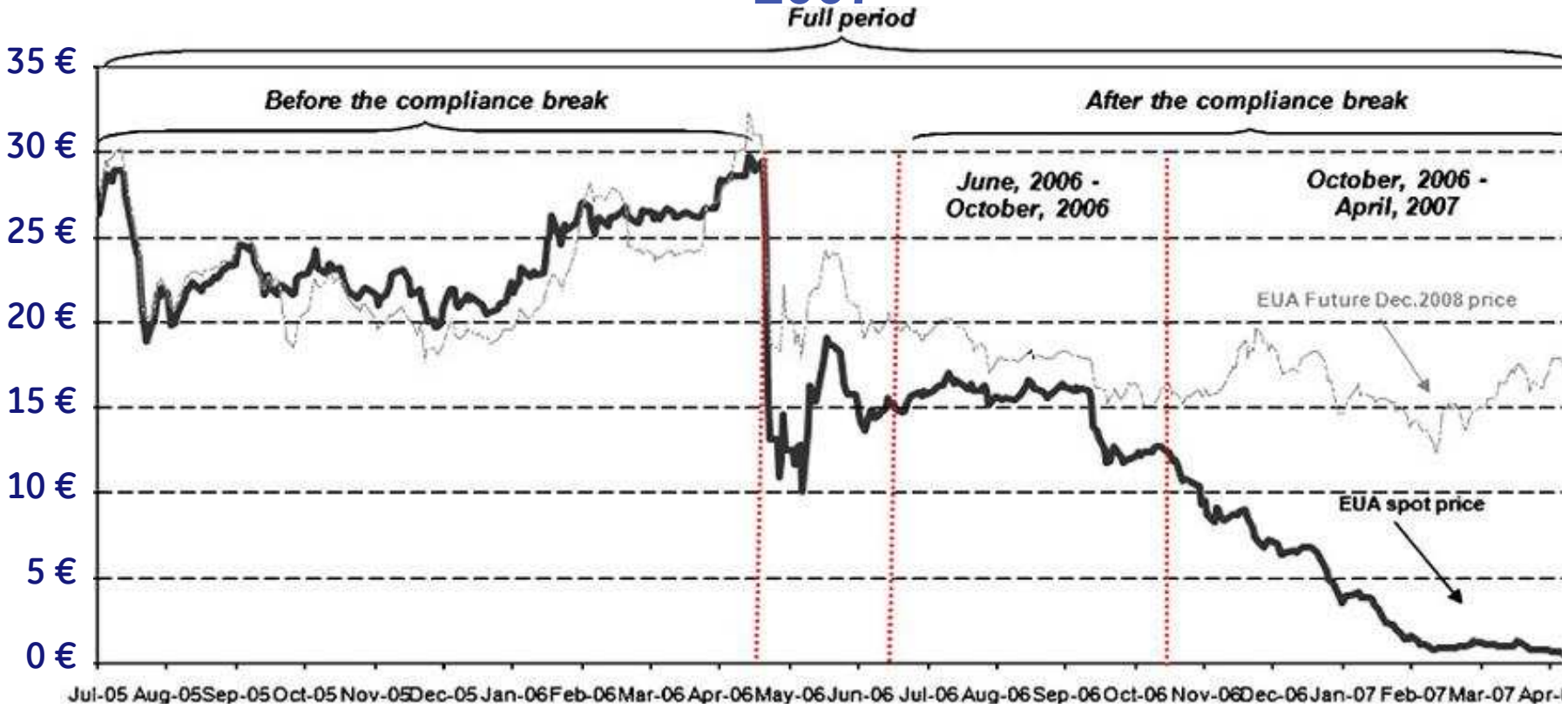
US Energy Funding Relative to Other Priorities



Source: Kammen and Nemet, 2005

CO_2 a basis for financeable projects?

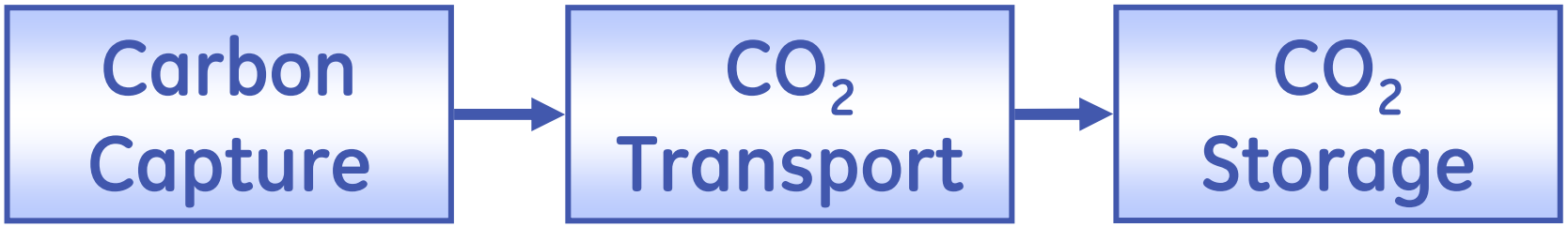
EUA price development July 1, 2005 to April 30, 2007



Source: Powernext Carbon and ECX

Early incentives needed to mitigate risk

CCS regulatory gaps



- No current carbon value
- Cap and Trade to provide long-term market price
- Performance standards to motivate deployment
- Early incentives needed to offset cost

- Major national infrastructure investment
- Coal plant may require 100kms of pipeline to storage
- Will cross jurisdiction boundaries & land ownership
- Eminent domain debate

- Ownership of CO_2 & long-term liability
- Property rights & trespass
- Ownership of "pore space"
- Mitigation & Enforcement
- No-harm/No-foul
- State vs. Federal jurisdiction

Global strategy for commercializing CCS

CO_2 policy established

CO_2 value mature market

Phase I (Now – 2015)

- Government support for 5 large scale commercial CCS projects
- Integrated CC+S demos with min. 1M tons of CO2
- Build IGCC CC-Ready with pre-characterized storage sites
- Storage regulations
- Government assumes long term liability of storage

Validated sequestration & integration with CC

Phase II (2015 - 2020)

- Government incentives for first movers in Cap & Trade
- Performance standards
- New build is 65% capture
- Retrofit installed base to NG equiv. CO_2 (65%)

Deployment to slash CCS cost

Phase III (2020 - 2030)

- Mature and stable carbon market
- CCS cost intersects carbon price
- International credit mechanism
- Phase-out of incentives
- Further increases in capture levels driven by reduced CCS cost and carbon market signals

CCS commercially mature option for climate targets

Comparison of existing coal plants to new IGCC was on MW- hrs basis.

What's the playbook for cleaner coal?

- **Begin CCS deployment now**
  - We already know how to capture carbon and there has been a lot of sequestration
  - We are ready to prove that capture and sequestration can be successfully integrated
  - Getting steel on the ground is the fastest and surest path to reducing cost
- **Continue RD&D of post-combustion capture**
  - Differing roles for pre-and-post combustion capture
  - We need solutions for the existing fleet
- **Establish a new private/public initiative**
  - Competitively awarded grants to deploy 5 US commercial-scale 500-1000 MW Cleaner Coal Power Plants with CCS
- **Make it International**
  - Couple this initiative to China, Australia and others on a plant-per-plant basis.

Questions?

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Industrial

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imagination at work