



DOE/NETL CO₂ Capture R&D Program

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U.S. DEPARTMENT OF

ENERGY

National Energy
Technology Laboratory

R&D Areas: CO₂ Capture

Pre-Combustion

- Solvents
- Sorbents
- Membranes
- Hybrid processes
- Water-gas shift reactor



Post-Combustion

- Solvents
- Sorbents
- Membranes
- Hybrid processes



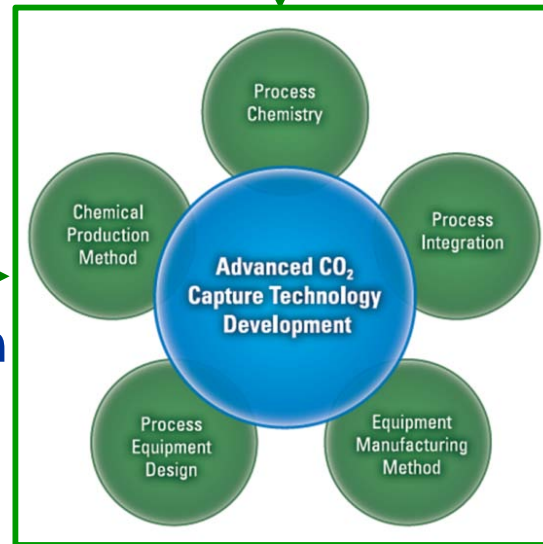
Advanced Combustion

- Atmospheric oxy-combustion
- Pressurized oxy-combustion
- Oxygen transport membrane
- Chemical looping



Advanced Compression

- Intra-stage cooling
- Cryogenic pumping
- Supersonic shock wave compression



Technology Classification

1st-Generation Technologies—include technology components that are being demonstrated or that are commercially available.

2nd-Generation Technologies—include technology components currently in R&D that will be ready for demonstration in the 2020–2025 timeframe.

Transformational Technologies—include technology components that are in the early stage of development or are conceptual that offer the potential for improvements in cost and performance beyond those expected from 2nd-Generation technologies. The development and scaleup of these “Transformational” technologies are expected to occur in the 2016–2030 timeframe, and demonstration projects are expected to be initiated in the 2030–2035 time period.

Pre-Combustion Research Focus

CARBON CAPTURE

TECHNOLOGY AREAS

POST-COMBUSTION CAPTURE

PRE-COMBUSTION CAPTURE

KEY TECHNOLOGIES

Solvents

Sorbents

Membranes

RESEARCH FOCUS

- High Pressure/Selectivity/Temperature
- Dual Swing Regeneration Cycles/
Hybrid Systems

- Cyclic PSA/High-Pressure Products
- WGS/CO₂ Process Intensification/
High Temp./Hybrid Systems

- High Temp./Novel Materials
- WGS/CO₂ Process Intensification/
Nanomaterials/High Temp./Hybrid Systems

■ 2nd Generation ■ Transformational

Post-Combustion Research Focus

CARBON CAPTURE

TECHNOLOGY AREAS

POST-COMBUSTION CAPTURE

PRE-COMBUSTION CAPTURE

KEY TECHNOLOGIES

Solvents

Sorbents

Membranes

RESEARCH FOCUS

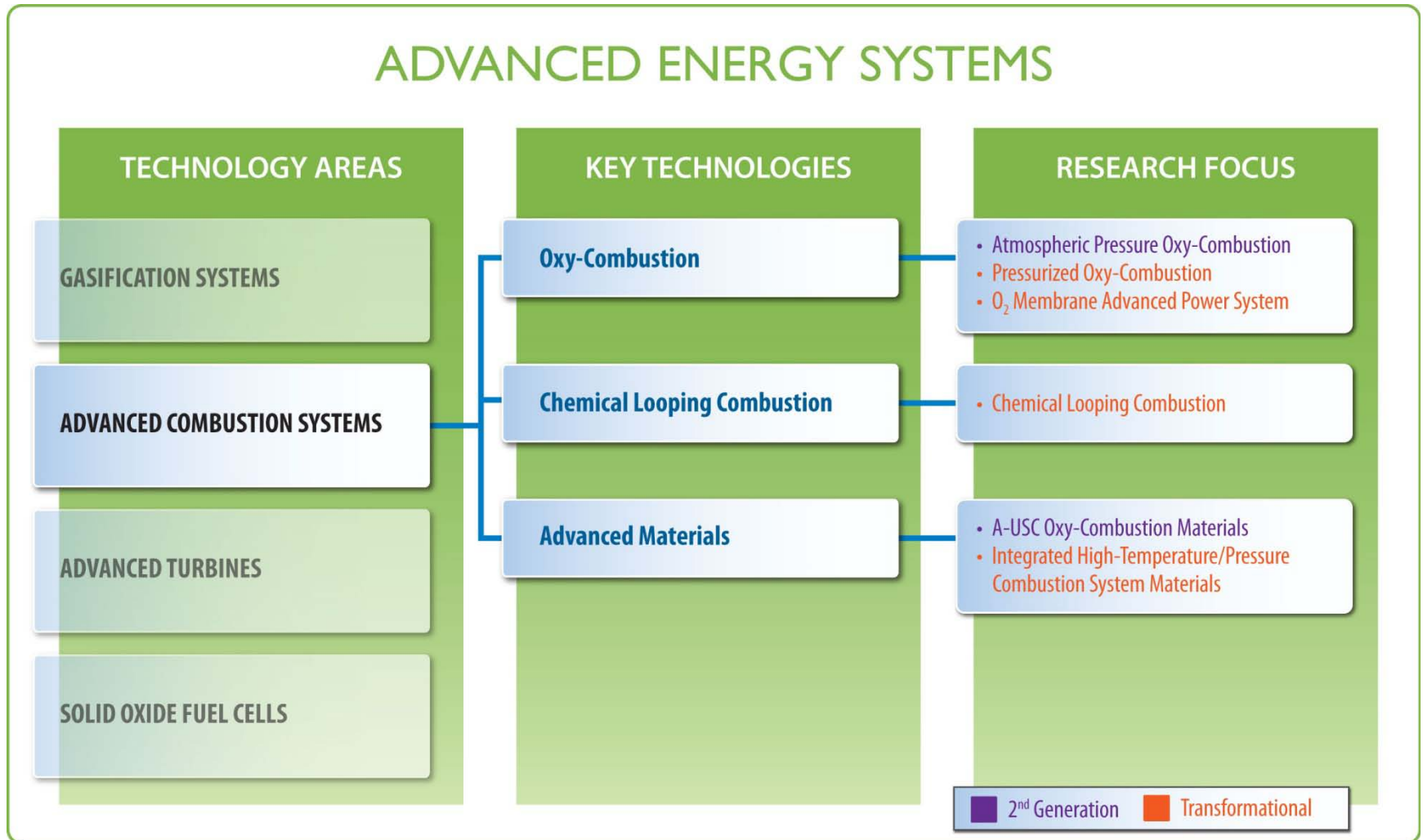
- Advanced Amine/Carbonate/Intensification
- Functionalized/Catalyzed/Phase Change/Hybrid Systems

- TSA/PSA/Process Enhancement/Materials
- Structured Adsorbents/Rapid TSA-PSA/Electrochemical/Hybrid

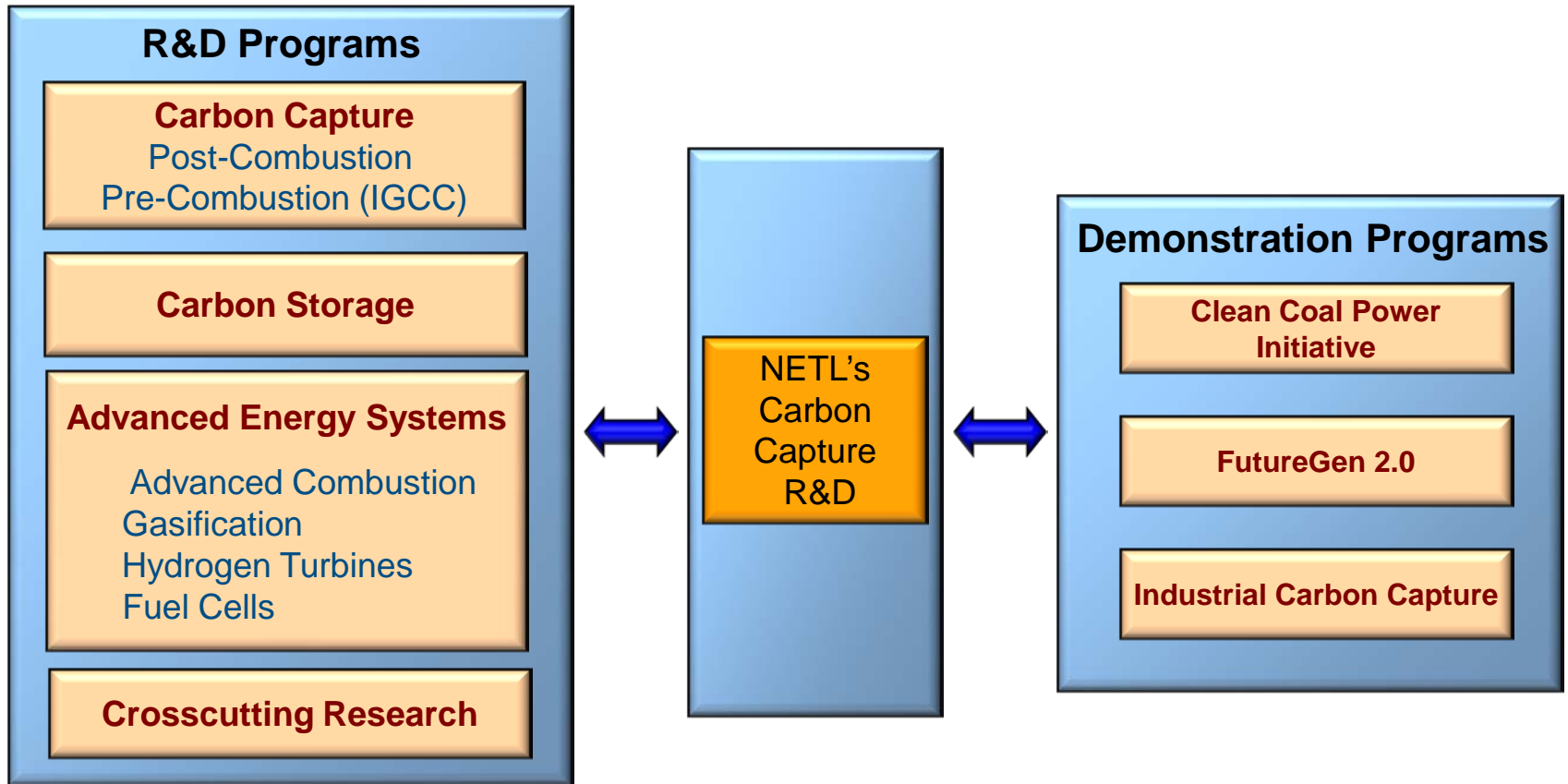
- High-Density Membranes/Novel Materials
- Nanomaterials/Novel Process Conditions/Hybrid Systems

■ 2nd Generation ■ Transformational

Advanced Combustion Program Overview

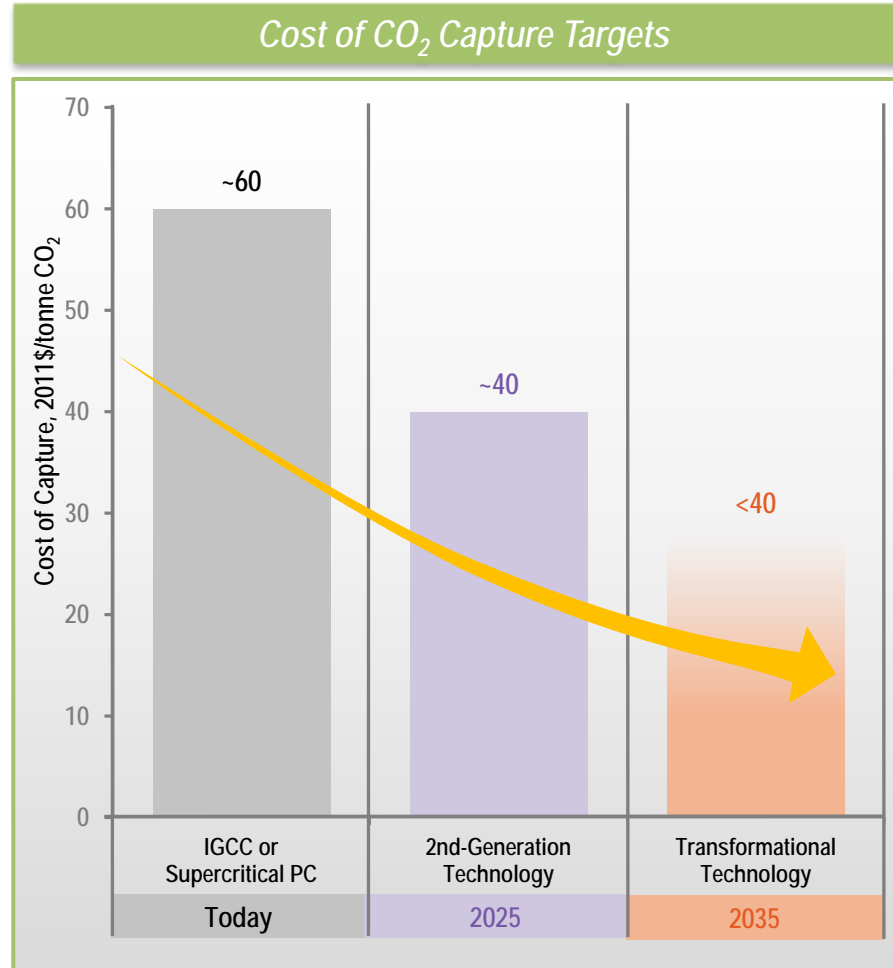


DOE/NETL Clean Coal Research Program



Clean Coal Research Program Goals

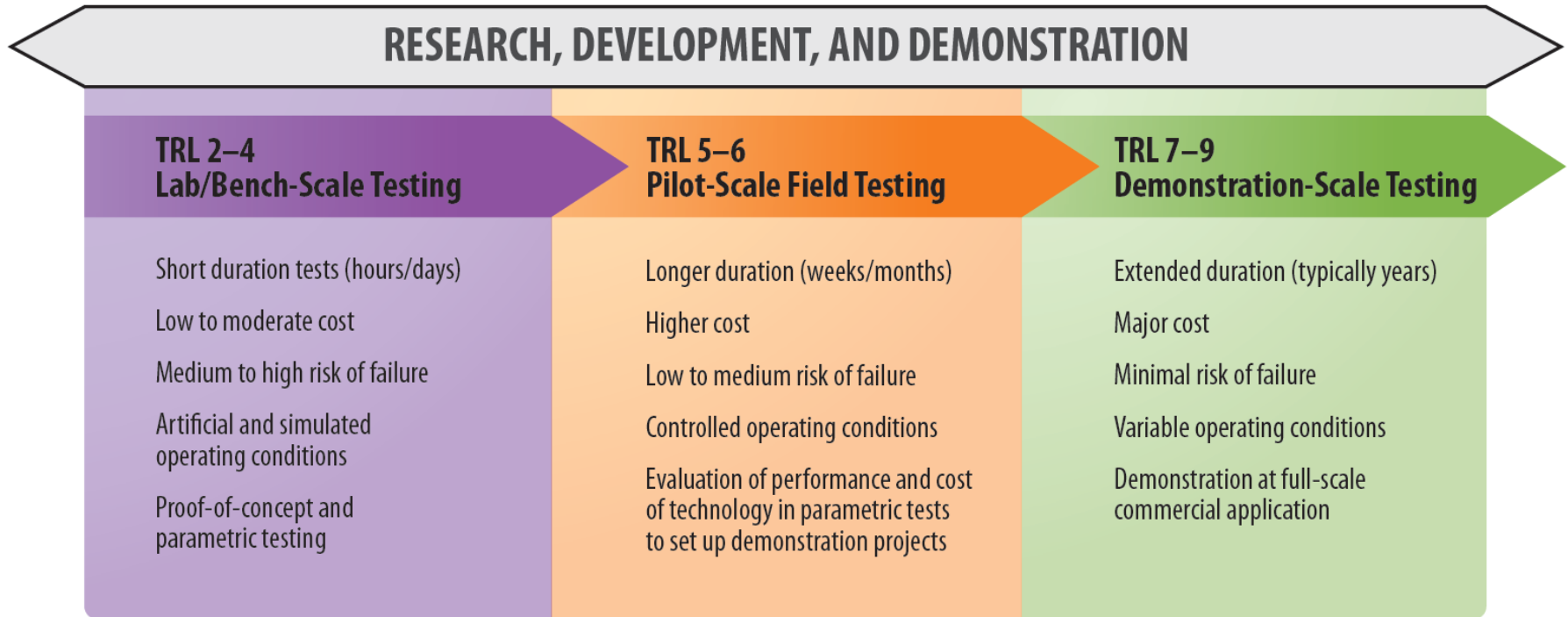
Driving Down the Cost of CO₂ Capture of Coal Power with CCS



Goals shown are for greenfield plants. Costs are nth-of-a-kind, for the first year of plant operation, and include compression to 2215 psia but exclude CO₂ transport and storage costs. Today's capture costs are relative to Today's SCPC without CO₂ capture. 2025 and 2035 capture costs are relative to an A-USC PC without CO₂ capture.

Implementation Plan: Overview

Progress Over Time



Carbon Dioxide Capture R&D Projects

Pre-Combustion

Laboratory/Bench Scale

- < 0.5 MWe
- Simulated or real syngas

1 Solvent

1 Solid Sorbents

5 Membranes

Pilot-Scale

- <0.1 MWe
- Coal derived syngas

MTR CO₂ Membrane

MTR H₂ Membrane

WPI H₂ Membrane

Parr Reactor Solvent

Post-Combustion

Laboratory/Bench Scale

- < 0.5 MWe
- Simulated or real flue gas

10 Solvents

8 Solid Sorbents

5 Membranes

Pilot Scale

- 0.5 – 5 MWe
- Coal flue gas

ADA Sorbent 1 MWe

MTR Membrane 1 MWe

Univ. KY Solvent 0.7 MWe

Southern Co. Solvent 1 MWe

Neumann Solvent 0.5 MWe

Linde Solvent 1 MWe

Oxy-combustion

Laboratory/Bench Scale

- < 0.5 MWe

5 Pressurized Oxy

1 Modeling

5 Chemical Looping

Pilot Scale

- 0.5 – 5 MWe

Alstom Oxy-comb. 5 MWe

Praxair OTM 1 MWe

Compression

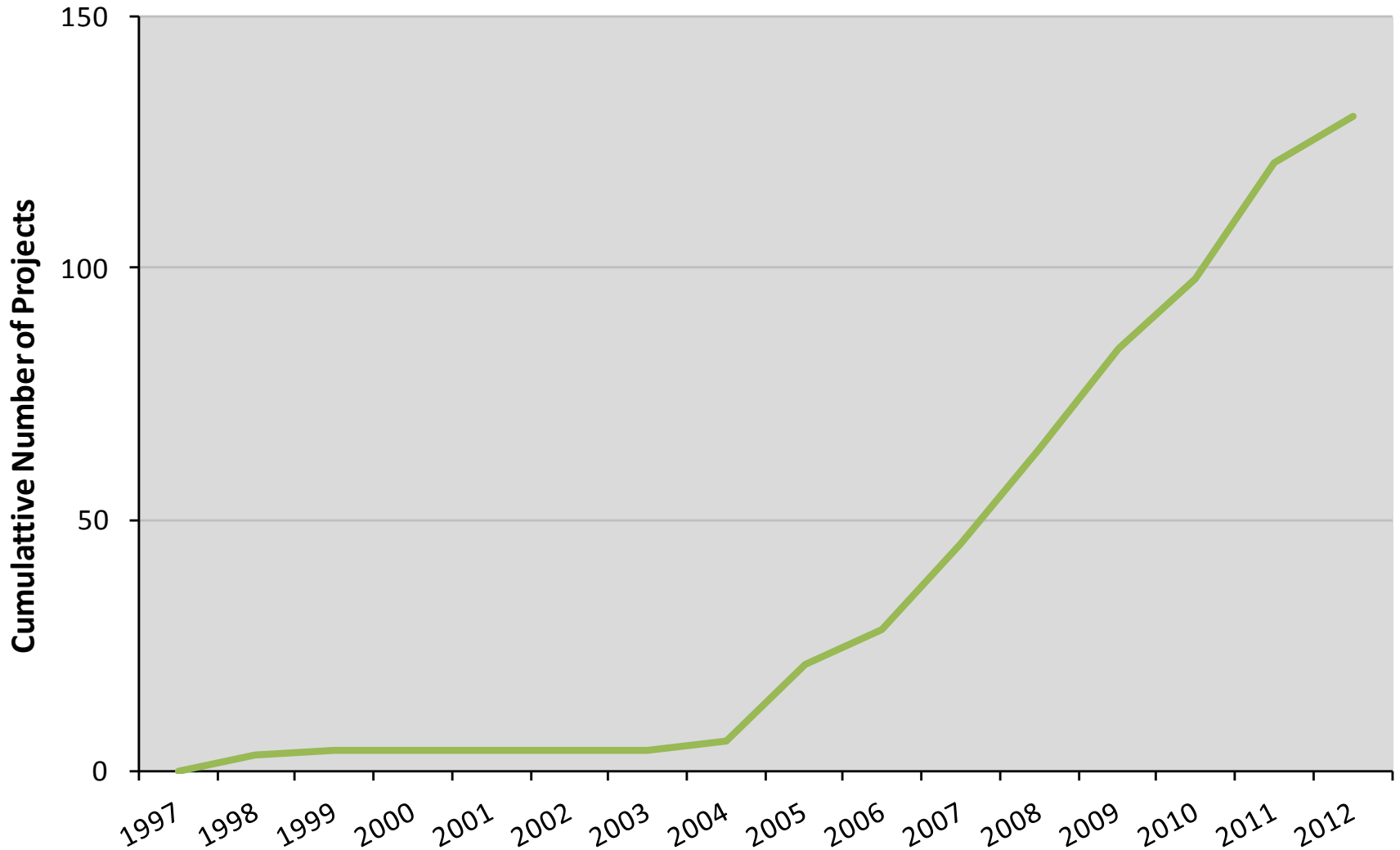
Pilot Scale

- > 0.5 MWe

Ramgen 13,000 hp

SwRI 3,000 hp

Growth of the NETL Carbon Capture Program



Budget

	FY 12 (\$M)	FY 13 (\$M)
Carbon Capture		
Post-combustion	55.5	52.9
Pre-combustion	13.4	12.8
Advanced Combustion	10.7	10.5
Total	79.6	76.2

Status Update

2012 Oxy-combustion FOA

- *Advanced Oxy-combustion Technology Development and Scale-up for New and Existing Pulverized Coal Power Plants*
 - **Two-phase Investigation of Pressurized Oxy-combustion and Chemical Looping Combustion Systems**
 - Phase I: Detailed Systems Analysis of Multiple Proposed Technologies
 - Phase II: Down-select Most Promising Systems for Component Development and Testing
 - **8 projects selected in Phase 1 (September 2012)**
 - **Proposals for Phase II received (June 30, 2013)**
 - **Announcement of down-selections in August**

FY 13 Accomplishments

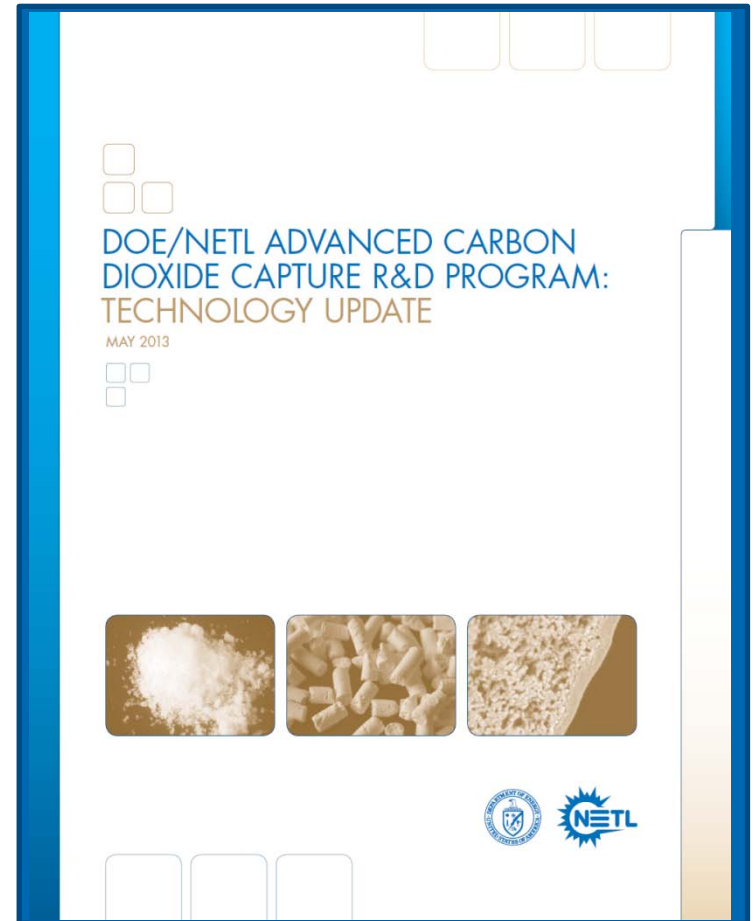
- **2013 FOA:** *Development of Post-Combustion and Pre-Combustion Carbon Dioxide Capture Technologies for New and Existing Power Plants*
- **Bench Scale and Small Pilot/Slipstream Scale**
 - Advance bench scale technologies from Technology Readiness Level 3 to Level 4
 - Advance small pilot scale technologies from Technology Readiness Level 5 to Level 6
 - Issued March 14, Closed May 2
 - Review in Progress
 - Announcement of Selections in August

FY 13 Accomplishments (Cont.)

- **Carbon Capture Program External Peer Review**
 - Independent Review of Pre- and Post-Combustion Capture
 - 16 Projects Reviewed
 - Evaluations Based on Nine Different Criteria
 - Over half the Projects Received Scores Higher than 6/10
 - Positive Feedback
 - “The panel was impressed by the high-caliber of the projects it reviewed ... These projects have ambitious goals and significant potential to advance carbon capture technology. The projects represent a well-balanced portfolio of fundamental science, national laboratory research, and large-scale industrial projects.”
- **Program Plans Developed for Carbon Capture and Advanced Combustion**
 - <http://www.netl.doe.gov/technologies/coalpower/ewr/pubs/Program-Plan-Carbon-Capture-2013.pdf>
 - <http://www.netl.doe.gov/technologies/coalpower/ewr/pubs/Program-Plan-Adv-Comb-Systems-2013.pdf>

DOE/NETL Advanced CO₂ Capture R&D Program: *Technology Update (June 2013)*

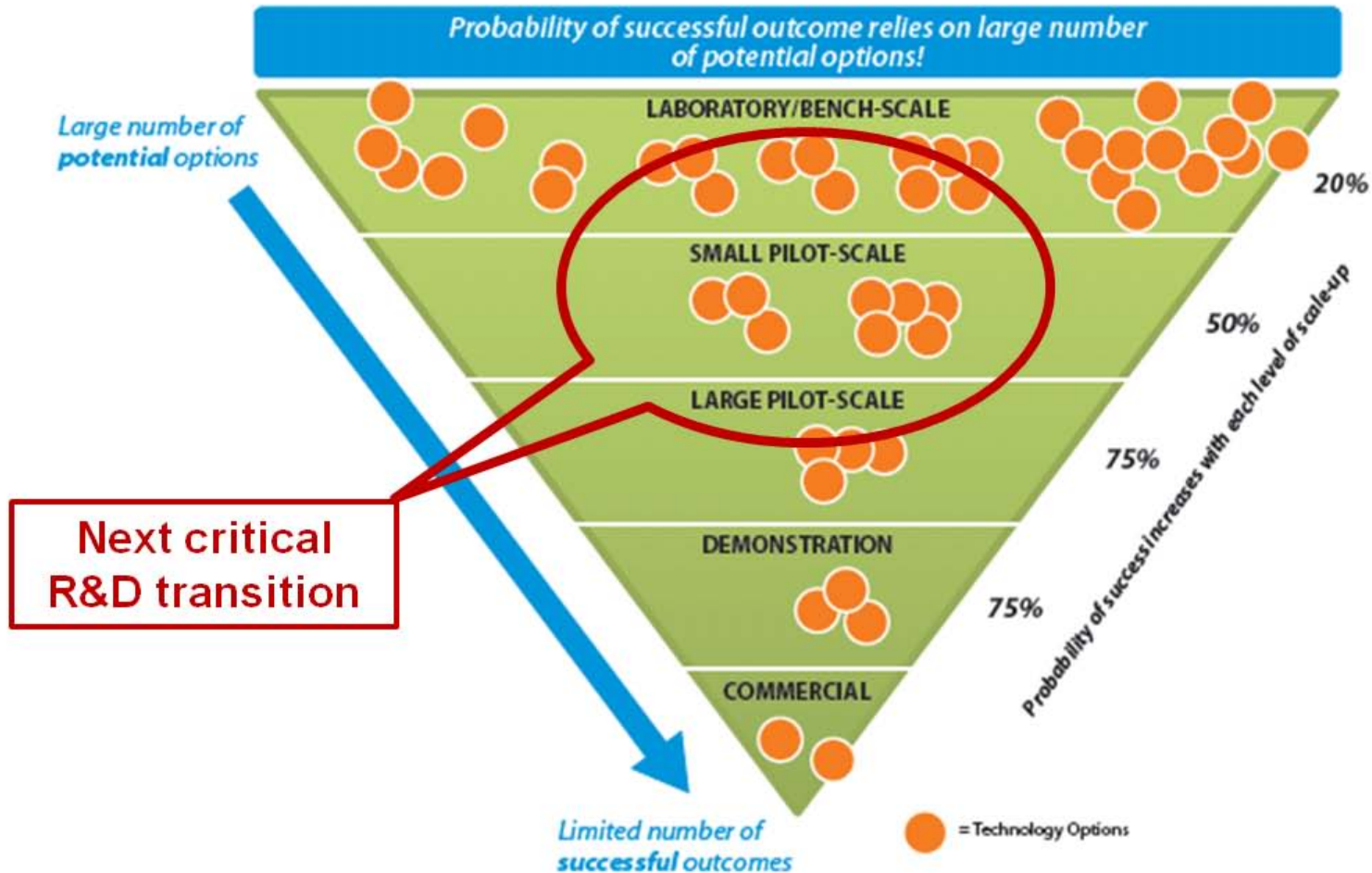
- This is the third edition of a comprehensive handbook that provides an update on DOE/NETL R&D efforts on advanced CO₂ capture technologies for coal-based power systems.
- The report tracks the progress of DOE/NETL pre-combustion, post-combustion, and oxy-combustion technologies for CO₂ capture.
- The handbook is available for download on the NETL website at:



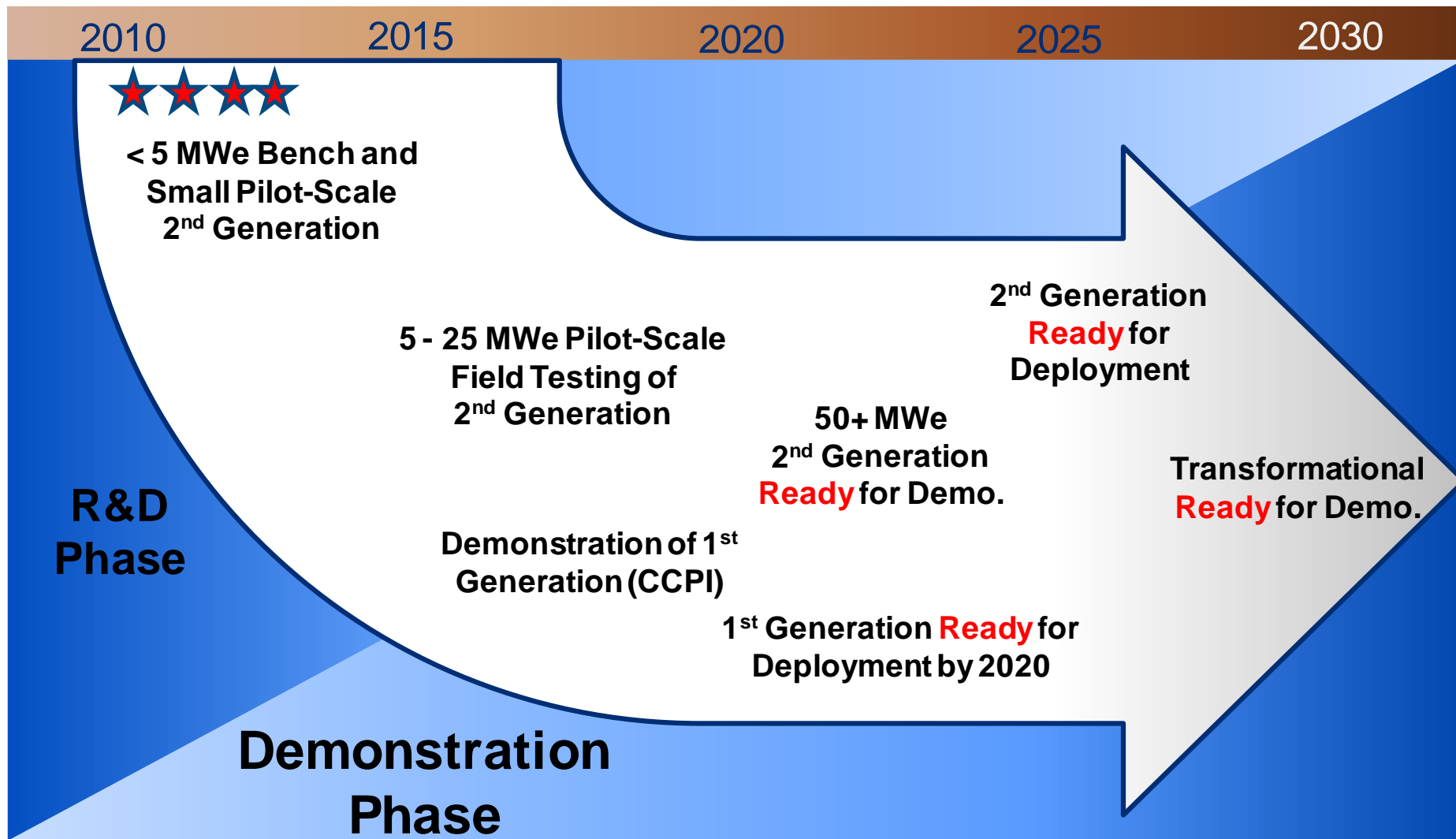
<http://www.netl.doe.gov/technologies/coalpower/ewr/pubs/CO2Handbook/>

Looking Forward

- **2nd Generation:** Increased Focus on Pilot-Scale
- **Transformational:** Continue Development at Bench Scale



DOE/NETL CO₂ Capture RD&D Timeline



 Funding Opportunity Announcements

Conference Overview

Monday	Post-Combustion Sorbents
Tuesday	Post-Combustion Solvents
	CO ₂ Compression
Wednesday	Post-Combustion Membranes
	Pre-Combustion Projects
Thursday	ARPA-E Projects
	System Studies and Modeling
	Oxy-Combustion/Chemical Looping Projects

Participating Projects



Carbon Capture Solutions

Carbon Capture Scientific, LLC



FuelCell Energy
Ultra-Clean, Efficient, Reliable Power



For More Information About the NETL Carbon Capture Program

- NETL Website:
 - www.netl.doe.gov
- Capture Program Website:
 - www.netl.doe.gov/technologies/coalpower/ewr/co2/index.html

Reference Shelf

- Annual CO₂ Capture Meeting

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- Office of Fossil Energy website:
 - www.fe.doe.gov

Innovations for Existing Plants
CO₂ Emissions Control

[Capturing Carbon from Existing Coal-Fired Power Plants \(Apr 2009\)](#)
[Annual NETL CO₂ Capture Technology for Existing Plants R&D Meeting Presentations - March 24-26, 2009](#)
[DOENETL's Monthly Carbon Sequestration Newsletter](#)

Welcome to the Innovations for Existing Plants (IEP) Program's CO₂ emissions control R&D homepage. In FY08, the IEP Program redirected its focus to include CO₂ emissions control for existing coal combustion-based plants, e.g. conventional pulverized coal-fired plants. The focus on CO₂ emissions control technology – both post-combustion and oxy-combustion – and related areas of CO₂ compression and CO₂ beneficial reuse is in direct response to the priority placed on advancing technological options for the existing fleet of coal-fired power plants for addressing climate change. In addition to funding R&D projects conducted externally, DOE/NETL also conducts in-house research to develop new breakthrough concepts for carbon capture that could lead to dramatic improvements in cost and performance relative to today's technologies. The IEP CO₂ emissions control R&D activity also sponsors systems analysis studies of the cost and performance of various carbon capture technologies. The program goal is to develop advanced CO₂ capture and separation technologies for existing power plants that can achieve at least 90% CO₂ removal at no more than a 35% increase in cost of energy services.

Use the hyperlinks located in the adjacent blue box to find detailed information on the IEP CO₂ emissions control R&D activities. Information on pre-combustion CO₂ emissions control technology applicable to coal gasification-based (e.g. integrated gasification combined cycle) plants is located at the [CO₂ Capture](#) webpage of DOE/NETL's [Carbon Sequestration Program](#) website.

Prior to FY08, DOE/NETL's CO₂ emissions control R&D effort was conducted under the [Carbon Sequestration Program](#). With responsibility for existing plant CO₂ emissions control R&D now being conducted under the IEP Program, the Carbon Sequestration Program continues to focus on pre-combustion CO₂ emissions control and geological sequestration. Since its inception in 1997, the Carbon Sequestration Program has been developing both core and supporting technologies through which carbon capture and storage (CCS) will become an effective and economically viable option for reducing CO₂ emissions from coal-based power plants. Successful R&D will enable CCS technology to overcome the existing technical barriers.

- ▶ [Program Goals and Targets](#)
- ▶ [Post-Combustion CO₂ Control](#)
- ▶ [Oxy-Combustion CO₂ Control](#)
- ▶ [CO₂ Compression](#)
- ▶ [CO₂ Beneficial Use](#)
- ▶ [Systems Analysis](#)
- ▶ [CO₂ Emissions Control Reference Shelf](#)