EPRI | ELECTRIC POWER RESEARCH INSTITUTE

CO_2 Capture R&D at EPRI

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Palo Alto, CA

NETL CO_2 Capture Technology Meeting

Pittsburgh, PA

July 8-11, 2013

EPRI Overview

Mission

To conduct research, development and demonstration on key issues facing the electricity sector on behalf of our members, energy stakeholders, and society

Members

450+ participants in more than 30 countries

EPRI members generate approximately 90% of the electricity in the United States

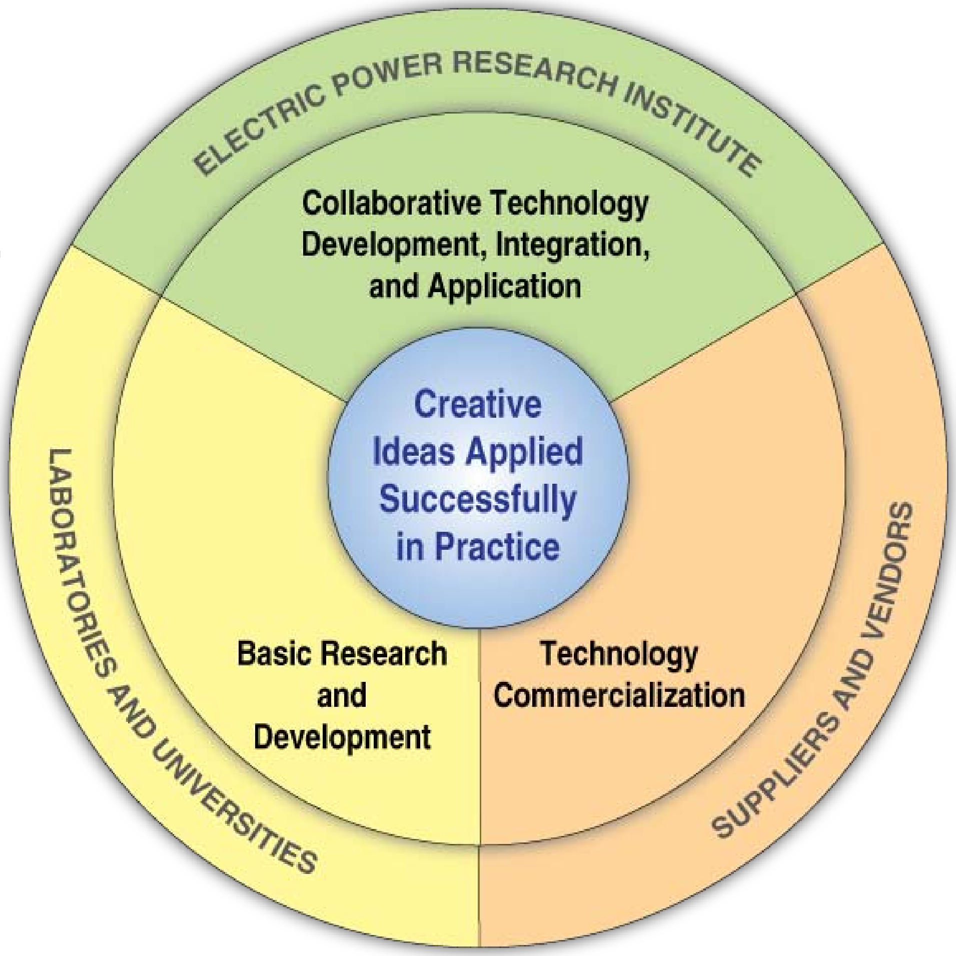
International funding of nearly 25% of EPRI's research, development and demonstrations

Three Key Aspects of EPRI

Independent
Objective, scientifically based results address reliability, efficiency, affordability, health, safety and the environment

Nonprofit
Chartered to serve the public benefit

Collaborative
Bring together scientists, engineers, academic researchers, industry experts



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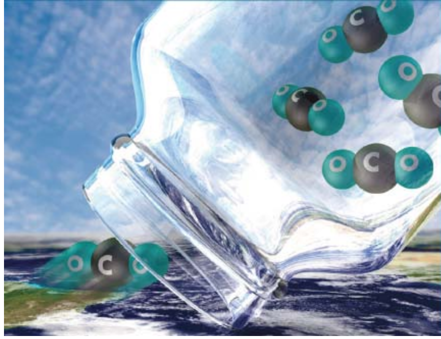


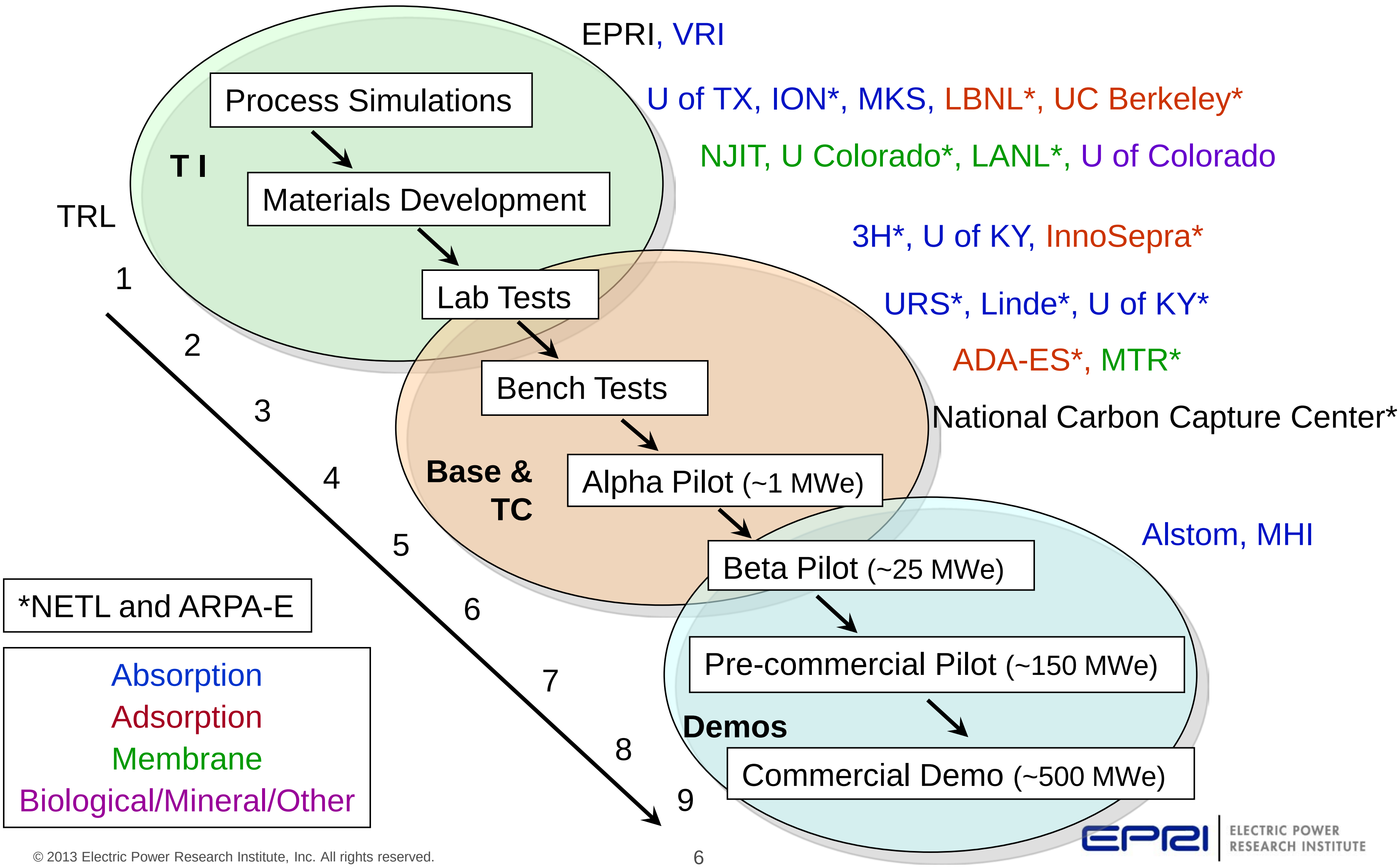
CCS Status Today

- In 2007, there were 50+ large-scale carbon capture and storage projects proposed; over 30 have been cancelled and none are operating
- What happened?
  - Bad economy, lack of sufficient financial incentives, lack of regulatory clarity
  - Storage and transportation issues caused some cancellations
  - Economic and energy penalty of current technologies too high
- CCS projects still needed to improve technologies and gain public acceptance

Post-Combustion Capture
Beyond Lab and Bench Scales

Type, TRL	Size MWe	$, millions Source	Now	Future
Alpha-pilot TRL 5-6	1-2	10’s Private Public+Private	Dozens	Existing Facilities – dozens New Facilities – dozens
Beta-Pilot TRL 6-7	10-20	100’s More Private Less Public	~5	Existing Facilities – handful New Facilities – handful
Demo & Commercial TRL 8-9	100 - 200+	100’s-1000’s Mostly tax and rate payers	1 (almost)	New Facilities – Scaled back ~15-20 now at various stages

Post-Combustion CO_2 Capture R&D at EPRI



Mountaineer Overview

Alstom's Chilled Ammonia Process at AEP's Mountaineer
Property of Alstom Power and/or AEP

- **Alstom's chilled ammonia CO_2 post-combustion capture**
  - ~20-MW_e demonstration at AEP's Mountaineer Plant in WV
  - Designed for ~100,000 tonnes CO_2/year
  - Injection occurred in saline reservoir using two on-site wells
  - Capture started in September 2009 and storage in October 2009;
  - 51,000 tonnes captured and 37,500 tonnes stored
  - Capture project completed in May 2011, storage monitoring nearing completion
- EPRI's role:
  - Managed collaborative (20 power companies)
  - Measured and reported on CO_2 capture performance and economics
  - Monitored storage activities and reported findings

Performance Results: Base Case Kenosha

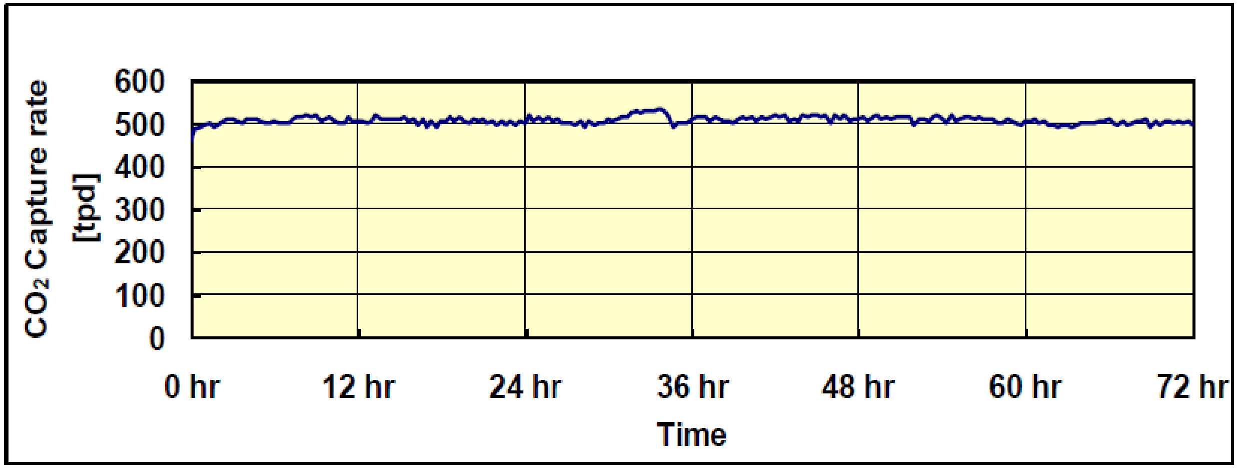
	Pre-CAP PCC Retrofit (No CO_2 Recovery)	Post-CAP PCC Retrofit (with CO_2 Recovery)
CO_2 Vented (100% Basis) STPD (MTPD)	16,950 (15,377)	1,649 (1,496)
CO_2 Recovered (100% Basis), STPD (MTPD)	-	15,302 (13,882)
CO_2 Recovered %	-	90%
<u>Power Generation, MW:</u>		
Steam Turbine Gross Output	815.2	694.7
<u>Extraction BPST Gross Output</u>	-	5.3
Total Turbine Generator Gross Output	815.2	700.1
<u>Auxiliary Loads, MW:</u>		
Power Plant Equipment Loads	65.2	64.9
CAP PCC CO_2 Recovery Loads	-	70.7
Total Consumption	65.2	135.6
Net Power Export, MW	750	564.5
Net Plant Efficiency, % HHV	38.4%	28.9%
Net Efficiency Loss, Percentage Points HHV	-	9.5

Plant Barry Overview

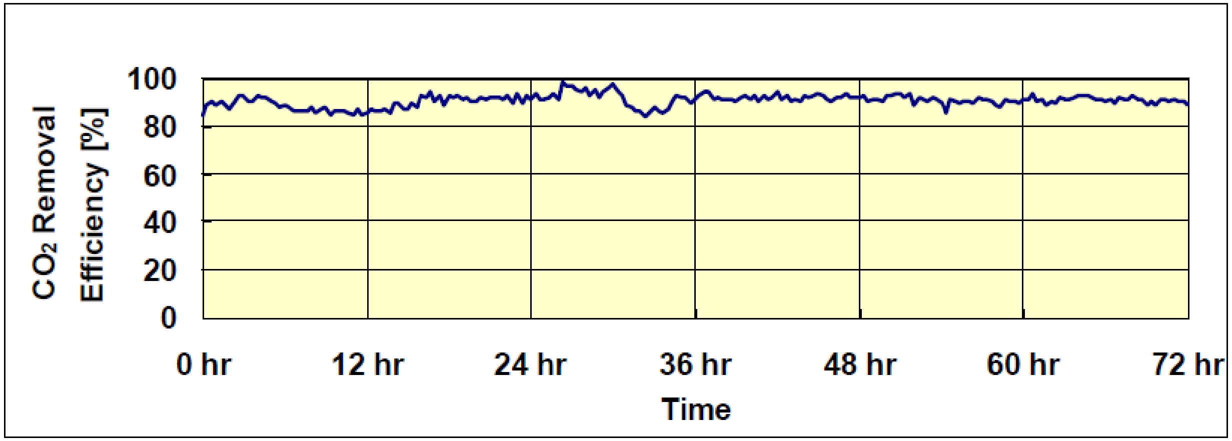
MHI's KM-CDR Process at Plant Barry
Property of MHI and/or Southern

- **MHI KM-CDR advanced amine CO_2 post-combustion capture**
  – ~25-MW_e demonstration at Alabama Power's Plant Barry in AL
  – ~500 tonnes CO_2/day
  – Capture started June 2011; ~140,000 tonnes captured
  – Injection started August 2012 at 200 tonnes CO_2/day
  – Over 55,800 tonnes stored in Citronelle oilfield 20 km away
  – Plan is to continue capturing CO_2 for up to 4 more years with the goal to store more than 100,000 tonnes
- EPRI's role:
  – Manage collaborative (20 power companies)
  – Measure and report on CO_2 capture performance and economics
  – Leading all storage activities including reporting findings

Plant Barry: CO_2 Capture Results



CO_2 Capture Rate



Courtesy of Southern Company

CO_2 Removal Efficiency

Stable operation achieving high CO_2 removal

CCS Comparative Study: Sites and Locations

- Site: **Coal Creek**
- Owner: **Great River Energy**
- Location: **North Dakota**

- Site: **Powerton**
- Owner: **MidWest Generation**
- Location: **Illinois**

- Site: **Lingan**
- Owner: **Nova Scotia Power**
- Location: **Nova Scotia**

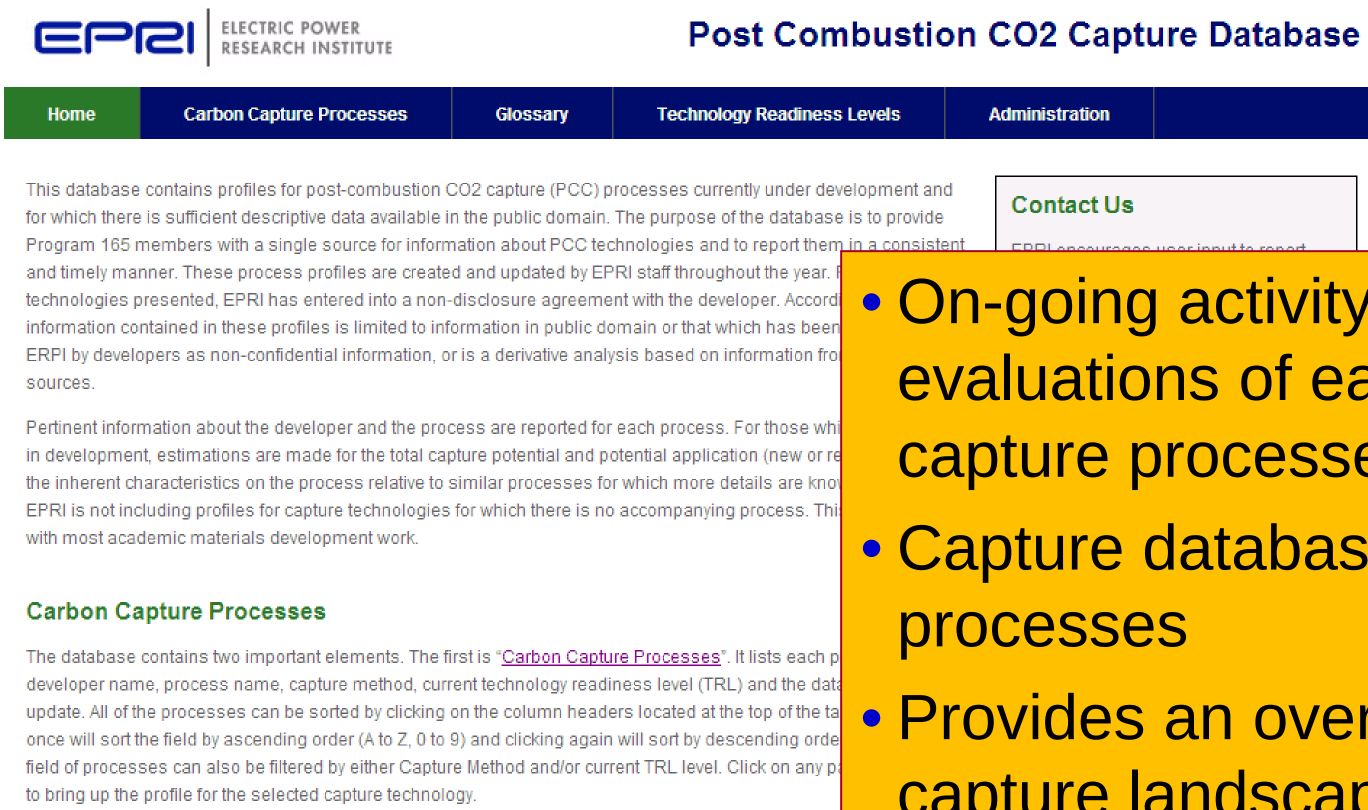
- Site: **Intermountain**
- Owner: **Intermountain Power**
- Location: **Utah**

- Site: **Bayshore**
- Owner: **FirstEnergy**
- Location: **Ohio**

Comparison Summary

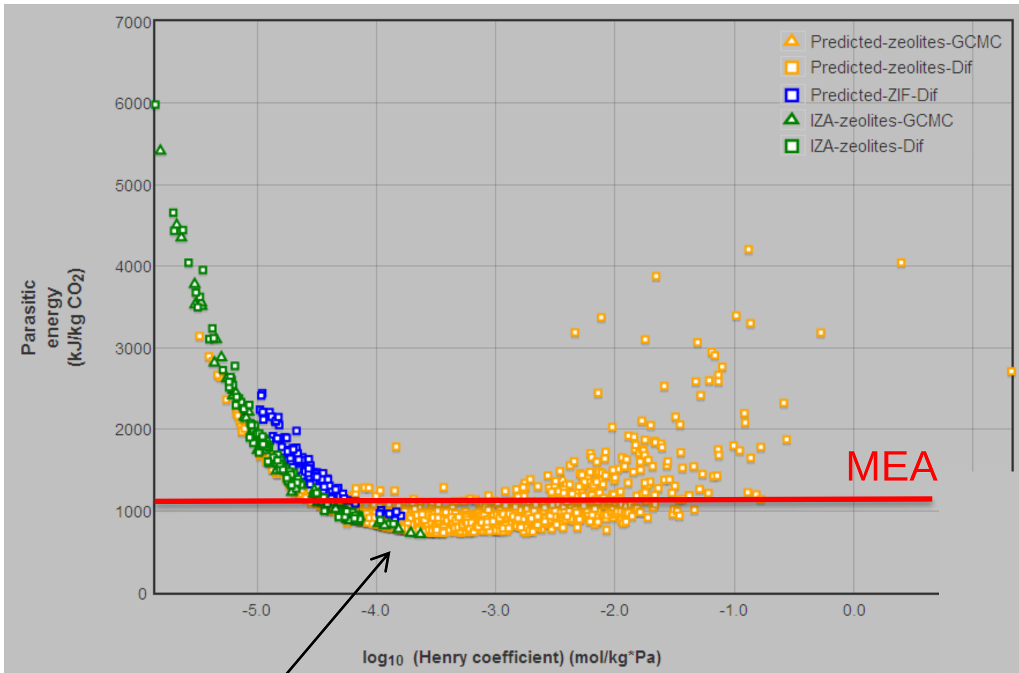
- Despite the variances in base plants, all the sites can be retrofitted with 90% post-combustion capture
  - No technical showstoppers with the available technology
  - Cogeneration lowers generating efficiency of Bayshore unit making it an unattractive capture option. (Not a reflection on CFB!)
- The capital investment required can vary considerably:
  - Approximately **$2000/kW** difference in the PC sites studied
- The LCOE after capture plant can vary considerably:
  - Approximately **$37/MWhr** difference in the sites studied
- The CO_2 avoided cost can vary between sites:
  - Approximately **$30/ton** difference in the sites studied
- The more advanced solvents, currently in development , lower the efficiency penalty by **~2.5** percentage points

Process Evaluations And Capture Database

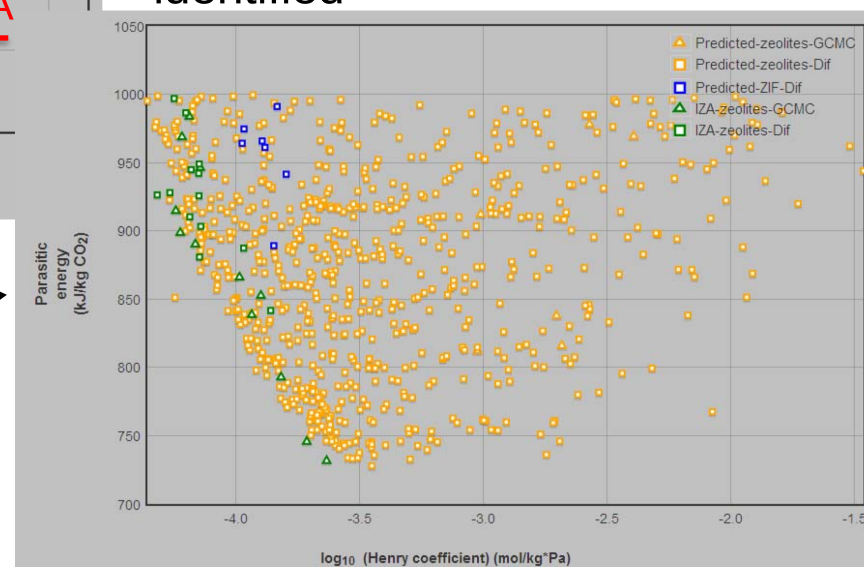


- On-going activity in technical evaluations of early-stage capture processes
- Capture database on processes
- Provides an overview of the capture landscape
- Able to identify gaps, overlaps, and acceleration pathways

Screening of Low-Energy Capture Adsorbents



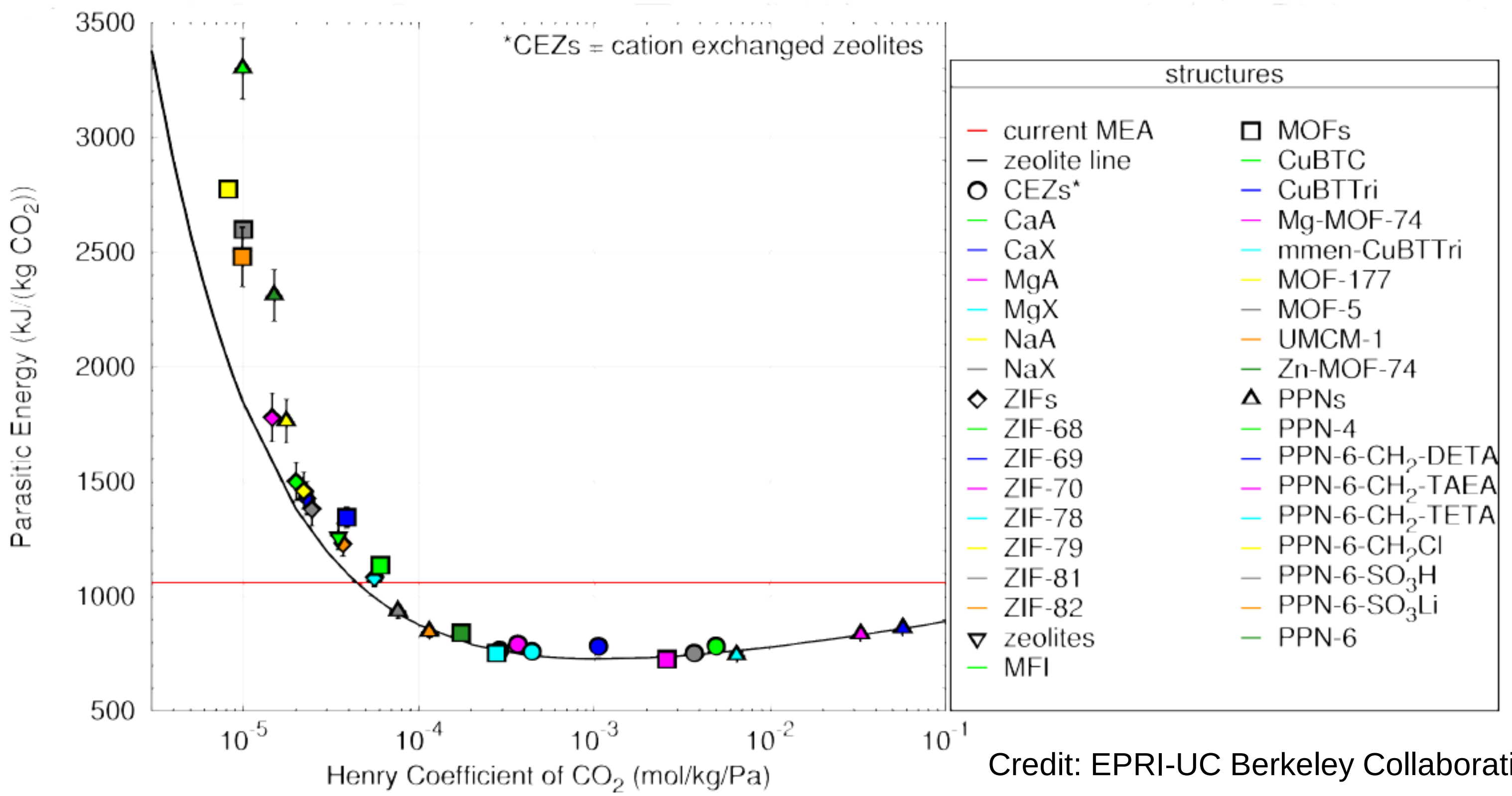
- Compute properties (UC Berkeley and LBNL) for a database of 4+ million zeolites (Rice Univ)
- Calculate minimal energy consumption for each material (EPRI)
- Thousands of new adsorbents identified



- Most promising materials
- Very broad minimum
- 2×10^{-4} < Henry's Coefficient < 2×10^{-3}
- No single defining characteristic
- www.carboncapturematerials.org

Nature Materials, 11, 633 (2012)

Energy penalty of synthesized materials

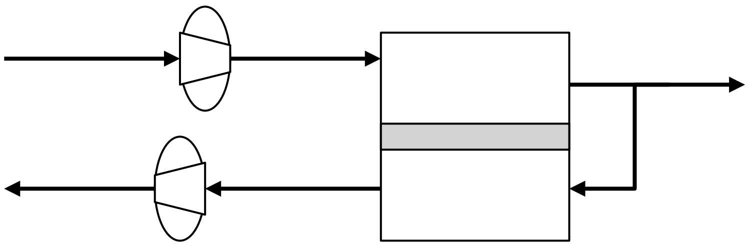


Credit: EPRI-UC Berkeley Collaboration

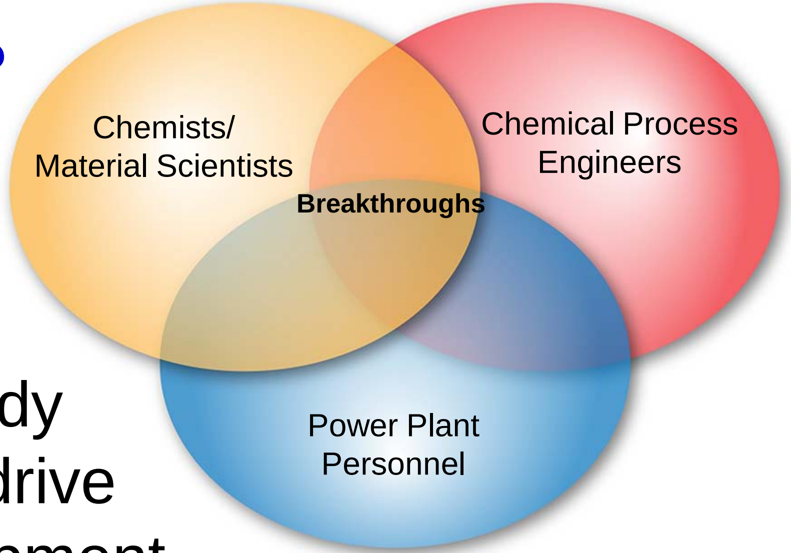
- 30% lower energy materials relative to MEA (capture and compression)
- Synthesized materials very close to computed parasitic energy line
- Providing guidance and insights not just for new materials, but also how to reduce energy consumption further

Membrane Processes

- Models of solution-diffusion membranes for co-, cross-, and counter-current flow, with and without sweep, incorporated into ASPEN+
- Benchmarked against published results
- Use model to study effect of membrane properties on system performance to support new materials development
- Can modify models for other mechanisms, e.g., facilitated transport



Where Do We Go from Here?



- Integrate models for membranes, adsorption, and solvents into coal and gas power plant models to study hybrids and system integration to drive new materials and process development
- Actively guide development of materials based on predicted system-level performance
- Closely monitor development of capture technologies
- Identify gaps, areas to accelerate, strategic thrusts
- Establish proof of concept, lab-, bench-, pilot-, demo-, and commercial-scale

EPRI

Together…Shaping the Future of Electricity