Outlook for Carbon Capture and Storage

Presentation to
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Jeffrey P. Price, Managing Partner
Bluewave Resources, LLC
6830 Elm Street
McLean, Virginia 22101
Phone: 703-448-3400
jprice@bwres.com

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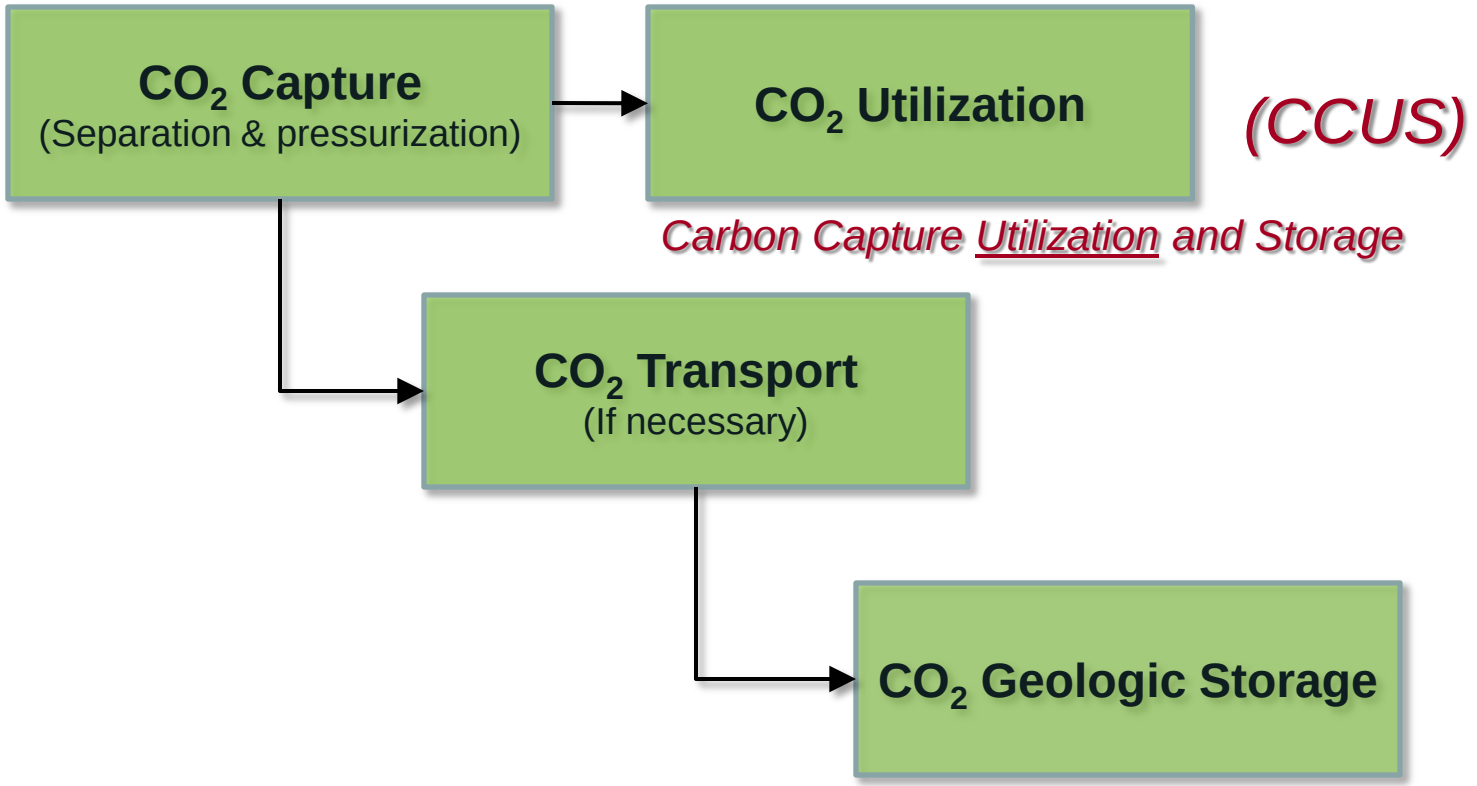
What is Carbon Capture and Storage (CCS) a.k.a. “Carbon Sequestration”



Purpose: Reduce CO_2 emissions to avoid climate change.

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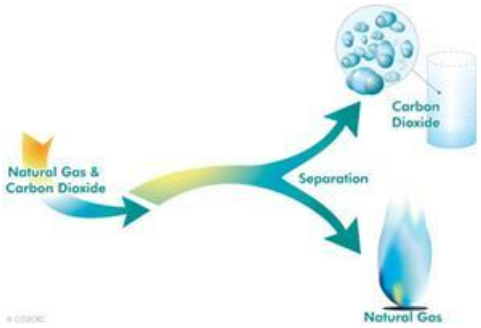
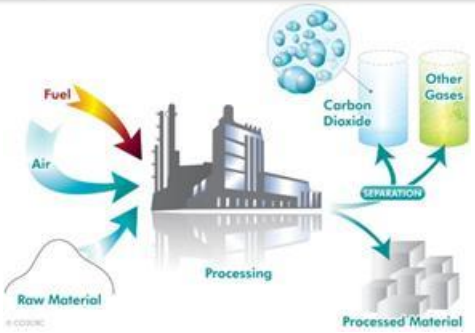
Capture for CCS

Industry: some applications commercial today; others not yet ready.



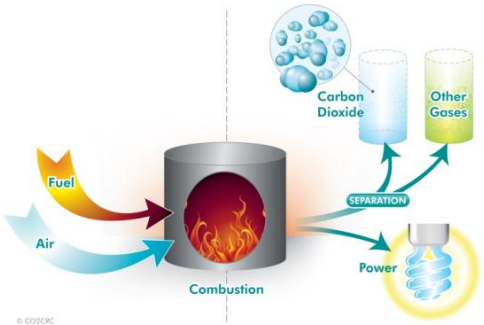
Natural Gas Separation



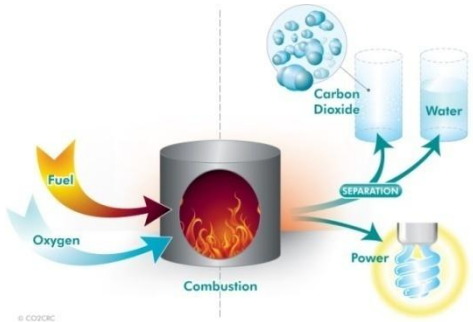
Capture From Industrial Processes

CCS is not just about power generation…

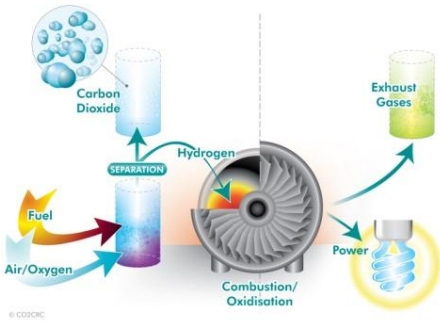
Power Generation: Mostly Under Development



Post-Combustion Capture



Oxyfiring



Pre-combustion Capture

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CCS for power generation is not just about "clean coal."

Utilization: the "U" in CCUS

Some examples now commercial.

Enhanced Oil Recovery (EOR)

Russell Ethanol Plant, KS

Great Plains Gasification Plant, ND; EOR in Saskatchewan

Fire Extinguisher, Dry Ice

Warrior Run power plant, MD: 90% CO_2 capture.

Flowers

Greenhouses, Netherlands

Fertilizer Production

CO_2 Capture for Urea Production, China

Carbonated Beverages

Kingsport Power Plant, TN

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Capture at Power Plants: Status and Outlook

Achieved so far…

- Pre-combustion—most experience, but IGCC expensive
- Post-combustion—several pilot projects conducted or underway
- Oxyfiring—first integrated pilot projects now going on line; FutureGen 2.0 in U.S.

Remaining to be done…

- Achieving scale
- Integration at scale
- Multiple generations at scale
- Technology shakeout at scale

Issues: Cost, integration, efficiency, reliability

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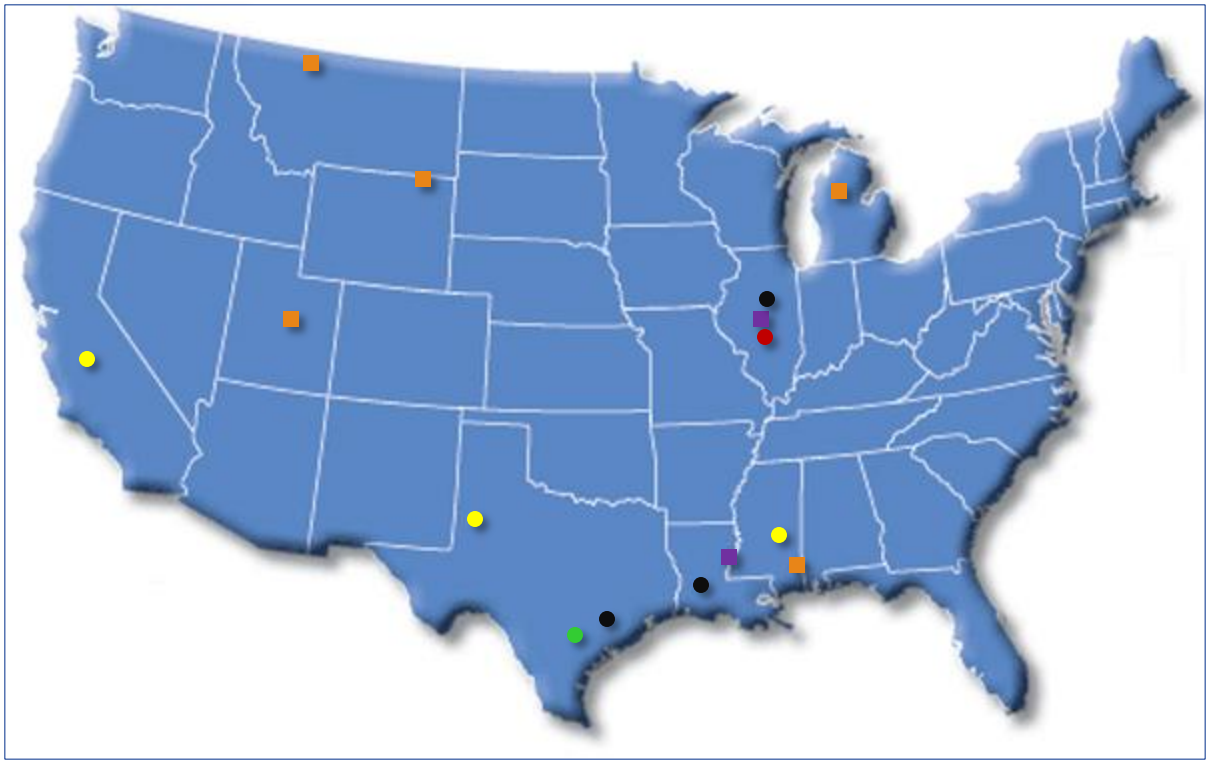
Large-Scale U.S. CCS Demonstrations



Integrated Projects

- CO_2 Capture from Industrial Facilities
- Post-Combustion Capture with Enhanced Oil Recovery
- IGCC with Enhanced Oil Recovery
- Oxyfiring (FutureGen 2.0)

Geologic Storage

- Ongoing
- Planned

Source: U.S. Department of Energy

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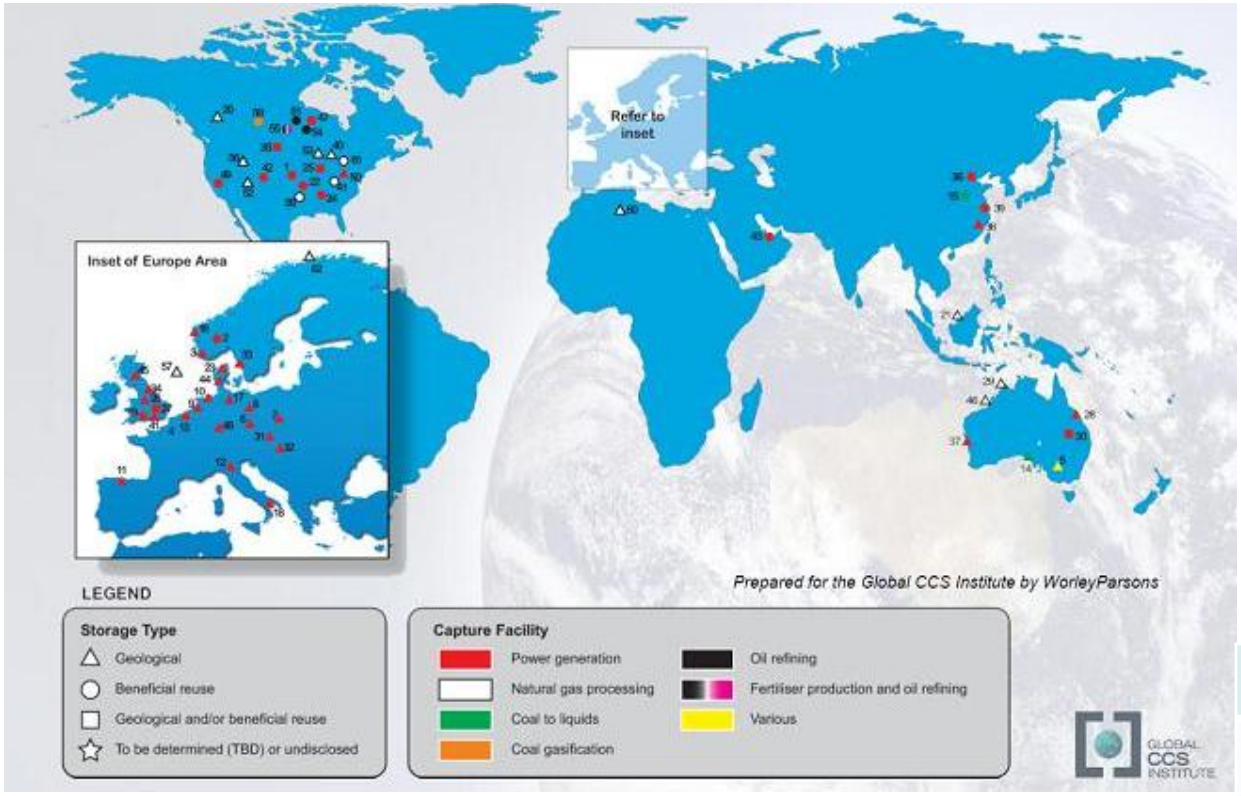
Commercial-scale fully-integrated CCS projects.
The Global Picture



Status as of 5/12	Number
Operational	8
Execution	7
Define	23
Evaluate	28
Identify	9
Total	75

Of these, 35 are in North America.

Power Projects	Number
Pre-combustion	17
Post-combustion	18
Oxyfuel	5
Total	40

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Source: Global Carbon Capture and Storage Institute, May 21, 42012

Pipeline Transport: Commercial Today

Current U.S. Carbon Dioxide Pipelines

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Source: United States Department of Transportation, Bluewave Resources, LLC

Storage: Status and Outlook

Achieved so far…

- Storage resource increasingly well known
- Hundreds of millions of tons injected for EOR
- Many successful saline formation projects, mostly small
- Monitoring, verification & Accounting (MVA) tools and procedures developed
- Initial “best practices” developed

Remaining to be done…

- Transition from CO_2-EOR to geologic storage
- Gain further experience at scale in diverse formations
- Develop storage infrastructure
- Evaluate of offshore storage resource
- Refine best practices with experience

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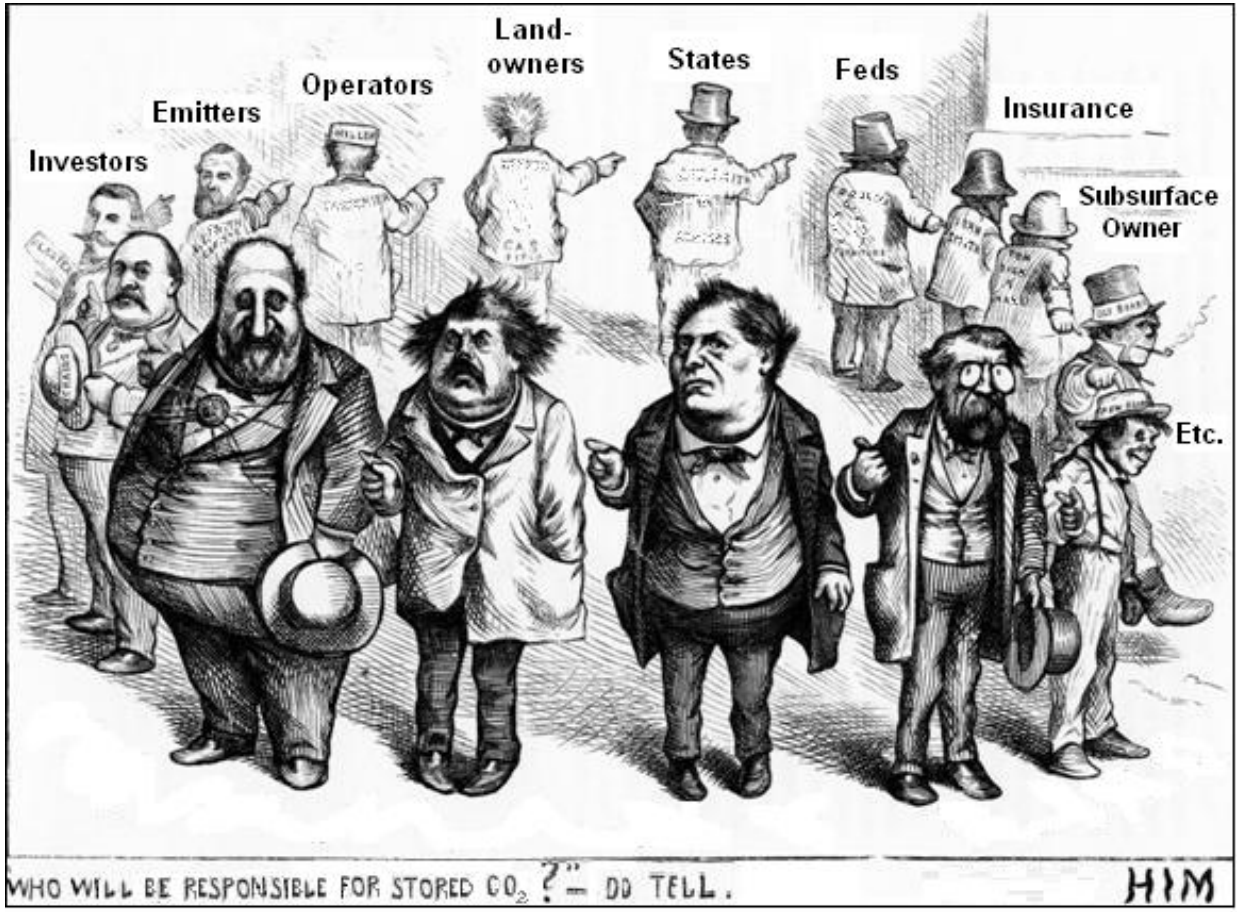
Who will bear post-closure liability for storage?



With apologies to Thomas Nast.

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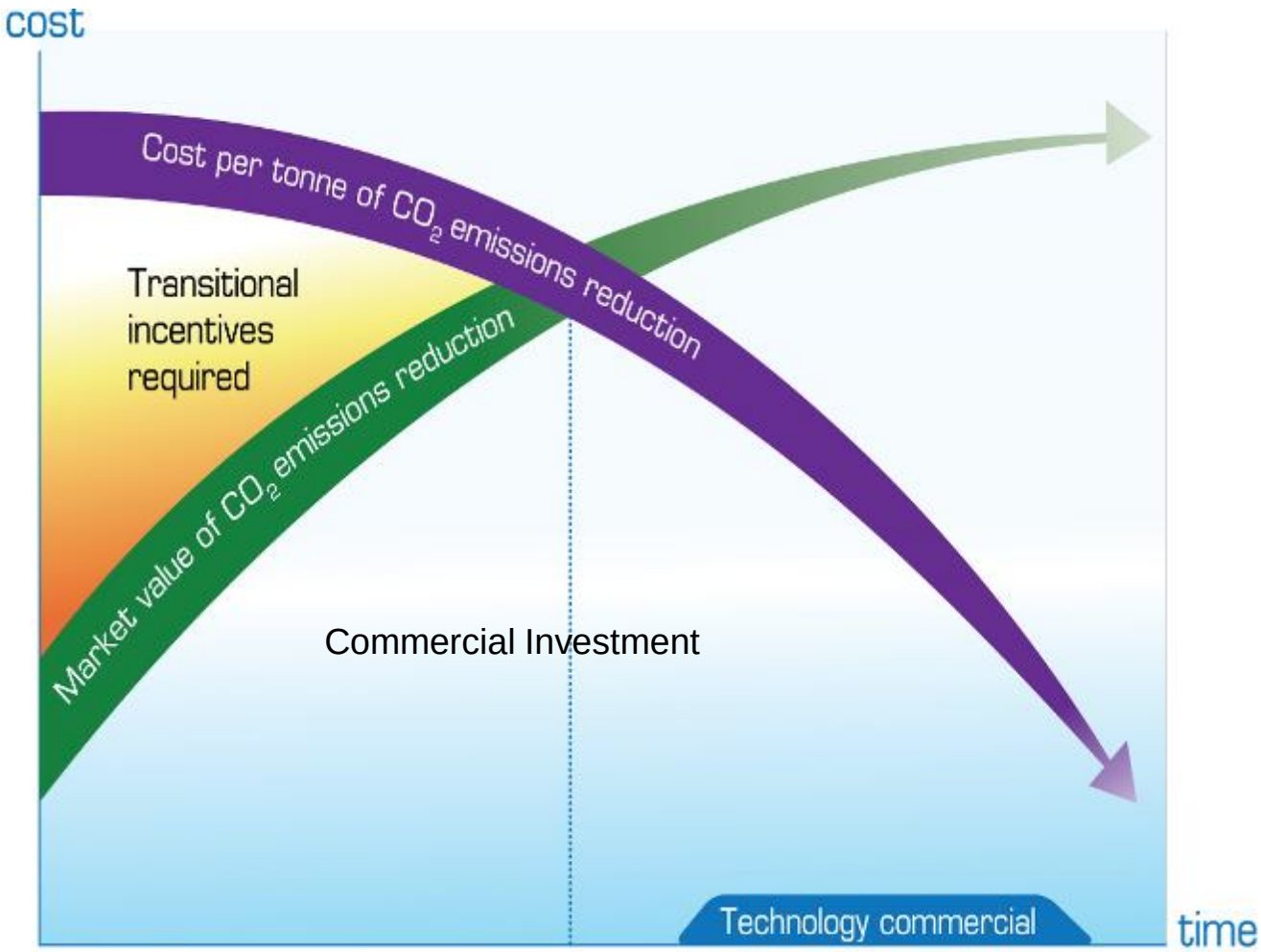
From RD&D incentives to commercial investment…



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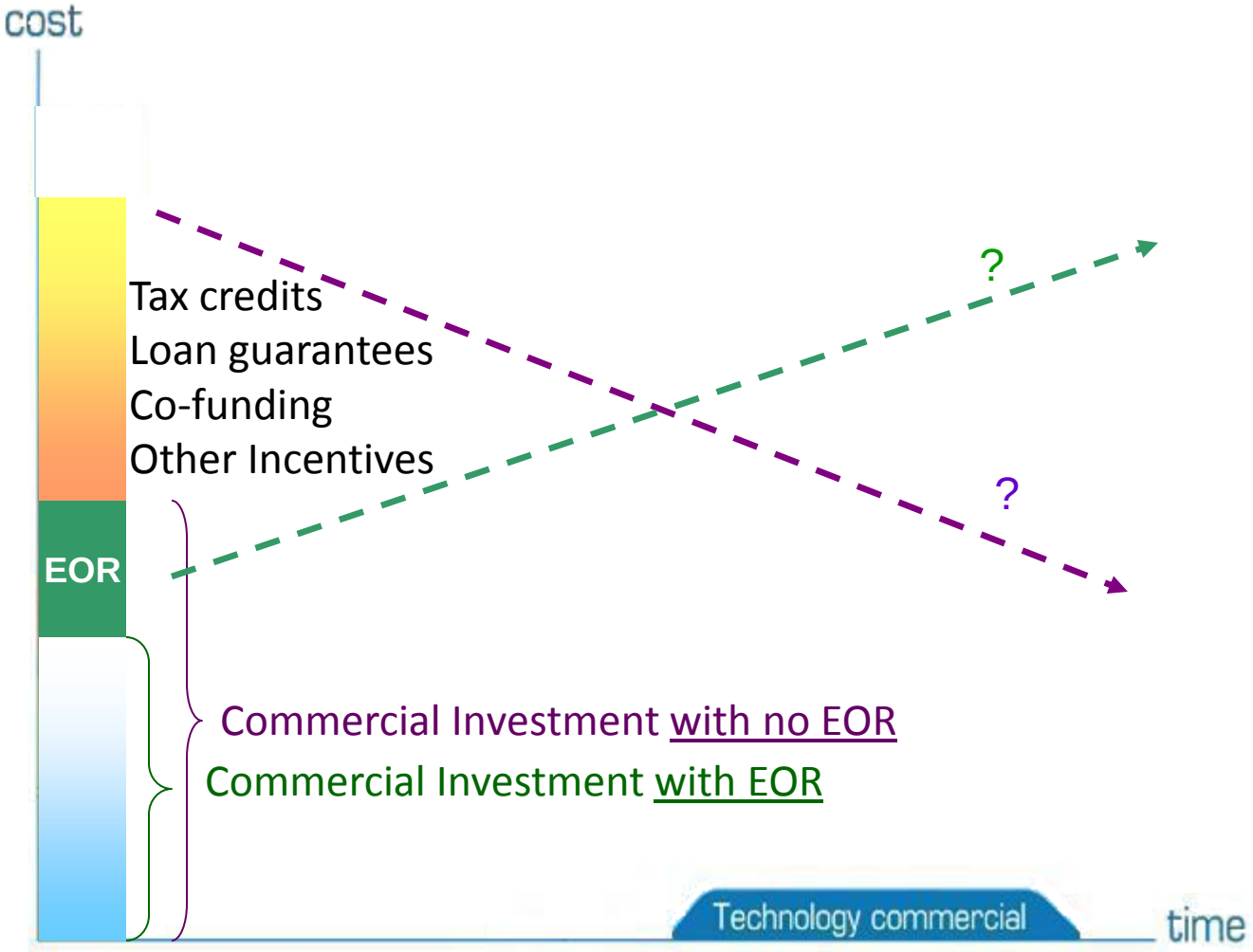
The Theory

Source: Bluewave Resources, LLC and CO2CRC

From RD&D incentives to commercial investment…



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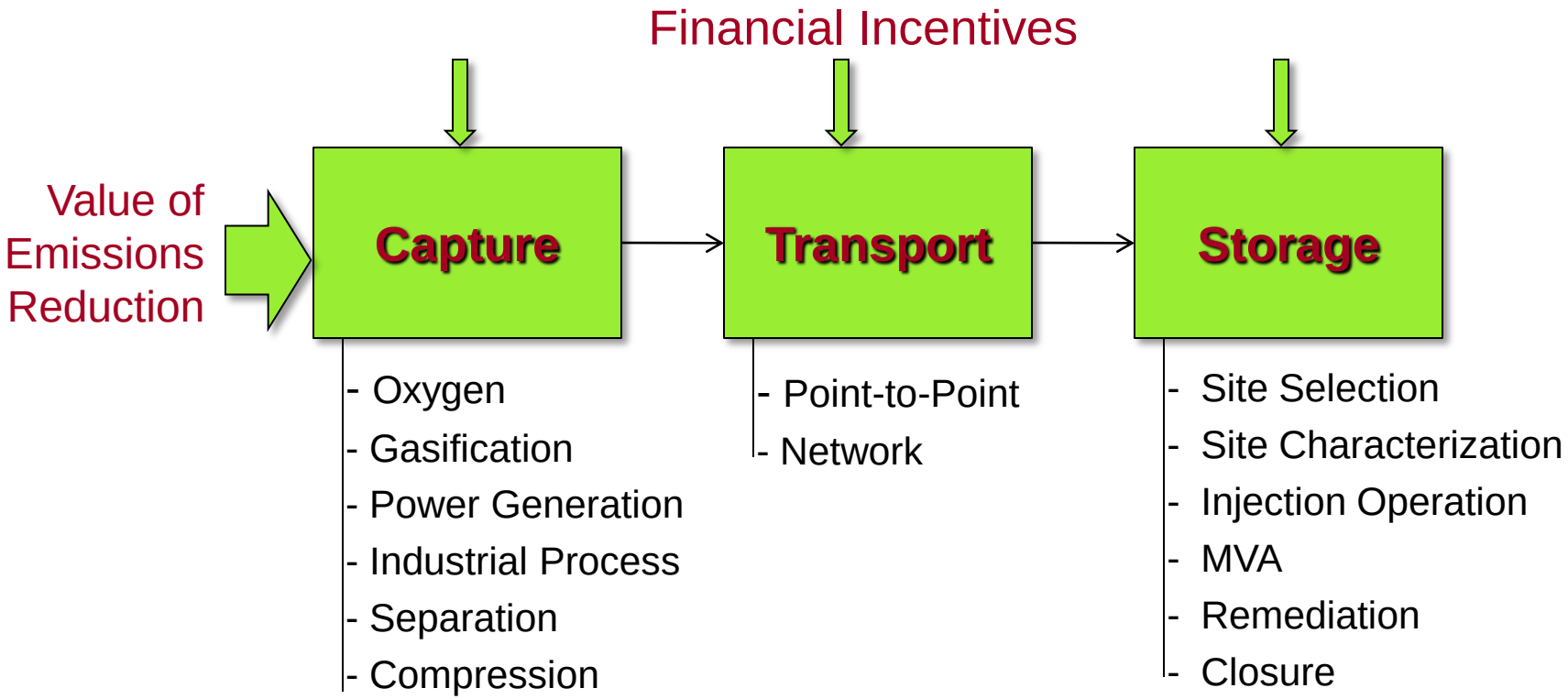
Actual Situation

Source: Bluewave Resources, LLC

How can the CCS value chain be assembled?



Key Issues

- ✓ *How are value, cost and risk allocated?*
- ✓ *Treatment by public utility commissions?*
- ✓ *Other economic regulation?*

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How do we address public acceptance?

Cover of Dutch Magazine NWT, April 2009

http://www.natutech.nl/00/nt/nl/47_58/artikel/order/200904/4_2009.html

CCS projects cancelled or in trouble due to public opposition:

- Barechdrecht, Netherlands
- Carson, California
- Greenville, Ohio
- Neutrebbin, Germany
- Stadum/Hörup, Germany

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Power Plant CCS: The state of play …

- Considerable technical progress has been made with more needed.
  - For capture—several generations of plants at scale
  - For storage—further experience at scale in diverse geologic formations.
- The real challenges are economic and institutional.
- Economic challenges:
  - Large project size and commensurate CAPEX
  - Lack of adequate incentives
  - Constrained government RD&D budgets
  - Low-cost natural gas
  - Level playing field with other low-carbon options
- Institutional challenges:
  - Need for viable legal/regulatory framework, especially on liability
  - Lack of public understanding and acceptance
- EPA CO_2 NSPS allows CCS as an option for coal plants, no path exists to commercial viability.

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