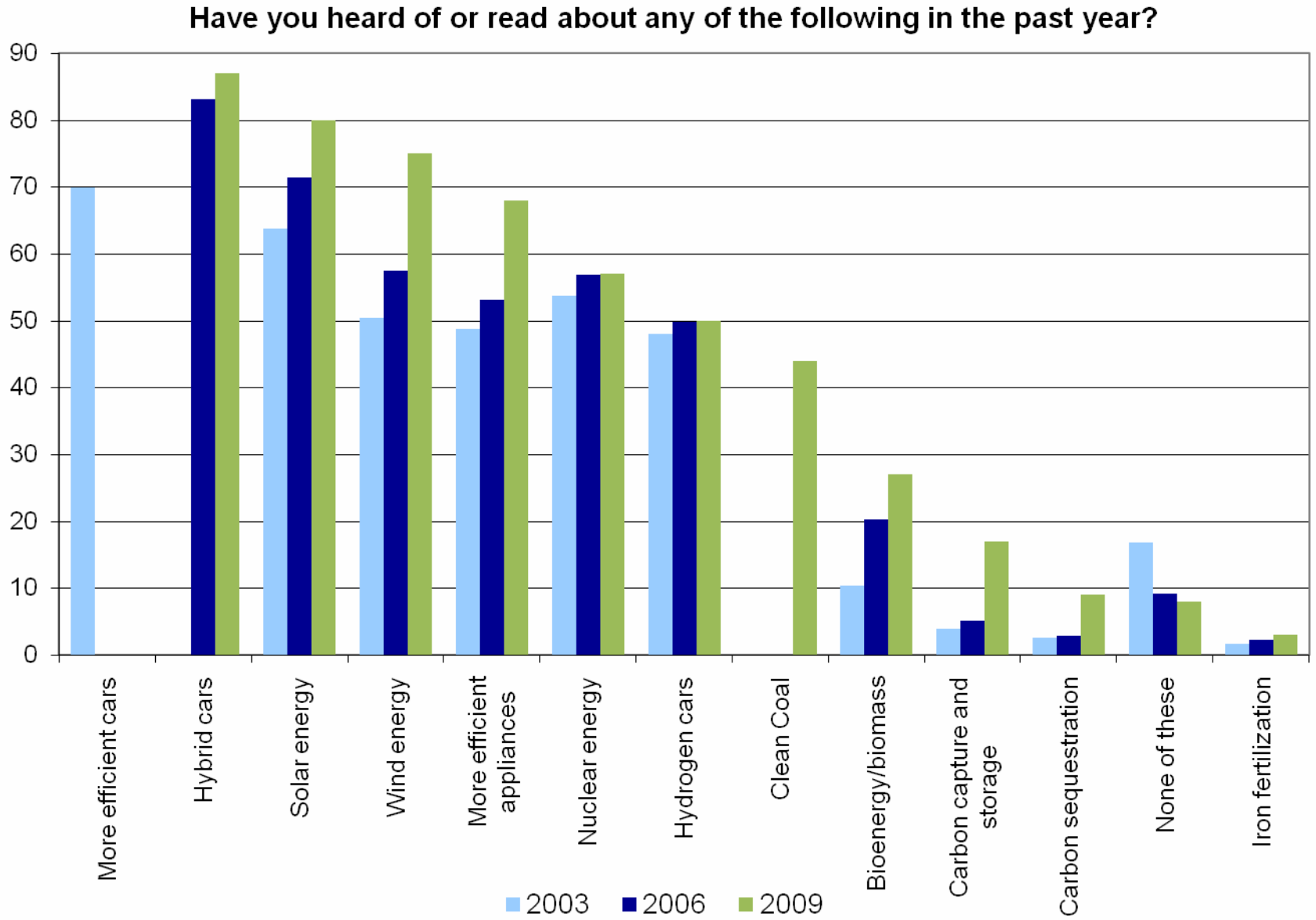
The Carbon Capture and Storage (CCS) Challenge: From Megatonnes to Gigatonnes

Council of Industrial Boiler Owners

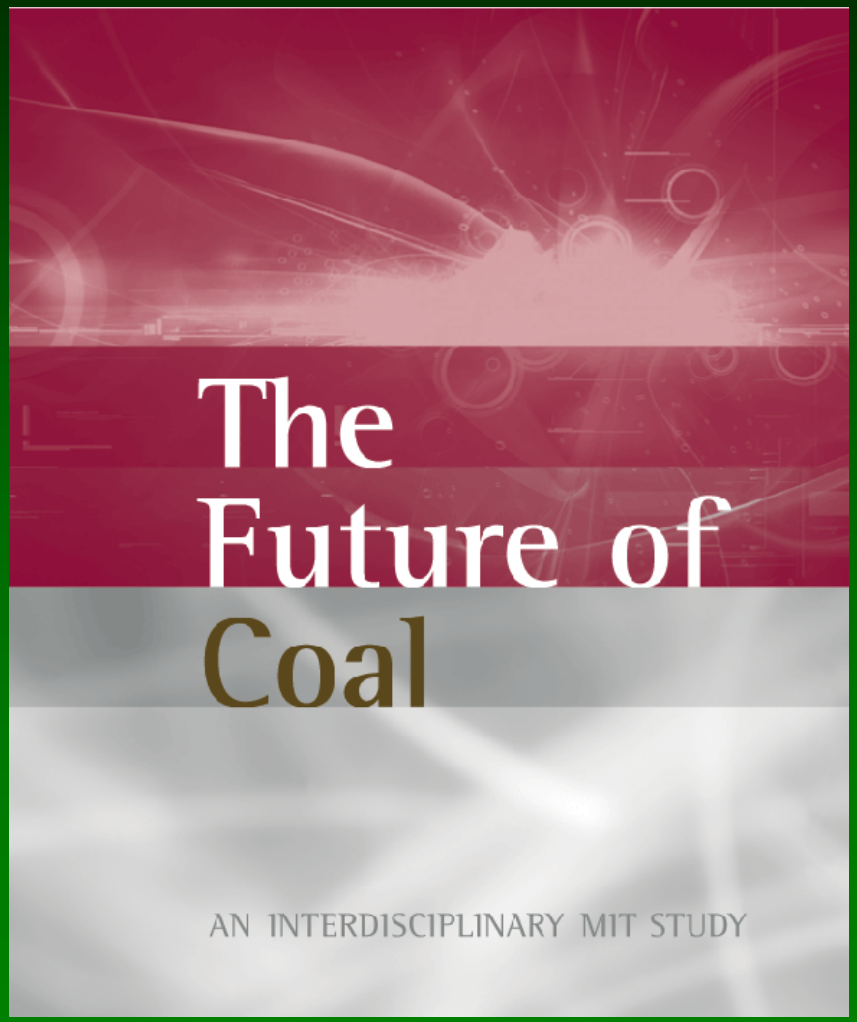
Howard Herzog

MIT

March 9, 2010

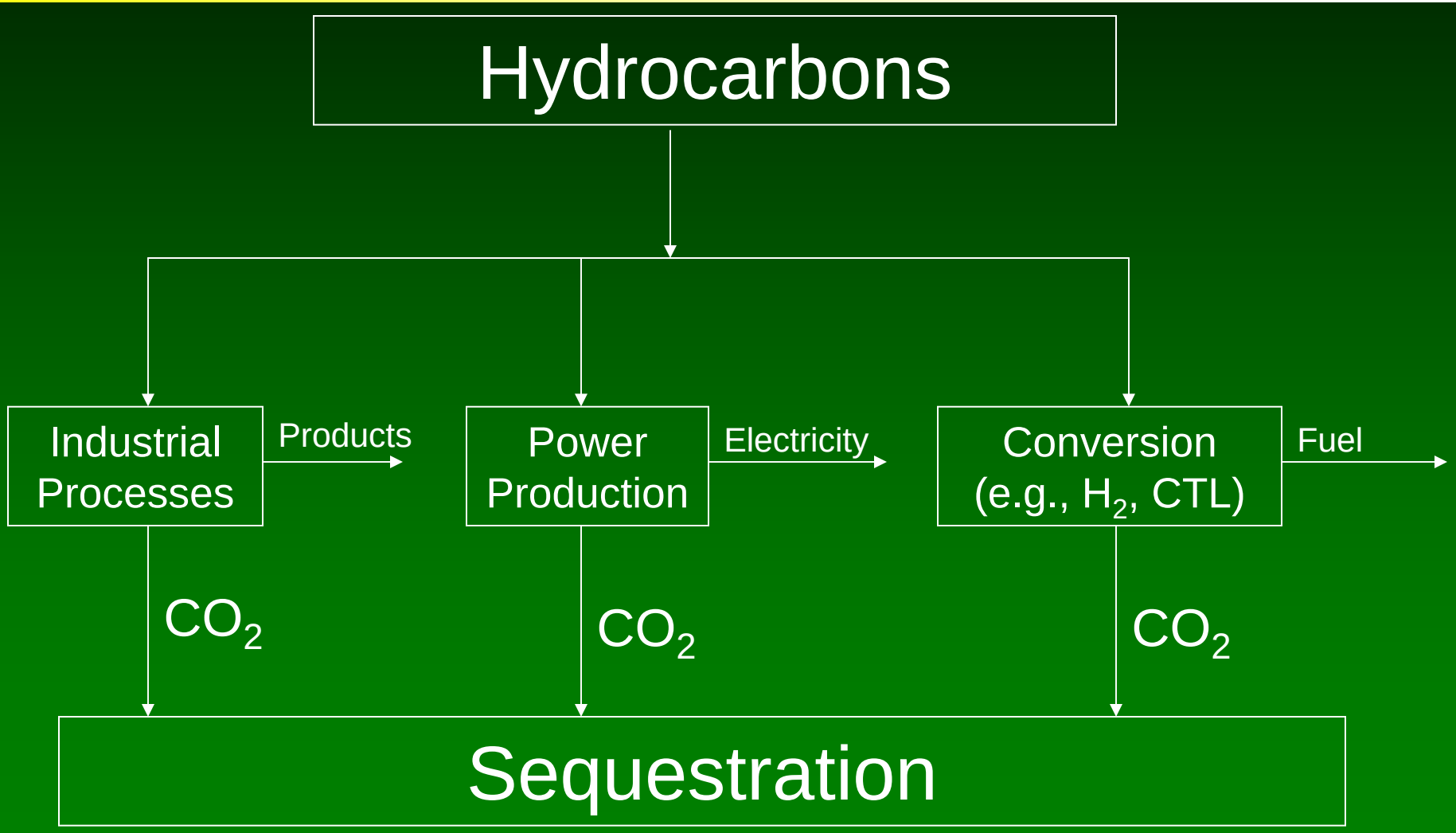

Have you heard of or read about any of the following in the past year?
90
80
70
60
50
40
30
20
10
0
More efficient cars
Hybrid cars
Solar energy
Wind energy
More efficient appliances
Nuclear energy
Hydrogen cars
Clean Coal
Bioenergy/biomass
Carbon capture and storage
Carbon sequestration
None of these
Iron fertilization
2003
2006
2009

The MIT Coal Study



- Released March 14, 2007
  - On web at mit.edu/coal
- We conclude that CO_2 capture and sequestration (CCS) is the critical enabling technology that would reduce CO_2 emissions significantly while also allowing coal to meet the world's pressing energy needs.

CCS Pathways



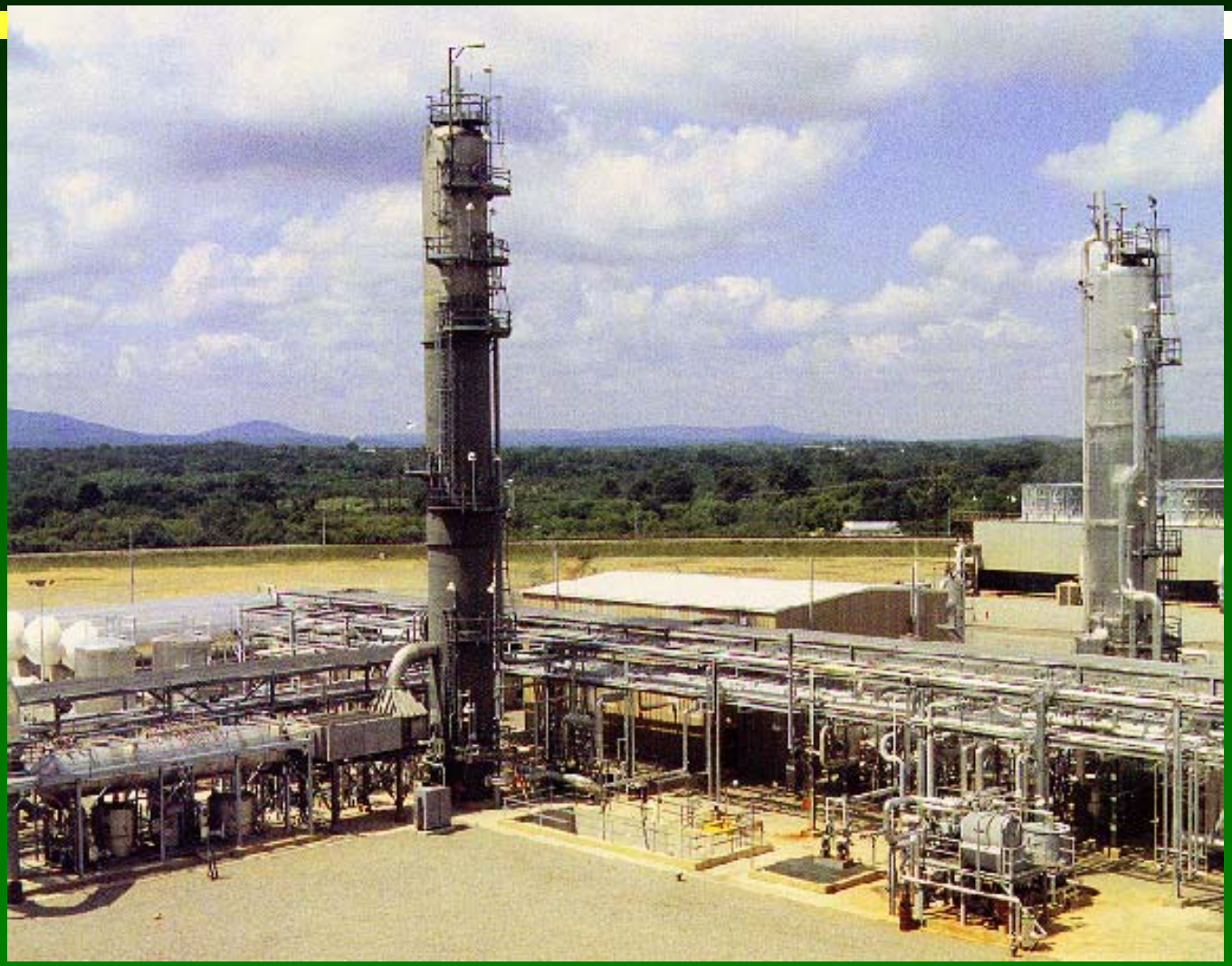
Outline

- CCS Today
- The Scale-up Challenge
- Moving Forward

CCS Today

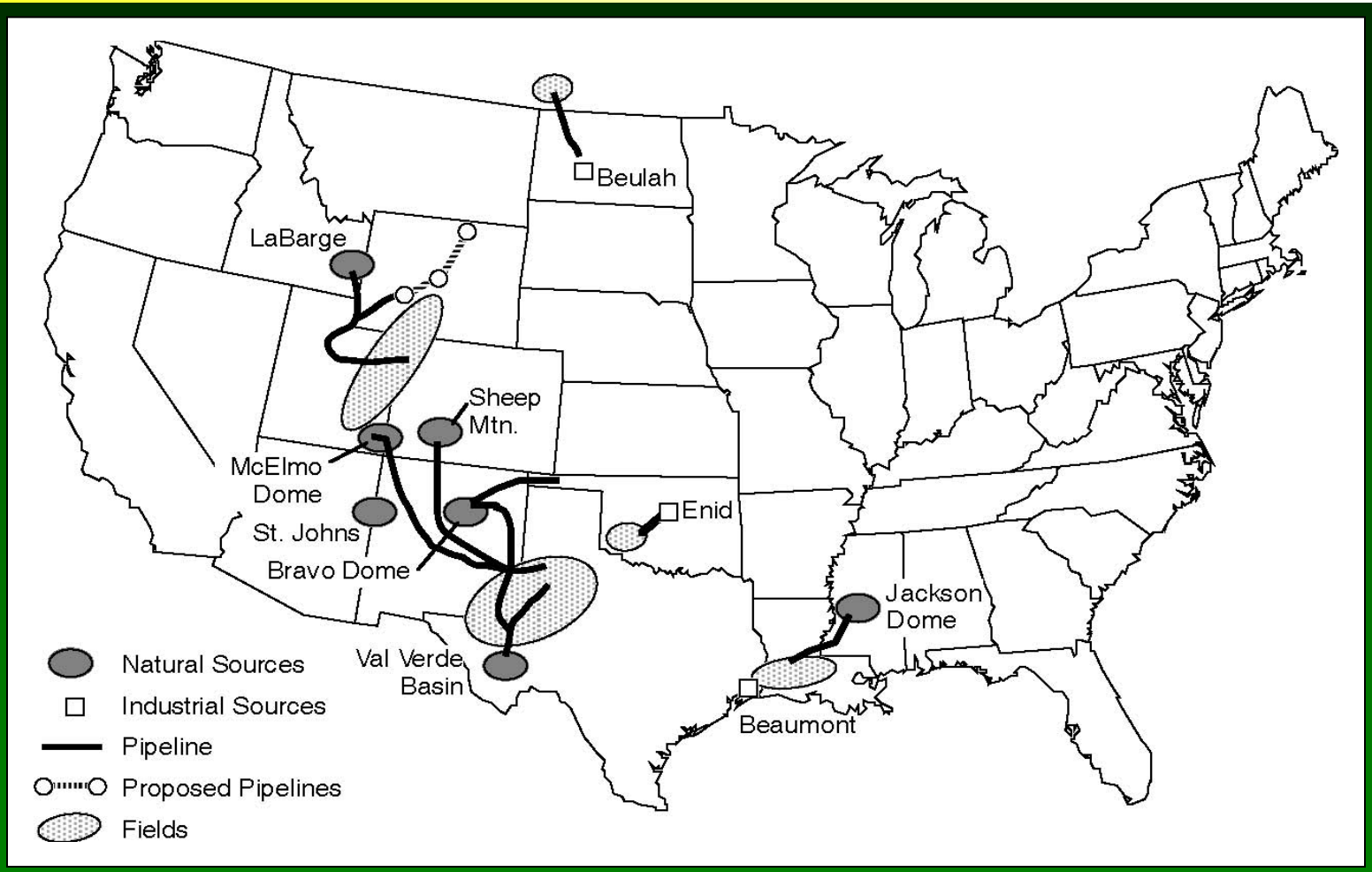
- All major components of a carbon capture and sequestration system are commercially available today.
  - Capture and compression
  - Transport
  - Injection
  - Monitoring
- However, there is no CCS industry – even though the technological components of CCS are all in use somewhere in the economy, they do not currently function together in the way imagined as a pathway for reducing carbon emissions.

CO_2 Capture at a Power Plant



Source: ABB Lummus

US CO_2 Pipeline Network



3400 miles of CO_2 pipelines in US

Howard Herzog / MIT Energy Initiative

CO_2 Injection Experience

- Acid Gas Injection
- Enhanced Oil Recovery (EOR)
- Natural Gas Storage
- Commercial CCS Projects (4 worldwide)

CO_2 Injection Projects Million Tonne per Year Scale

Project	Leader	Location	CO_2 Source	CO_2 Sink
Sleipner (1996)	Statoil	North Sea Norway	Gas Processing	Deep Brine Formation
Weyburn (2000)	Pan Canadian	Saskatchewan Canada	Coal Gasification	EOR
In Salah (2004)	BP	Algeria	Gas Processing	Depleted Gas Reservoir
Snovit (2008)	Statoil	Barents Sea Norway	Gas Processing	Deep Brine Formation

The Scale-up Challenge
From Megatonnes to Gigatonnes

- We have yet to build a large-scale (>1Mt CO_2/yr) power plant CCS demonstration
- In order to have a significant impact on climate change, we need to operate at the billion tonne (Gt) per year level
- This implies that 100s of power plants will need to capture and store their CO_2

Challenges for Large-Scale Deployment

- Costs
- Transportation Infrastructure
- Subsurface Uncertainty
  - Storage Capacity
  - Leakage from Storage Reservoirs
- Regulatory and Legal Issues
- Public Acceptance

Estimated CCS Costs for Coal

- Estimated CCS Costs for coal:
  - additional $40 per MWh to cost of generation
  - $60-65/tonne CO_2 avoided
- This cost assumes:
  - 2007$
  - Nth plant
  - 90% capture
  - Includes transport and storage (~$10/tonne CO_2 avoided)
  - Based on SCPC technology with post-combustion capture
  - Today's technology (i.e., no technological breakthroughs required)
  - Regulatory issues resolved without imposing significant new burdens
  - Operations at scale
- For details see:
  - http://sequestration.mit.edu/pdf/GHGT9_Hamilton_Herzog_Parsons.pdf

Comparison of Capture Technology Pathways

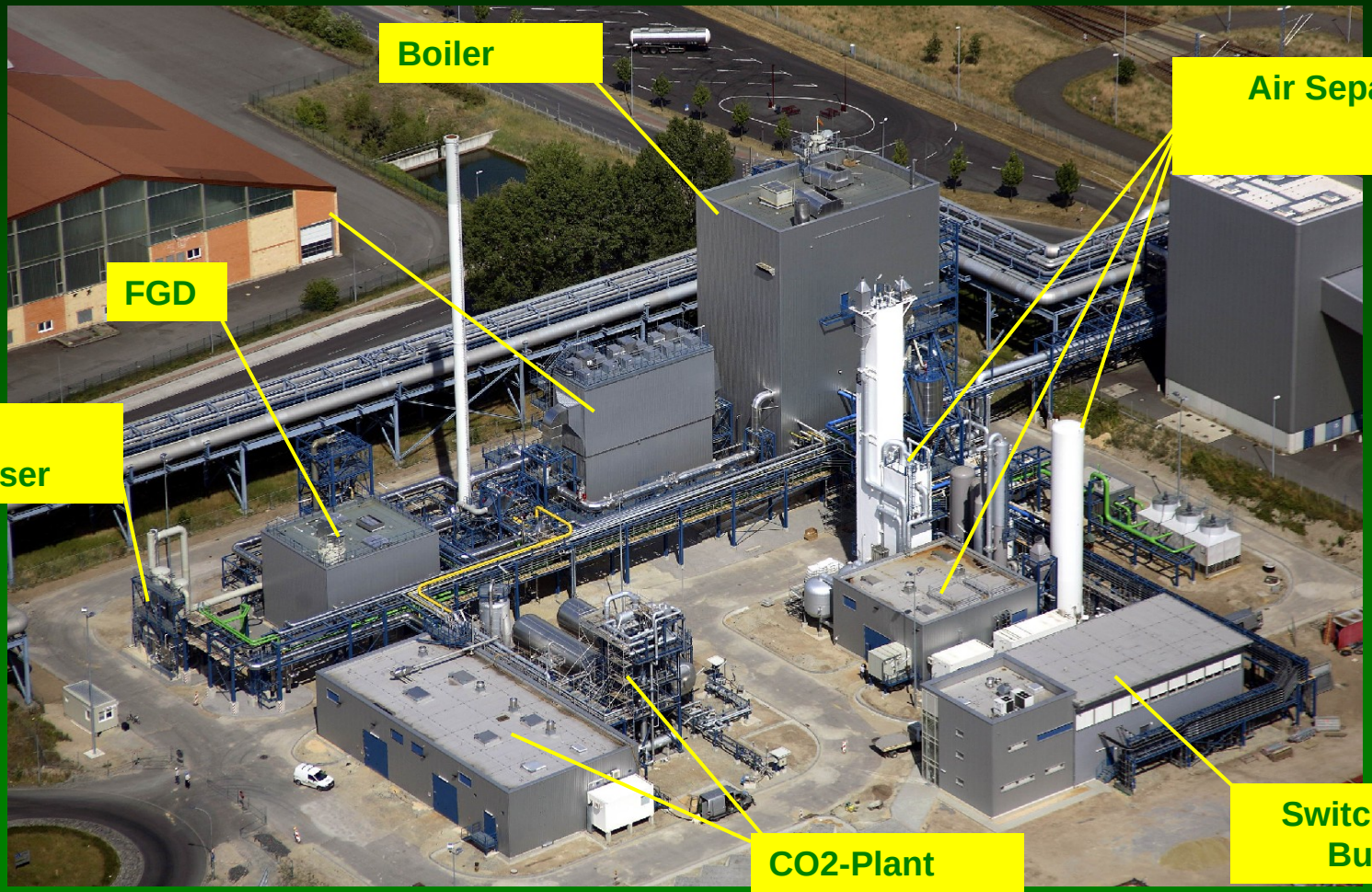
	Plusses	Minuses
Post-Combustion	Compatible with existing infrastructure; retrofits; flexibility	Current methods have high energy penalties
Oxy-Combustion	Potentially less expensive than post-combustion; retrofits	Cost of oxygen; lack of experience
Pre-Combustion	Projected lowest incremental cost for capture	Slow progress of IGCC in power sector

Mountaineer AEP/Alstom

- West Virginia
- 100,000 tpy (30 MW_{th})
- Chilled Ammonia
- Recently started operation
- Storage in a saline formation

Vattenfall Schwarze Pumpe Plant

Oxy-combustion 30 MW_{th} Pilot Plant



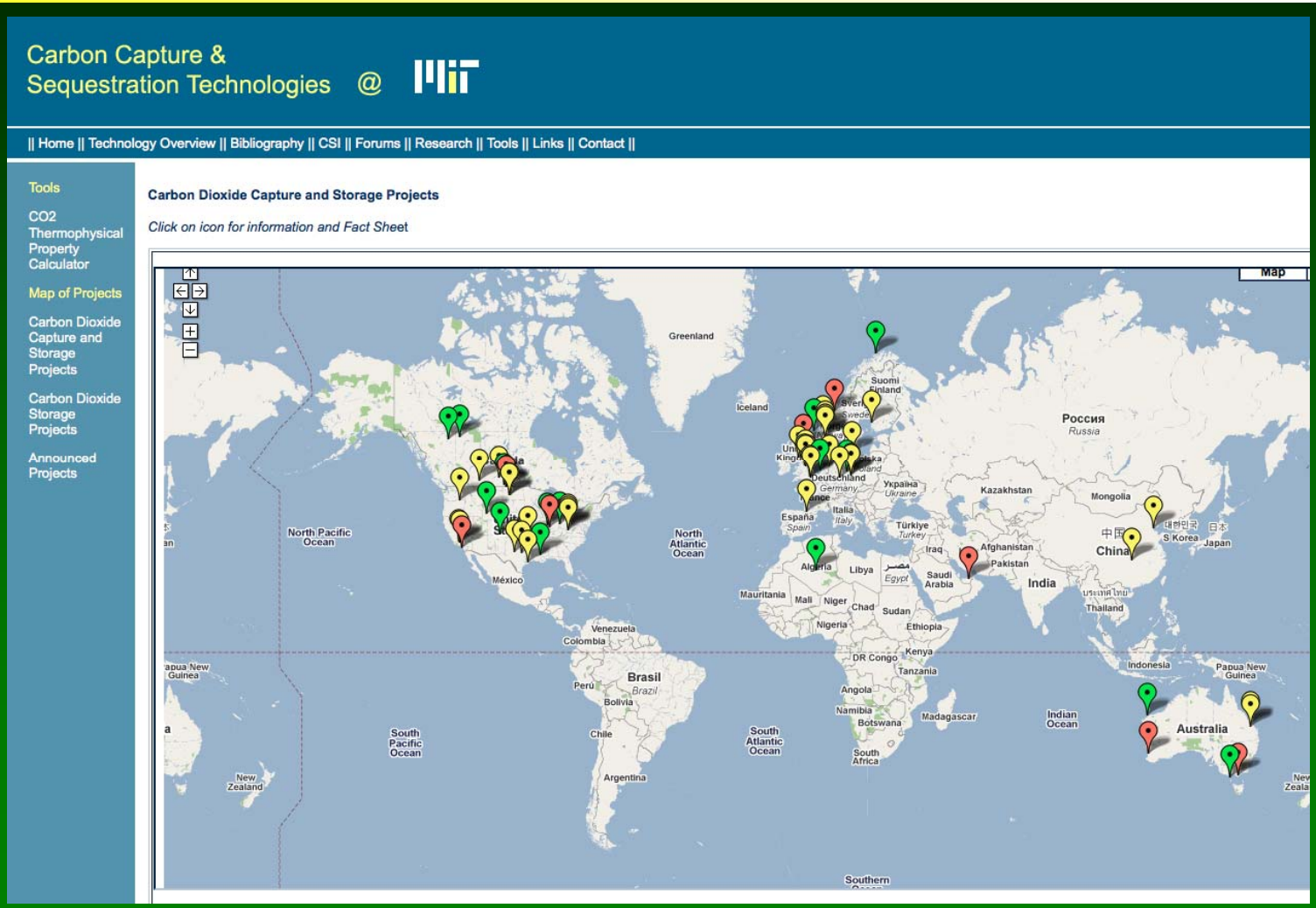
Essential Elements in Moving Forward

- Demonstration Phase
  - A number of large-scale demonstration projects worldwide – urgency to get going
- Deployment Phase
  - Creation of a market for CCS

Demonstration Phase

- Characteristics (from MIT Coal Study)
  - On order of 10 worldwide
  - Scale of a million tons per year
  - In a variety of geologies
- G8 called for 20 worldwide by 2020
- Recent Activity
  - EU:
    - » Support in stimulus bill
    - » 300 million permits from ETS
  - US: Support in stimulus bill
  - Australia: Global Carbon Capture and Storage Institute

Interactive map of Projects



FutureGen

- 275 MW_e IGCC coal plant with CCS
- Matton, IL
- Projected cost over $2 billion
- Storage in saline formation

Clean Coal Power Initiative Awards

Company	Location	DOE Contribution (million $)	Size	Technology	Fate
Basin Electric	Beulah, ND	100	120 MW 1 $MtCO_2$/yr	PCC HTC PurEnergy	EOR
Hydrogen Energy	Kern County, CA	308	390 MW 2 $MtCO_2$/yr	IGCC Coal/PetCoke	EOR
AEP	New Haven, WV	334	235 MW 1.5 Mt CO_2/yr	PCC Chilled NH_3	Saline Formation
Southern Company	Mobile, AL	295	160 MW 1 $MtCO_2$/yr	PCC MHI	Saline plus EOR
Summit Energy	Midland-Odessa, TX	350	400 MW 2.7 $MtCO_2$/yr	IGCC	EOR

Southern Company Barry Steam Plant

- Feb 22, 2010
  - Dropping CCPI project
  - Will proceed with smaller tests
- Tight deadline
  - DOE wanted firm commitment by Feb 19
  - Not “sufficient time” to understand “financial ramifications”

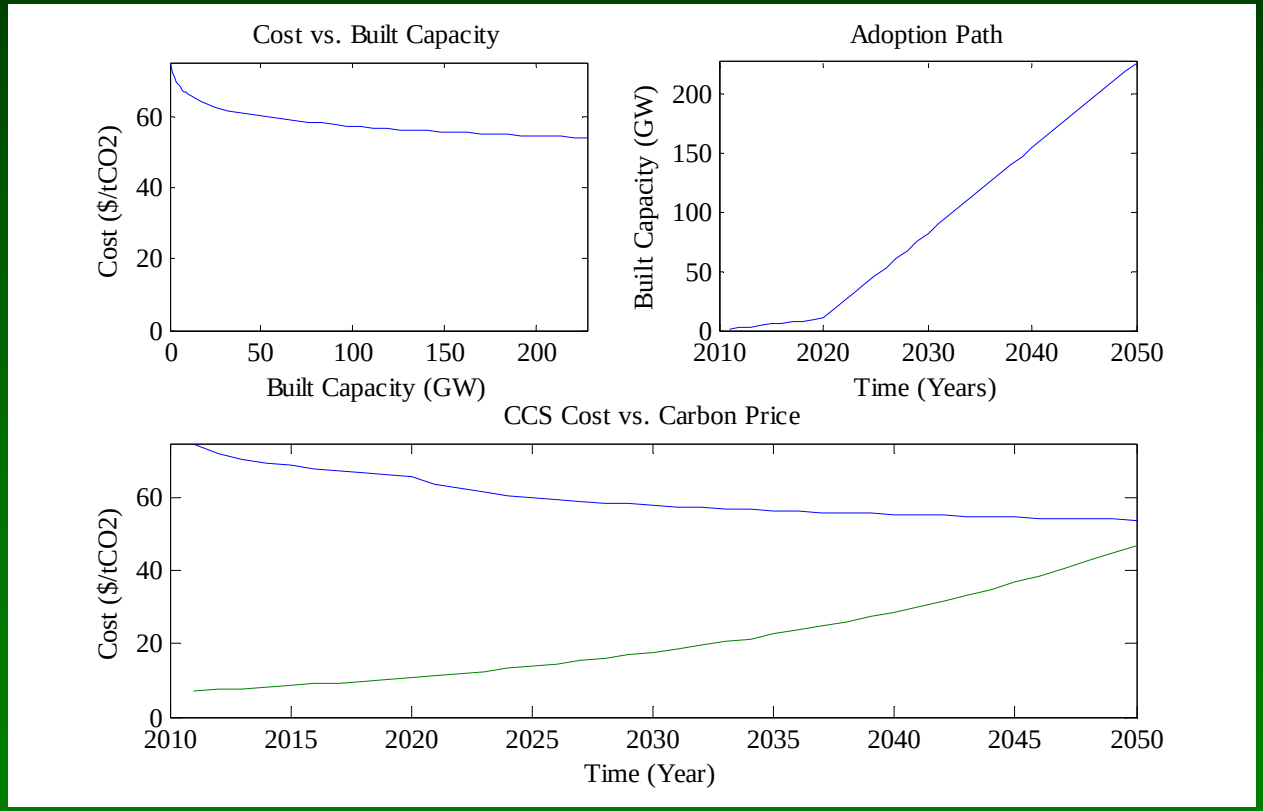
EU's CCS Awards

Company	Location	EU Contribution (million €)	Size	Technology	Fate
Vattenfall	Jaenshwalde Germany	180	385 MW 2.7 $MtCO_2$/yr	Oxy	EGR
E.ON	Rotterdam Netherlands	180	250 MW 1.43 $MtCO_2$/yr	PCC	EGR
PGE & Alstom	Belchatow Poland	180	250 MW 0.1 $MtCO_2$/yr	PCC	Saline Formation
ENDSA	Compostilla Spain	180	30-320 MW 1 $MtCO_2$/yr	Oxy	Saline Formation
Powerfuel	Hatfield UK	180	900 MW 4.5 $MtCO_2$/yr	IGCC	EOR
Enel	Porto Tolle Italy	100	250 MW 1 $MtCO_2$/yr	PCC	Saline Formation

Deployment Phase

- A market for CCS must be created
- Early on, it is likely that a carbon price will be insufficient to support large-scale CCS deployment – additional support will be required
- It appears that the only realistic source of support for early deployment of CCS will need to come from cap-and-trade revenues

At first, a cap-and-trade system will not be sufficient for deployment



CCS in a Mitigation Portfolio

- In order to meet the stated goal of significant cuts (50%-80%) in greenhouse gas emissions by 2050
  - CCS is not a silver bullet
  - However, it may be a keystone technology
- We will need to capture and store Gts of CO_2 every year by 2050

Contact Information

Howard Herzog
Massachusetts Institute of Technology (MIT)
Energy Initiative
Room E19-370L
Cambridge, MA 02139
Phone: 617-253-0688
E-mail: hjherzog@mit.edu
Web Site: sequestration.mit.edu