

# **The Economics of Technologies to Combat Global Warming**

## **Scaling Up Mitigation Technologies: CCS**

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**August 3, 2009  
Snowmass, CO**

# Herzog: Scaling-up CCS

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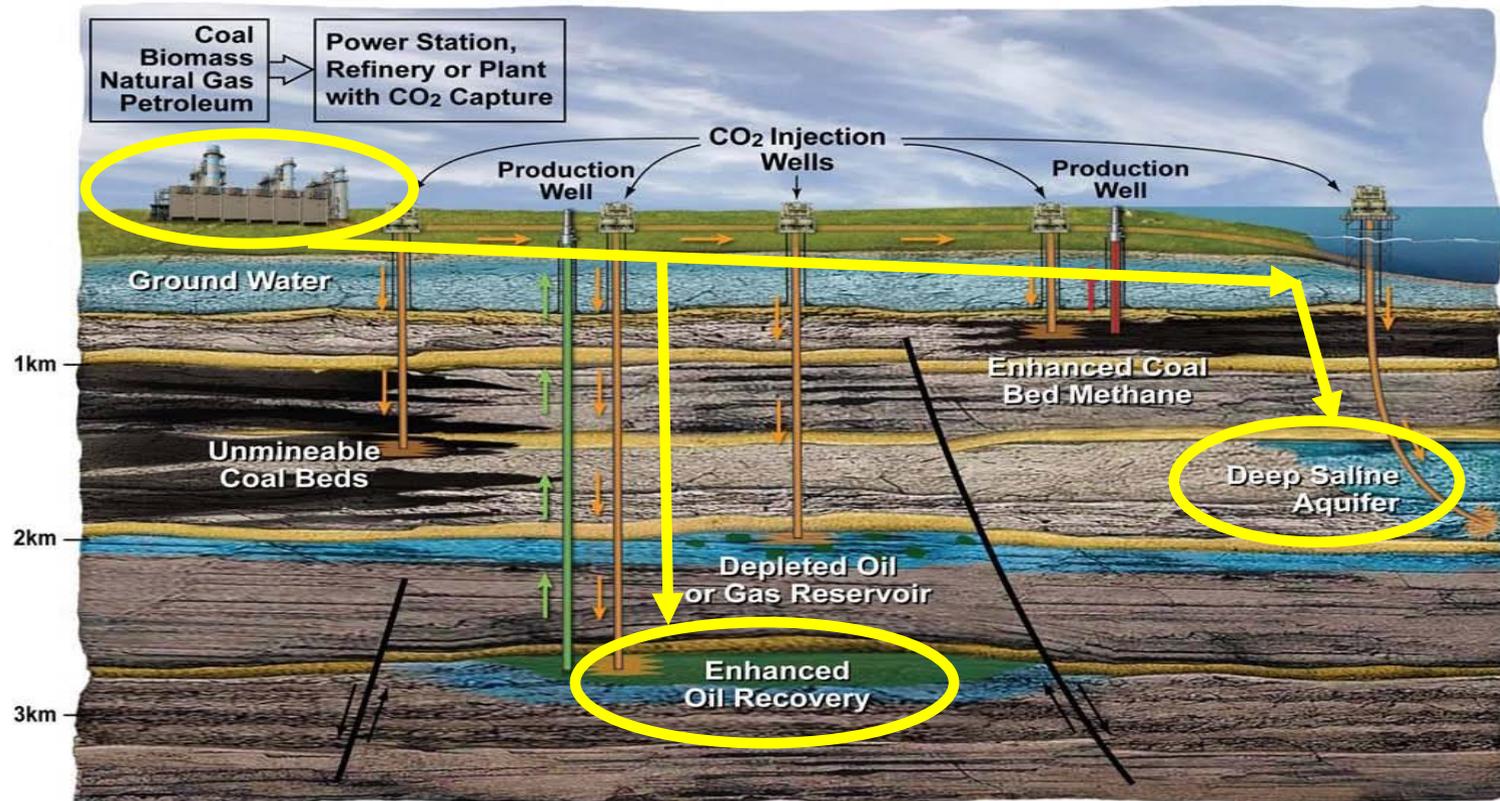
## Herzog's paper, research program

- A good, up-to-date summary of most issues
- Credible voice for objective analyses
- Engaged in the process for decades
- Open to input from a variety of sources
- Not an advocate

## Flannery comments: no basic disagreement

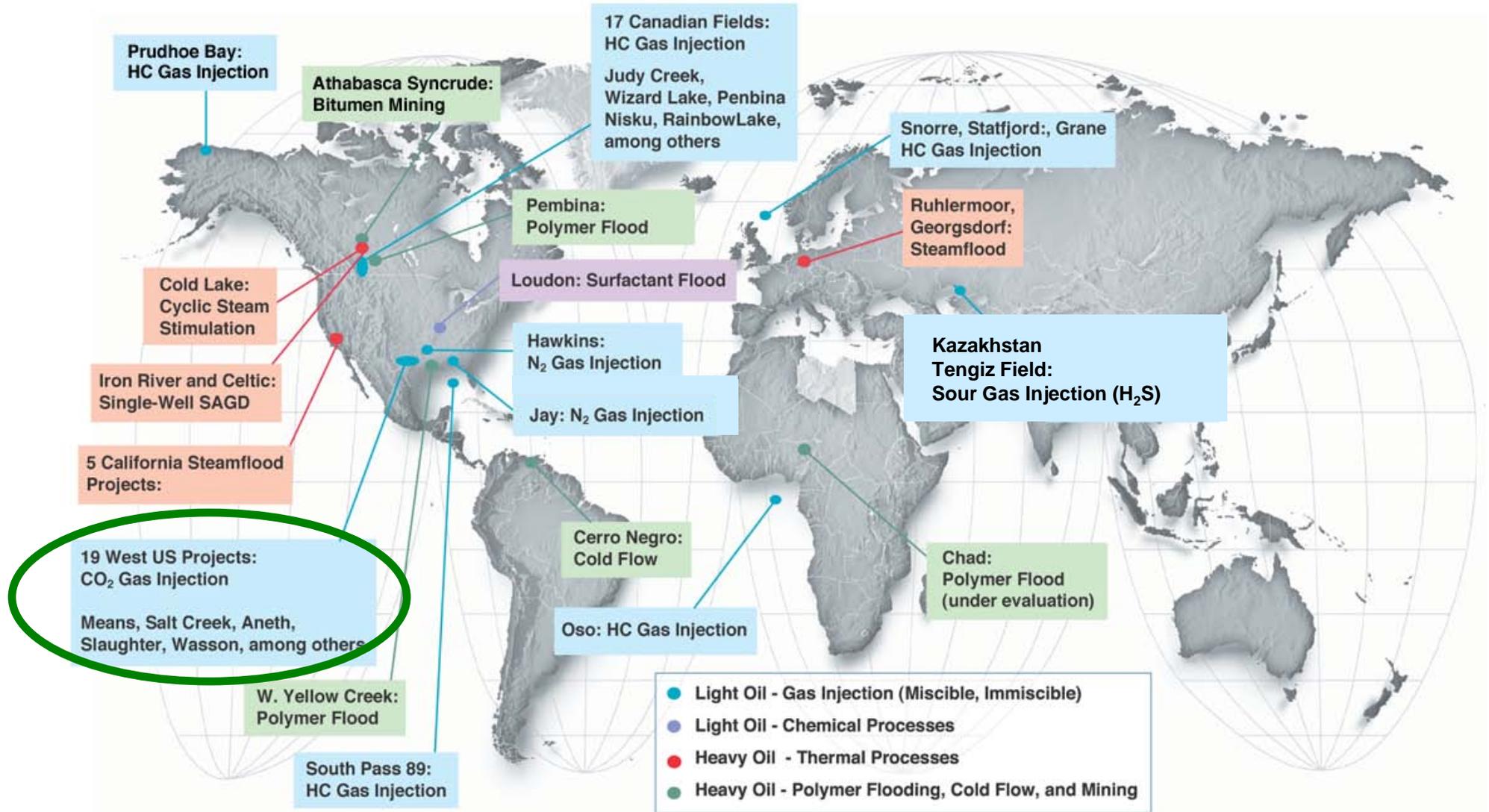
- ExxonMobil experience
- Added perspectives: cost, public acceptance, liability, scale-up

# CCS a Promising Long-term Option

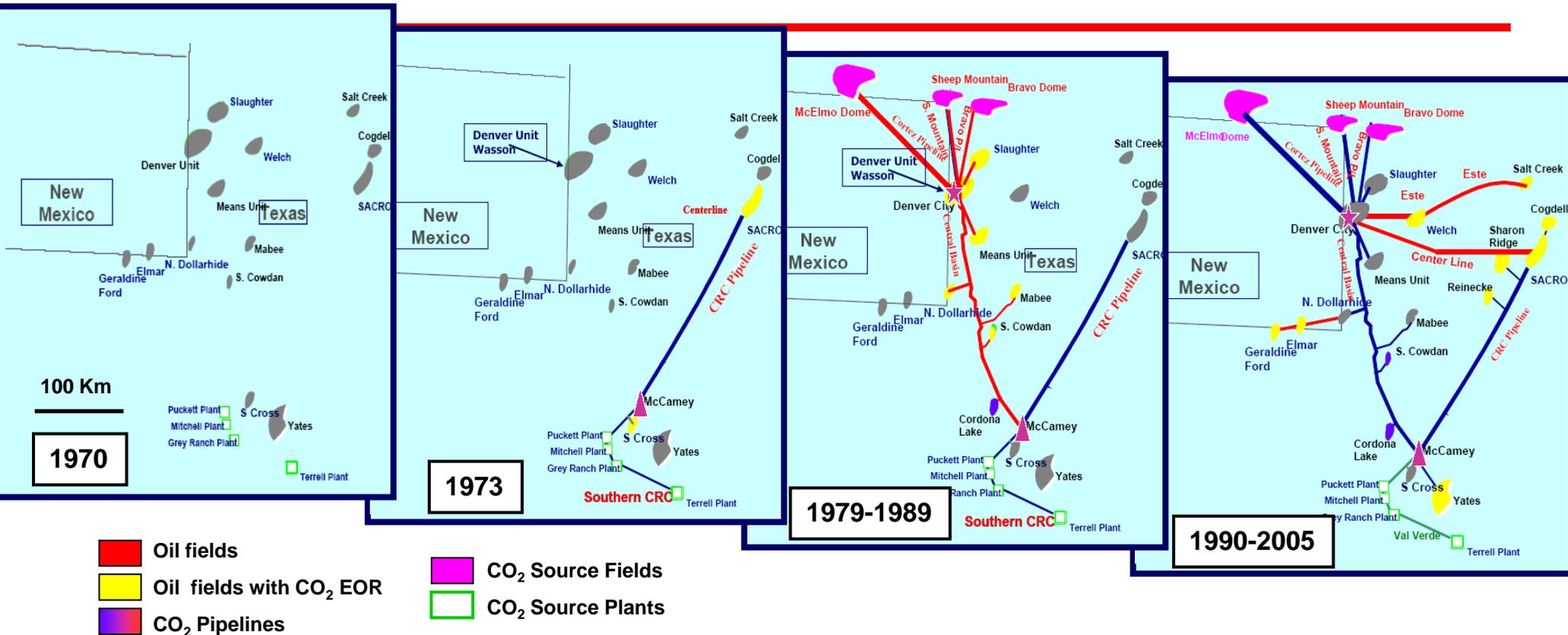


- Large scale GHG mitigation opportunities (coal and gas-fired power and disposal to saline aquifers) will require significant economic incentive
- Early opportunities for CCS require economic niche: CO2 already separated, enhanced oil recovery, or government supported demonstration projects

# ExxonMobil Enhanced Oil Recovery Experience



# U.S. Permian Basin: CO<sub>2</sub> EOR Development History

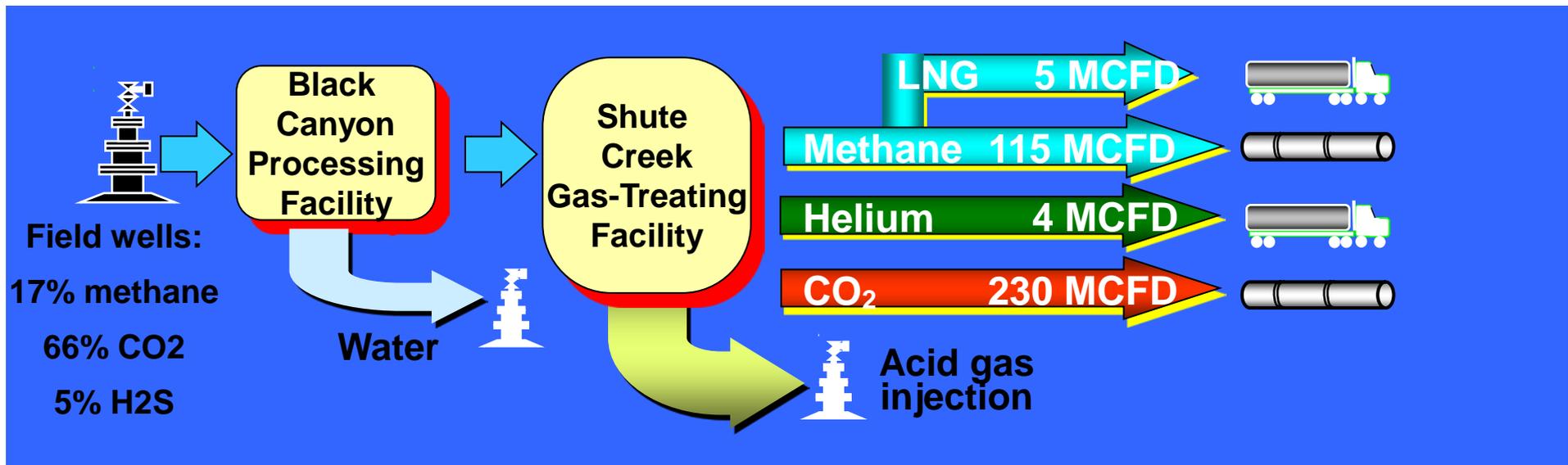


- **1973 first CO<sub>2</sub> pipeline (300 Km): large-scale CO<sub>2</sub> flood SACROC field (EM interest)**  
– CO<sub>2</sub> sourced from Terrell gas plant at Brown Bassett field (EM-operated)
- **1980s major infrastructure connecting naturally occurring CO<sub>2</sub> at McElmo Dome (EM 44%), Sheep Mountain (EM 50%), and Bravo Dome (EM minor %), to oil fields**  
– ExxonMobil leading investor in tertiary CO<sub>2</sub> recovery in the Permian Basin (source fields, pipelines, gas plants, EOR floods at oil fields)
- **1990s CO<sub>2</sub> infrastructure expanded, additional oil fields supplied for EOR projects**

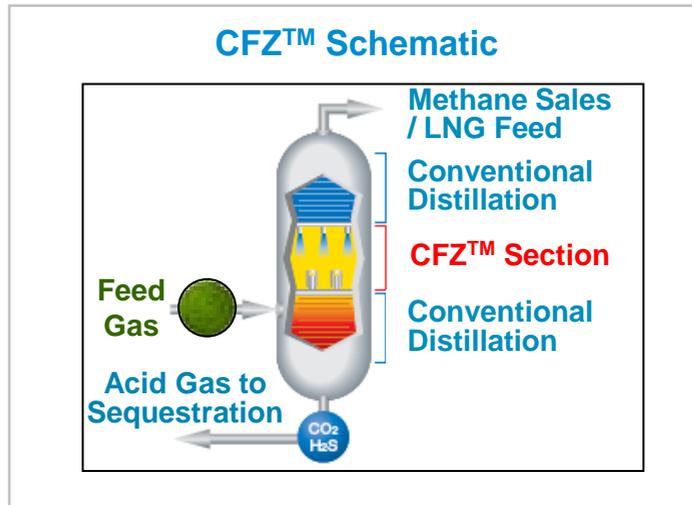
# LaBarge Project, Wyoming



CO<sub>2</sub>:  
50 CFD  $\approx$  1 tonne/yr

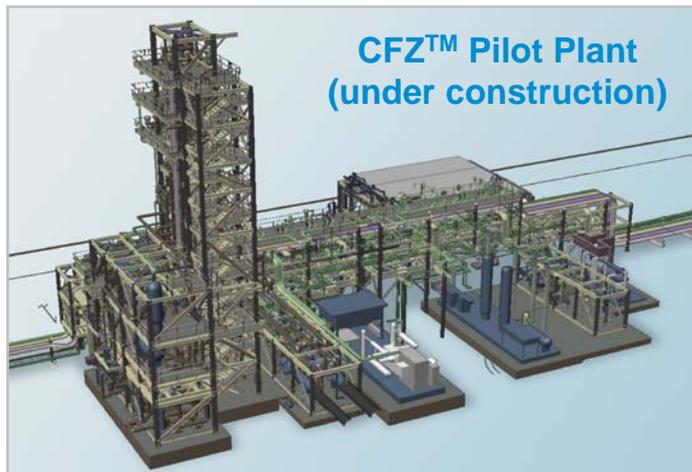


# Controlled Freeze Zone™ Technology



***Controlled Freeze Zone (CFZ™): a single step process to separate CO<sub>2</sub>***

- Replaces traditional two step amine separation
- Lower cost process that may make CCS a more practical option for CO<sub>2</sub> from natural gas
  - One-step process
  - Smaller footprint
  - CO<sub>2</sub> stream as a high pressure liquid
- Commercial scale demonstration under construction at LaBarge, Wyoming
  - 2010 start-up



# ExxonMobil CCS Research Partnerships



- **Sponsored research**
  - CO2ReMoVe, GCEP, Georgia Tech, IEA GHG, MIT CSI, University of Texas
- **Program support**
  - USDOE Regional Program Partner, Southeast and Southwest programs
  - University of Wyoming data sharing and research
- **Founding member Australia's "Global CCS Institute"**
  - To promote CCS demonstration projects around the globe

# **ExxonMobil Engagement in CCS Policy, Regulatory and Professional Development**

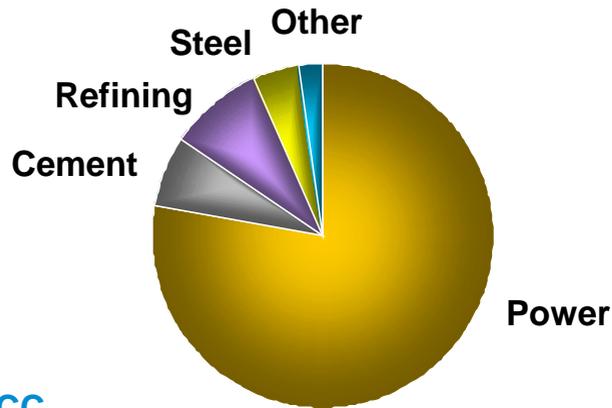
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- **IPIECA CCS Network**
  - **GHG guidelines for CCS emission reduction projects**
  - **Workshop on CCS business models**
  - **IPCC SR CCS, as authors and reviewers**
  - **UNFCCC workshop and side sessions**
  - **IEA input to G8**
- **Contributing to regulatory development**
  - **US, Europe, Canada, Australia, ...**
  - **API, Europa, CAPP, AIP, ...**
- **Leadership of profession society activity**
  - **Society of Petroleum Engineers**
  - **AICHE Energy Initiative**
  - **IEEE/ASME/ASCE/AICHE/AIME Carbon Management Project**

# Challenges of Commercial Scale CCS

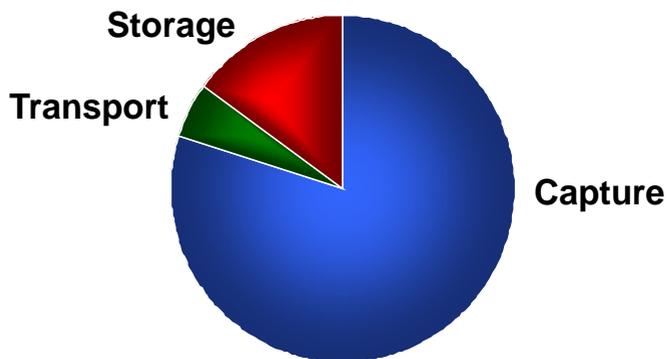
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## Stationary CO<sub>2</sub> Sources



IPCC  
2005

## CCS Cost Distribution



- Large scale demonstration of integrated component technologies
- Technology improvements to reduce capital cost and energy intensity
- Sound legal, regulatory framework
  - Stable economic basis
  - Property rights/access
  - Long term site responsibility
- Recognition of scale
  - Rivals existing oil and gas production infrastructure
  - 1 Bt/y of carbon stored as compressed CO<sub>2</sub> produces 85 MBD

**Large scale, market-driven deployment is many years off**

# Key Issues

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## Still hardly getting started (pilot plants, prototypes)

- **Cost**
- Public acceptance: politics, lack of regulatory framework
- Multiplicity of choices, integrating required expertise

## Scaleup

- **Cost & Finance**
- Public acceptance: politics, lack of regulatory framework
- Absence of business models and supply chain
- Infrastructure
- Finance

# Cost, Cost Estimates

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- **Costs are far higher than anticipated C-price for many years**
- **Wide variety of results: methodology and assumptions matter**
  - **Materials and equipment specification**
  - **Capitalization of construction costs**
  - **Cost of capital and rates of return**
  - **Today or in the future**
- **Costs for transport and storage are usually *assumed* to be small compared with capture**
  - **Site dependent (design must be matched to geology)**
  - **Site selection criteria may limit available sites**
- **Costs for First vs Nth plant**
  - **Learning curves with steep cost declines may be optimistic—required equipment available in widespread use today, opportunities to reduce production and assembly costs limited**
  - **Cost environment will depend on global competition for large-scale capital projects (see IEA stabilization scenarios)**

**Need for large-scale demonstration plants to identify actual costs and opportunities for cost reduction**

# Finance and cost recovery

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- **Finance: availability, terms and cost recovery mechanisms will affect ultimate business models (and vice versa)**
- **Who will finance deployment of CCS in developing countries (China, India, ...) and under what terms**

# Regulatory Framework & Liability

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- **Investors need confidence that they can gain timely approval for *all permits* required to *site, operate, and decommission* facilities**
  - Information needs; design requirements; approval process
  - Site selection, monitoring, operating, transition criteria
- **Permitting and liability**
  - During operations: Clarity on requirements for site selection, safe operations, monitoring
  - After normal operations end: Clarity on transition monitoring and handoff (integrity of long-term CO<sub>2</sub> storage)
- **There is no practical alternative to having long-term liability rest with a government entity**
- **Other issues**
  - Property rights (differ significantly by region)
  - Dual use
  - Decommissioning existing oil & gas facilities

**Resolution of permitting and liability will affect site selection, design, capital and operating costs, ultimate business models for CCS**

# Coal and CCS: Scale and Volumes

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- **1 GW coal-fired power plant produces 7 MtCO<sub>2</sub>/year**
- **6 1-GW coal plants would produce 1 M bbl/day of supercritical CO<sub>2</sub>**  
(likely requiring 50-200 injection wells @ 5-20 k bbl/d)
- **520 1-GW coal plants produce 1 GtC/yr**
- **1 GtC/yr would produce ~85 M bbl/d of supercritical CO<sub>2</sub>**  
(equal to the volume of global oil production)
- **3 GtC/yr annual emissions from coal use today**
- **IEA (G8 goal: 50% reduction by 2050) Among other steps calls for:**  
30-35 500-MW coal power plants with CCS per yr  
yields 2.6 M barrels/day compressed CO<sub>2</sub>  
(size of ExxonMobil's current oil production)
- **Timely permitting and construction of pipelines will be a major issue (NIMBY and chicken and egg issue)**

Deployment of CCS technology on this massive scale would require many decades of investment

# Miscellaneous

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- **Early learning and development of infrastructure will occur in niche (but still large, industrial scale) applications, e.g. EOR where low cost CO<sub>2</sub>, infrastructure and economic drivers exist**
- **While CCS needs assistance in research and demonstration activities, in deployment it should compete with all other options to mitigate GHG risks**
- **Strong policy advocates seek to promote CCS for coal; CCS for gas appears to be less costly for power to consumers**

# Final Comments

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- **Technology developers have confidence that CCS can be developed and deployed safely with integrity of long-term storage**
- **Deployment will require clear procedures for site selection, operation and monitoring**
- **Resolution of short and long-term liability will be essential, and will affect design, cost and business models**
- **Deployment will require decades, finance will be a major consideration, especially in developing countries**
- **CCS is attractive only because it is less costly than other proposed solutions—in stabilization models CCS is an essential component**
- **Given the multi-decadal time-scale to deploy GHG solutions, deployment of CCS should compete on a level playing field with all options**

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**Thank You**