

Financing CCS Demonstration Projects: *Lessons Learned from Two Decades of Experience*

USEA Policy Series

Howard Herzog

MIT

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Acknowledgements

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 - <http://sequestration.mit.edu/bibliography/CCS%20Demos.pdf>
- The Carbon Sequestration Initiative, an industrial consortium housed in the MIT Energy Initiative (MITEI), has been tracking the progress of large-scale CCS projects for many years. The knowledge and data obtained in that project formed the basis of the white paper.
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Outline

- CCS Demonstration Projects
- Major CCS Demonstration Programs
- Lessons Learned
- CCS at a Crossroads

CCS Demonstration Projects

Defining a CCS Demonstration Project

- GCCSI lists 22 projects that got financing (list used for convenience, not an endorsement)
- Characteristics:
 - Scale: ~1,000,000 tons/yr or greater
 - CO₂ Source: NG processing or Anthropogenic
 - CO₂ Sink: Geologic formations
- I classify into 3 distinct categories

Commercial EOR Projects

Project	Location	Capacity (Mt/yr)	CO ₂ Source	Year of Operation
Enid	Oklahoma	0.7	Fertilizer	1982
Shute Creek	Wyoming	7.0	NG Processing	1986
Val Verde	Texas	1.3	NG Processing	1998
Weyburn	US/Canada	1.0	Coal Gasification	2000
Century	Texas	8.4	NG Processing	2010
Coffeyville	Kansas	1.0	Fertilizer	2013
Lost Cabin	Wyoming	0.9	NG Processing	2013
Lula	Brazil	0.7	NG Processing	2013
Uthmaniyah	Saudi Arabia	0.8	NG Processing	2015

Financing

Commercial EOR Projects

- High purity CO₂ is produced by the CO₂ Source
- CCS costs are limited to compression and transport
- The costs are covered by price EOR operators are willing to pay for the CO₂
- Are these really CCS projects?

Pioneer Projects

Project	Location	Capacity (Mt/yr)	CO ₂ Source	CO ₂ Sink	Year of Operation
Sleipner	Norway	0.85	NG Processing	Saline	1996
In Salah	Algeria	1.2	NG Processing	Depleted Gas	2004-2011
Snohvit	Norway	0.7	NG Processing	Saline	2008
Gorgon	Australia	4	NG Processing	Saline	2016

Financing Pioneer Projects

- They were built with little or no government support
- They started with a high purity CO₂ source that required only compression and transport
- The cost of adding CCS was a small percentage (roughly 10%) of overall project costs.
- The project could afford to absorb those costs and still be profitable.
- The companies could justify the costs as a cost of doing business and/or because the project aligned well with a broader business strategy.

CCS Demonstration Projects

Public-Private Partnerships

Project	Location	Capacity (Mt/yr)	CO ₂ Source	CO ₂ Sink	Year of Operation
Air Products	Texas	1.0	Methane Reformer	EOR	2013
Boundary Dam	Canada	1.0 (110 MW)	Coal Power	EOR/Saline	2014
Quest	Canada	1.1	Methane Reformer	Saline	2015
Decatur	Illinois	1.0	Ethanol	Saline	2016
Kemper	Mississippi	3.0 (582 MW)	Coal Power	EOR	2016
Petra Nova	Texas	1.6 (240 MW)	Coal Power	EOR	2016
Abu Dhabi	Abu Dhabi	0.8	Steel	EOR	2016
Alberta Trunk	Canada	0.3-0.6	Fertilizer	EOR	2016-17
Alberta Trunk	Canada	1.2-1.4	Refinery	EOR	2017

Financing CCS Projects

- Market Pull
 - Carbon markets
 - Electricity markets
 - Enhanced Oil Recovery (EOR)
 - Others (e.g., polygeneration)
- Technology Push
 - Direct Subsidies
 - Tax credits (e.g., investment, production)
 - Loan guarantees
 - Mandates (e.g., portfolio standards)
 - Others (e.g., Feed-in tariffs, contracts-for-differences)
- Other Drivers
 - Regulatory
 - Business

Boundary Dam Economics

- Regulatory Driver
 - 40-year old coal plants must be retrofitted with CCS or close down
- Business Driver
 - Did not want to strand their large lignite asset
- Technology Push
 - \$240 million direct subsidy (22% of initial cost estimate)
- Market Pull
 - By-product sales (EOR, fly ash, H_2SO_4)
 - Access to electricity markets if retrofit CCS is low-cost option (Had to be competitive with new NGCC)

Observations

- Only 3 projects in the power sector
- 21 of the 22 demonstration projects have occurred in a region with a significant oil & gas industry
 - 10 NG processing sources
 - 3 refinery sources
 - 16 EOR sinks
- 22nd project - Decatur (Ethanol source, Saline sink)
 - Ethanol is a gasoline additive, so indirectly linked to oil & gas

Major CCS Demonstration Programs

CCS Demonstration Programs

United States

- Clean Coal Power Initiative (CCPI)
 - Round 1 (2003) – focused on “advanced coal-based power generation and efficiency, environmental and economic improvements”
 - Round 2 (2004) – focused on “focused on gasification, mercury (Hg) control and carbon dioxide (CO₂) sequestration”
 - Round 3 (2009) – focused on “CO₂ capture and sequestration/beneficial reuse (CO₂ EOR)”
- American Reinvestment and Recovery Act (ARRA)
 - The CCPI received \$850 million to help fund their Round 3 call. Awards were made to six projects.
 - An Industrial CCS program was allocated \$1.52 billion, part of which went to fund three industrial CCS demonstrations in 2010.
 - The FutureGen project was “reconfigured” as FutureGen 2.0 and allocated \$1 billion.

US CCS Power Projects

CCPI and/or Stimulus Funds

Company	State	DOE Support (million \$)	Size	Technology	Fate	Status
FutureGen 2.0	IL	1000 (ARRA)	200 MW 1.1 MtCO ₂ /yr	Oxy	Saline Formation	Cancelled 2015
Basin Electric (Antelope Valley)	ND	100 (CCPI 3)	120 MW 1 MtCO ₂ /yr	PCC	EOR	Cancelled 2010
Hydrogen Energy (HECA)	CA	408 (CCPI 3)	400 MW 2.6 MtCO ₂ /yr	IGCC	EOR	Cancelled 2016
AEP (Mountaineer)	WV	334 (CCPI 3)	235 MW 1.5 Mt CO ₂ /yr	PCC	Saline Formation	Cancelled 2011
Southern (Plant Barry)	AL	295 (CCPI 3)	160 MW 1 Mt CO ₂ /yr	PCC	EOR	Cancelled 2010
NRG Energy (Petra Nova)	TX	167 (CCPI 3)	240 MW 1.6 Mt CO ₂ /yr	PCC	EOR	Under Construction
Summit Energy (TCEP)	TX	450 (CCPI 3)	400 MW 2 MtCO ₂ /yr	IGCC	EOR	Cancelled 2016
Southern (Kemper)	MS	270 (CCPI 2)	582 MW 3 MtCO ₂ /yr	IGCC	EOR	Under Construction

Kemper

- Awarded under CCPI Round 2 (all other CCS projects under Round 3)
- Plant originally planned for Florida without CCS. The project was motivated by the desire to commercialize a new gasification technology called Transport Integrated Gasification or TRIG.
- When the environment for building a new coal plant in Florida became problematic, Mississippi proved to be a desirable venue. Mississippi lignite and potential for using CO₂ for enhanced oil recovery were valuable attributes to the project. Further, the Mississippi Public Utilities Commission (PUC) was amenable to rate-base this project, thereby giving Kemper access to the electricity markets.

US Industrial CCS Projects

Stimulus Funds

Company	Location	DOE Support (million \$)	Size (MtCO ₂ /yr)	Source	Fate	Status
Leucadia Energy	Lake Charles. LA	261	4.5	New Methanol Plant	EOR	Cancelled
Air Products & Chemicals	Port Arthur, TX	284	1	Existing Steam Methane Reformers	EOR	Operational Jan, 2013
Archer Daniels Midland	Dacatur, IL	141	1	Existing Ethanol Plant	Saline Formation	Projected 2016

CCS Demonstration Programs

Alberta

- Carbon Capture and Storage Fund (2 billion CAD)
 - Quest (Steam Methane Reformer) - operating
 - Alberta Carbon Trunk Line (pipeline) – Under construction
 - Swan Hills Synfuel (Underground Coal Gasification) - cancelled
 - Pioneer Project (Power) – cancelled
- Other Drivers
 - Regulatory: \$15/tCO₂ Carbon Levy
 - Business: Protecting the Oil Sands

CCS Demonstration Programs

EU & UK

- EU
 - European Energy Programme for Recovery (EEPR)
 - NER300
- UK
 - £1 billion competition
 - Contract-for-differences
- Reference
 - Lupion, M. and H. Herzog, "NER300: Lessons learnt in attempting to secure CCS projects in Europe," International Journal of Greenhouse Gas Control, Vol 19, pp 19-25, Nov (2013).

NER300

- In January 2007, the European Commission issued the first *EU Energy Action Plan* which was endorsed by the European Council in March 2007
- European leaders agreed that the EU should aim to have up to 12 CCS demonstration projects by 2015
- The NER300 was the primary mechanism to incentivize the projects - funding to come from selling 300 million ETS permits
- 13 original CCS Projects
 - 11 are power projects, 2 are industrial projects
 - Of the 11 power projects:
 - » 10 are coal-fired, 1 is gas-fired
 - » 6 are post-combustion capture, 3 are pre-combustion, and 2 are oxy-combustion
- In end, no projects funded

NER 300 Issues

- Financial
 - No EOR (rely on Carbon Market instead)
 - Low ETS allowance price – double whammy
 - » Lowered revenue for NER300
 - » Lowered benefit of deploying CCS
 - Member states did not step up (less subsidy)
 - Diverted significant amount of potential funds to renewables
- Program parameters did not recognize the cost and complexity of CCS projects
 - Lack of flexibility
 - Competition with renewables

UK Competition

- UK Competition Round 1
 - November 2007 - the UK announced support of up to £1 billion for a post-combustion capture project
 - June 2008- four projects were pre-qualified: Peel Energy, BP, E.ON and Scottish Power
 - March 2010 - funding was awarded to E.ON and Scottish Power to conduct Front End Engineering and Design (FEED) studies.
 - E.ON and Scottish Power eventually dropped out
- Round 2
 - No longer limited to post-combustion capture
 - 4 qualifiers, 2 finalists
 - **November 25, 2015 – UK Government withdraws funds**

CCS Demonstration Programs

Results

- US
 - 2 industrial
 - 2 power
- Alberta
 - 1 industrial
 - 240 km pipeline
- EU (including UK)
 - 0
- Future
 - No programs in place anywhere

Lessons Learned

Markets

- Access to markets has to move beyond EOR.
- Regulatory drivers are critical to creating markets for CCS.

Markets

- Electricity Markets
 - Accessed by Boundary Dam and Kemper
 - Denied access for Mountaineer (reason, no “federal mandate to cut carbon emissions from power plants”)
 - Contracts for differences allows access
 - Other policies include portfolio standards or feed-in tariffs
- Carbon Markets
 - Most existing markets have too low a price to incentivize CCS
 - Need to avoid policies that undercut carbon markets

Business Drivers

- Business drivers play a major role.
 - Protecting or promoting assets, including the oil sands in Alberta or lignite in Mississippi, Saskatchewan, or Germany.
 - Going “beyond petroleum” at BP
 - The push for clean energy at NRG
 - The goal of “energy sustainability and environmental responsibility” at ADM

Financing Mechanisms

- Successful CCS power projects used multiple financing components.
- Over reliance on government subsidies is a risky business.
 - FutureGen and FutureGen 2.0 (from US)
 - Shell Peterhead and White Rose (from UK)
 - BP Peterhead (DF1) (from UK)
 - Mongstad (from Norway)

Timelines

- Setting arbitrary time limits on projects generally has led to failure (e.g., FutureGen 2.0, NER300).
- CCS projects that have shorter timelines have greater chances of success.
 - Develop smaller scale projects
 - Use brownfield sites
 - Minimize the technical risks (e.g., do the technology development at the pilot scale)
 - Work with government for a streamlined permitting process
 - Avoid complicated business arrangements

Technology

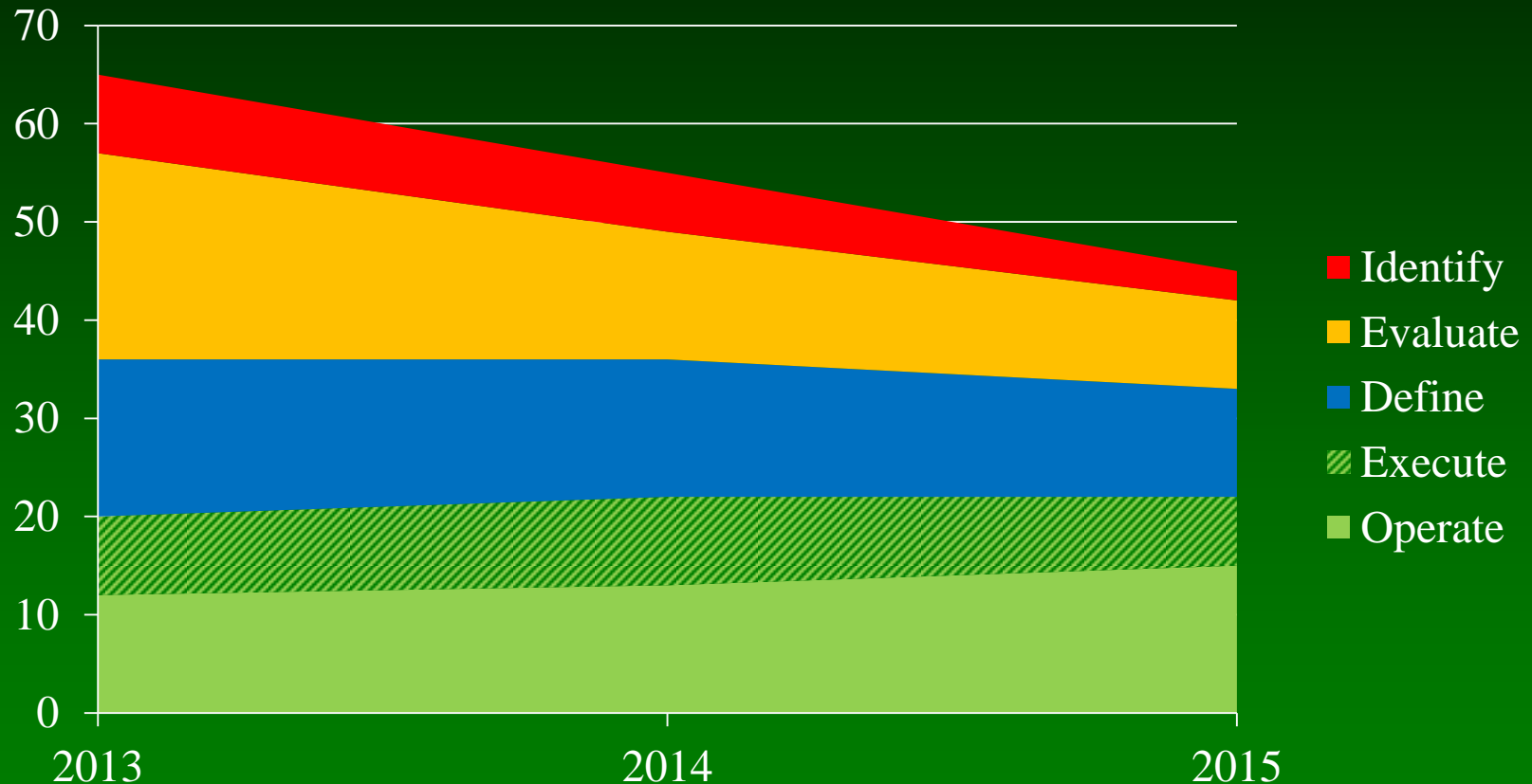
- Gasification-based power projects have a poor record.

Public Support

- Stronger political support is needed for CCS.
 - Cancellation of the UK's £1 billion competition
 - Forcing the EU's NER300 to include renewable projects
 - The UK not supporting BP's Peterhead (DF1) project
 - Germany not transposing the EU's CCS Directive
- All major CCS demonstration projects require a public outreach program.

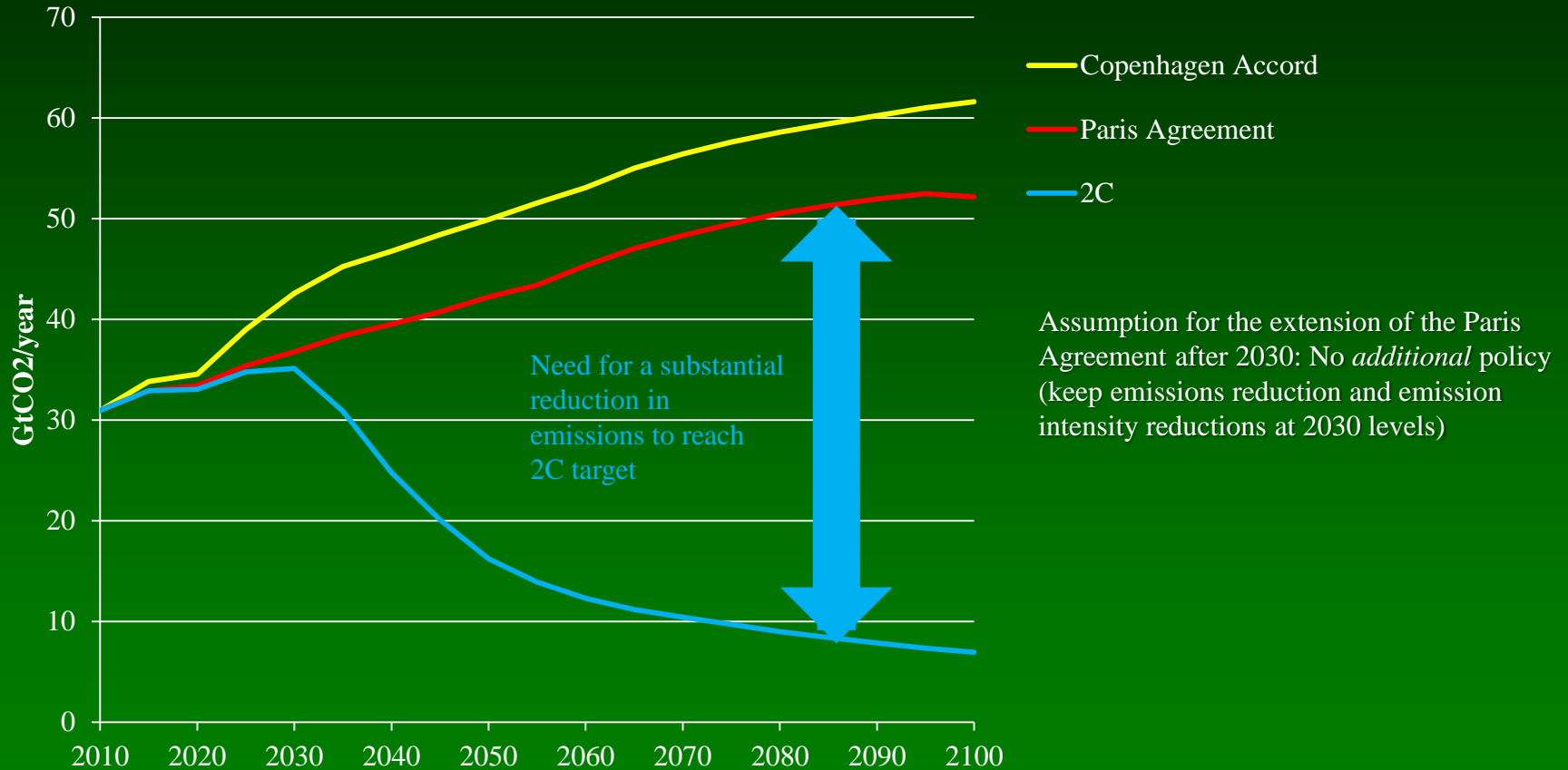
CCS at a Crossroads

CCS Project Pipeline



Data from the GCCSI

Mitigation Status Report



Source: MIT Joint Program Outlook (2013); MIT Joint Program Report 291 (2016)

Paris Agreement

- Nationally Determined Commitments
 - Commits to perhaps 20% of mitigation efforts ultimately needed to meet the aspirational goals
 - These will be the “easiest” 20%
 - Not even sure countries will follow through on their commitments
 - CCS not needed
- Aspirational Goals
 - Can we get their without CCS?
- No investments, etc. for what happens beyond 2030

NY Times Room for Debate

July 7, 2016

- Arguing that renewables can do it alone is a very risky proposition. One weakness of wind and solar is their intermittency. But proponents are now claiming energy storage can solve that problem. Here is what Bill Gates, generally a technology optimist, said in a recent interview in M.I.T.'s Technology Review: “I’m in five battery companies, and five out of five are having a tough time... When people think about energy solutions, you can’t assume there will be a storage miracle.”

Closing Thoughts

- All energy technologies have strengths and weaknesses. We need to build on their strengths and to minimize their weaknesses.
- The right denies the magnitude of the climate problem, the left denies the magnitude of the climate solution.

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