ELECTRIC POWER RESEARCH INSTITUTE

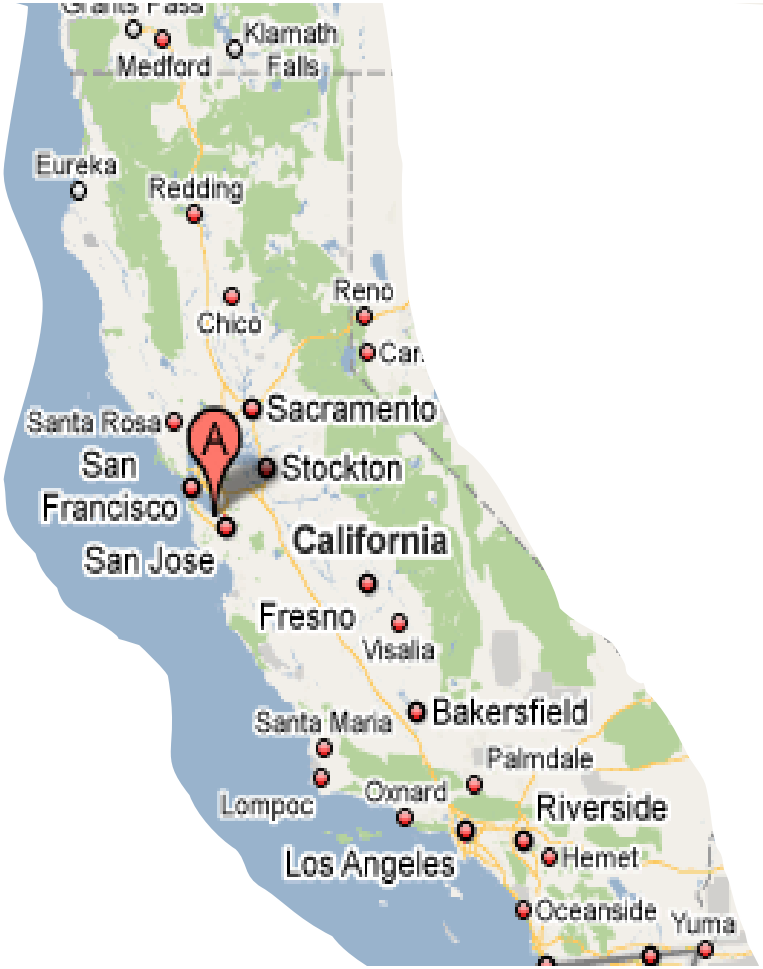
CO_2 Capture R&D at Electric Power Research Institute

Abhoyjit S. Bhown

NETL CO_2 Capture Technology Meeting
August 22, 2011

About The Electric Power Research Institute

- Major locations in Palo Alto, CA; Charlotte, NC; Knoxville, TN
- Established 1973 as independent, not-for-profit research center
- Nearly every area of electricity generation, delivery, use, health, environment, efficiency
- ~$400 million/yr revenue; 650 staff



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EPRI ELECTRIC POWER RESEARCH INSTITUTE

Portfolio Spans the Entire Electricity Sector

Generation

- Advanced Coal Plants, Carbon Capture and Storage
- Combustion Turbines
- Environmental Controls
- Generation Planning
- Major Component Reliability
- Operations and Maintenance
- Renewables

Nuclear Power

- Advanced Nuclear Technology
- Chemistry, Low-Level Waste and Radiation Management
- Equipment Reliability
- Fuel Reliability
- Instrumentation and Control
- Long-Term Operations
- Material Degradation/Aging
- Nondestructive Evaluation and Material Characterization
- Risk and Safety Management
- Used Fuel and High-Level Waste Management

Power Delivery & Utilization

- Transmission Lines and Substations
- Grid Operations and Planning
- Distribution
- Energy Utilization
- Cross Cutting Technologies

Environment

- Air Quality
- Environmental Aspects of Renewables
- Global Climate Change
- Land and Groundwater
- Occupational Health and Safety
- T&D Environmental Issues
- Water and Ecosystems

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EPRI's Role…

Help Move Technologies to the Commercialization Stage…

Technology Accelerator

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Industry Needs for CCS

- Affordable, energy-wise, demonstrated CO_2 capture and compression
- Understanding of transport systems (pipelines) and their requirements
- Permanent, environmentally-benign, publicly-accepted geologic storage
- Alternatives to geologic storage

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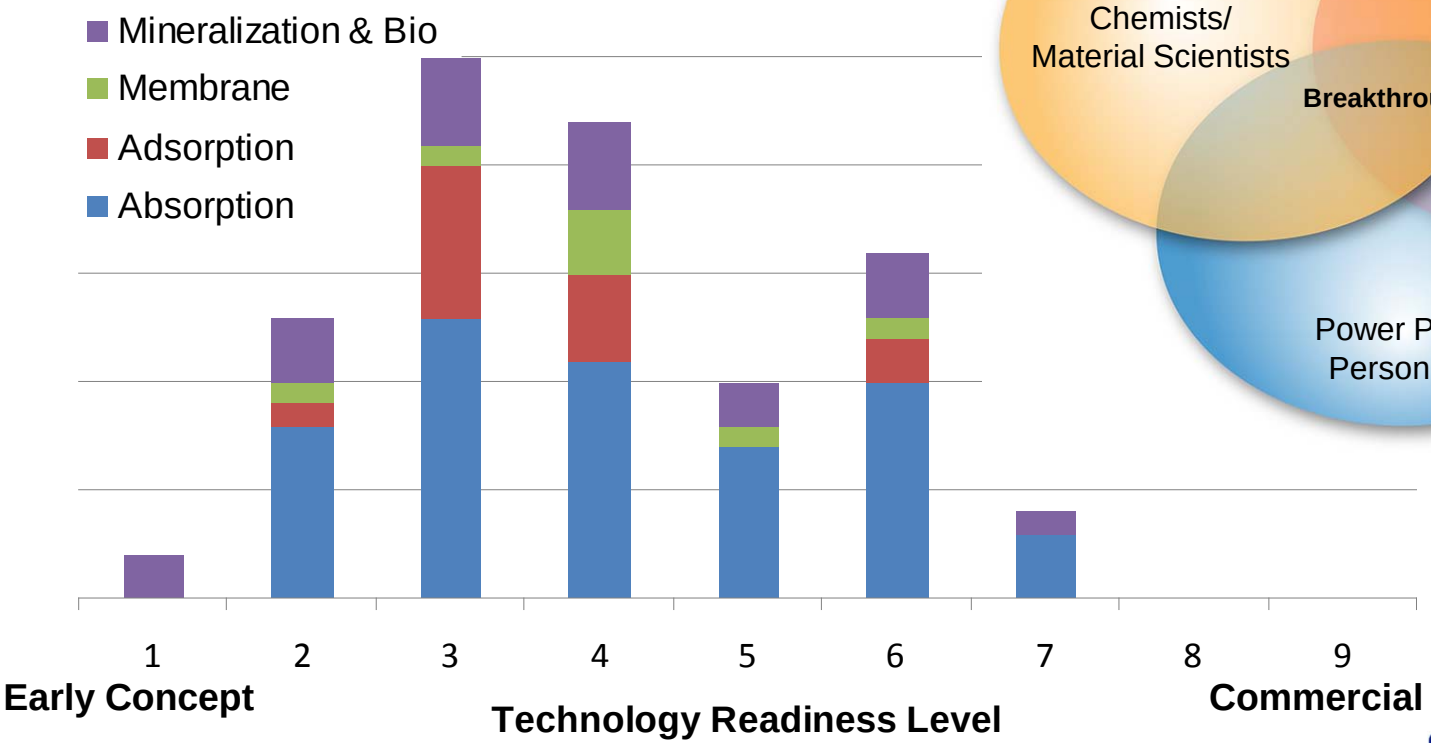
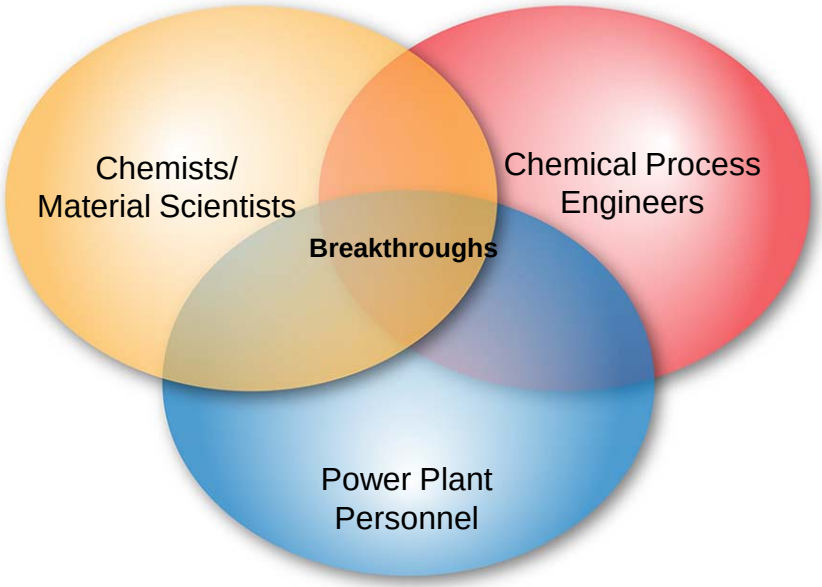
Foundation of EPRI's Work on Post-Combustion CO_2 Capture

- EPRI evaluated ~120 post-combustion technologies. Most are TRL 2-4.
- Breakthroughs will require collaboration between synthesis chemists, process developers, and power plant personnel
- Use process models to find new capture chemistry





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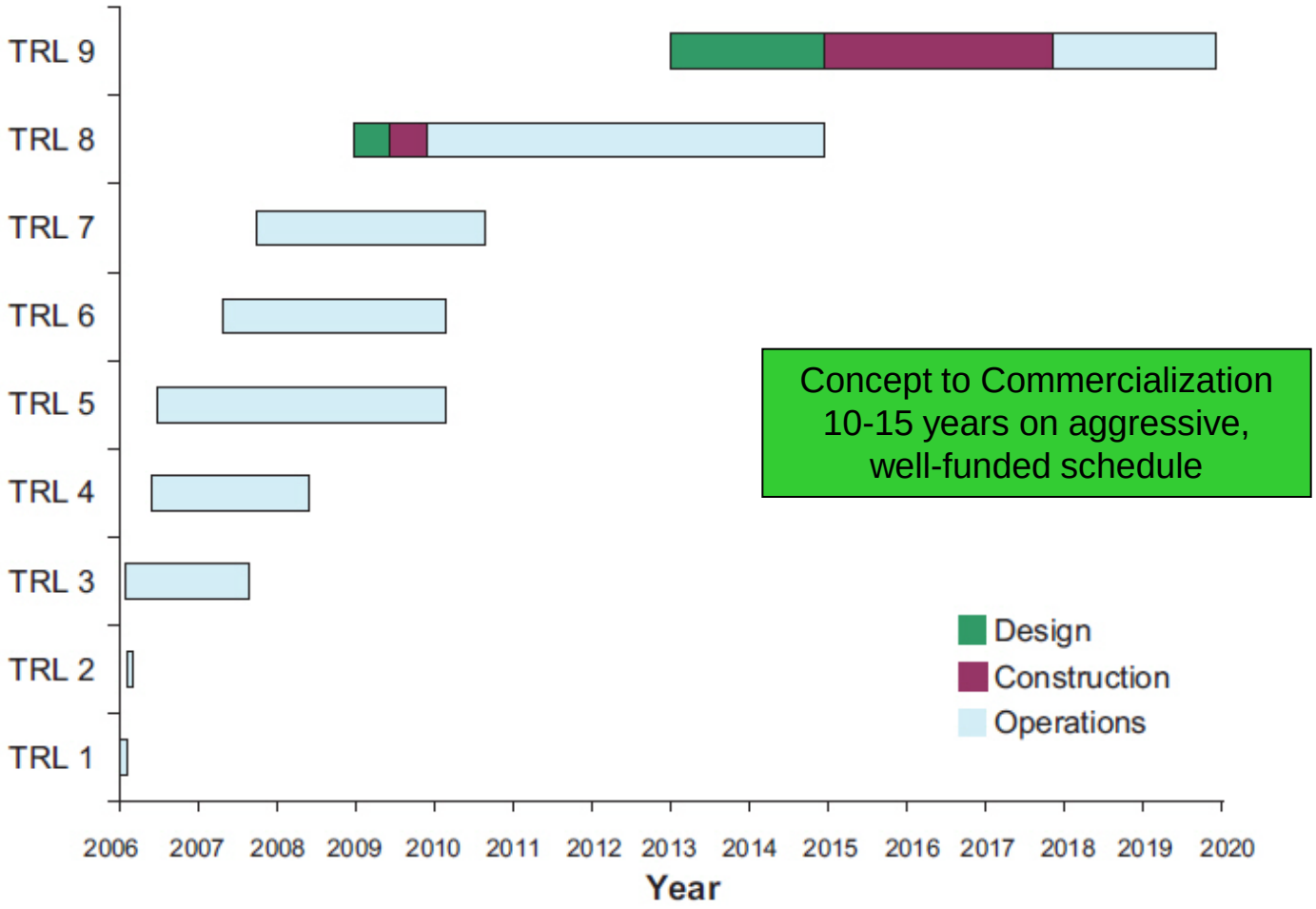
Timescale for Capture Process Development



Concept to Commercialization 10-15 years on aggressive, well-funded schedule

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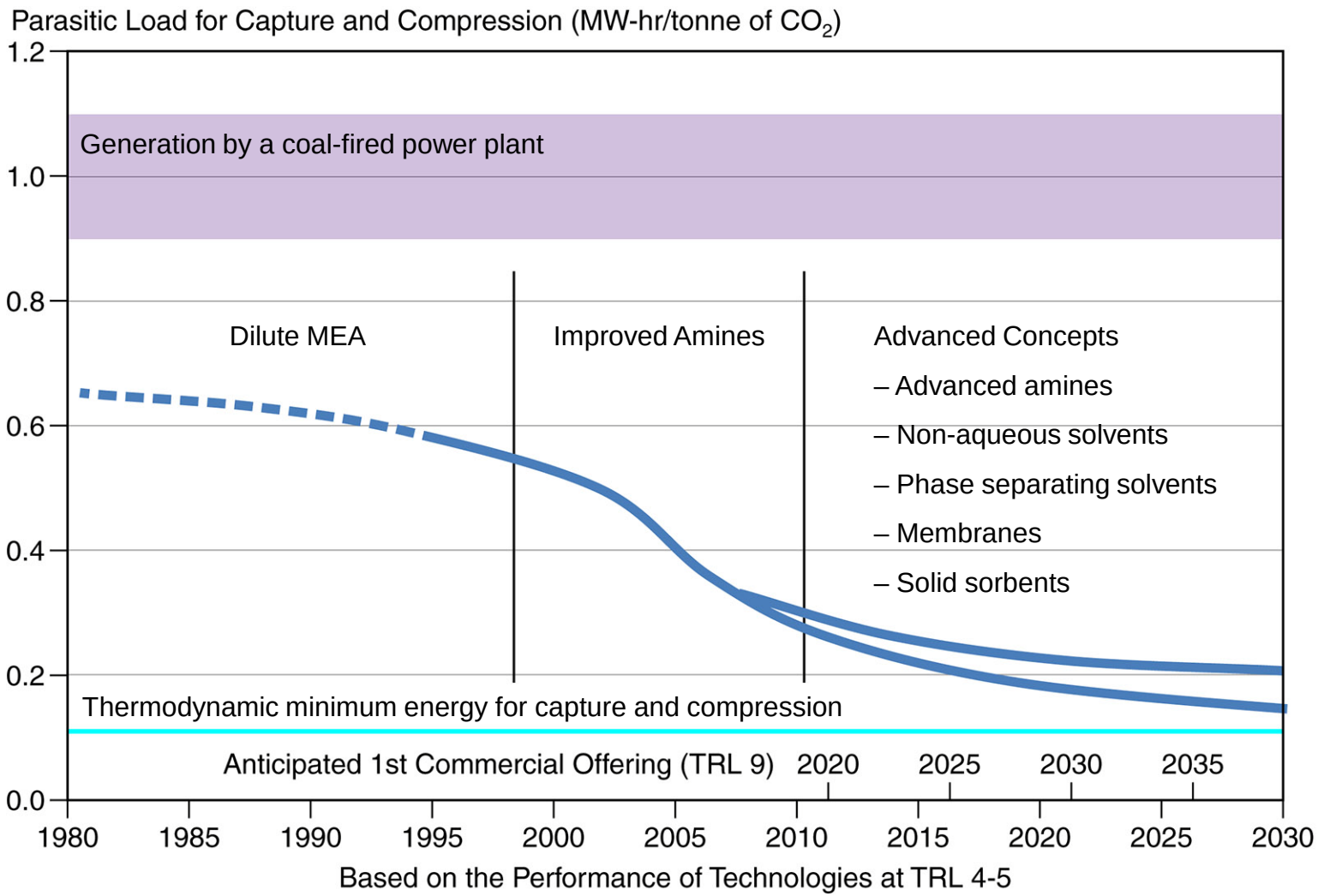
Parasitic Load for Post-Combustion Capture and Compression



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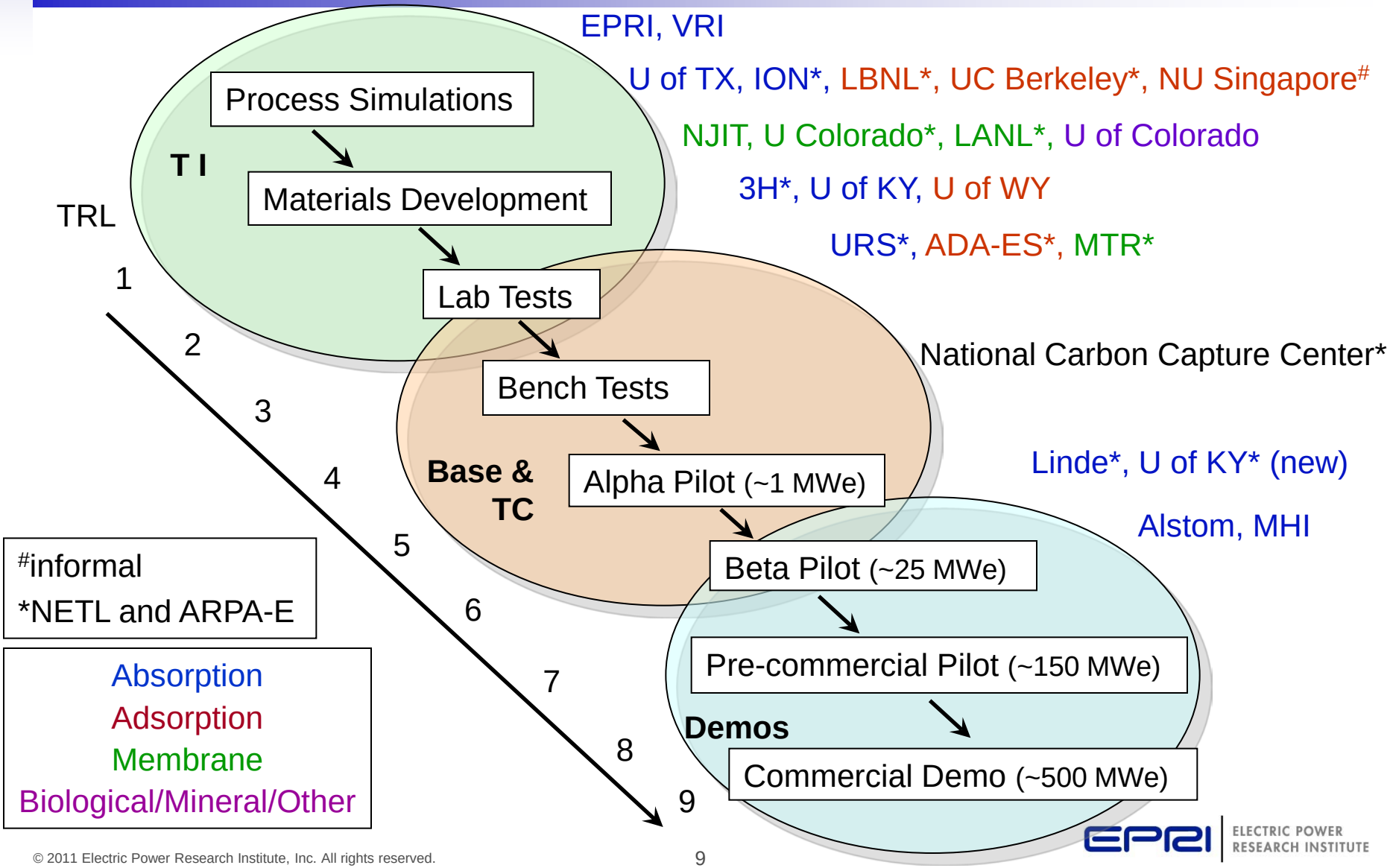
Post-Combustion CO_2 Capture R&D at EPRI



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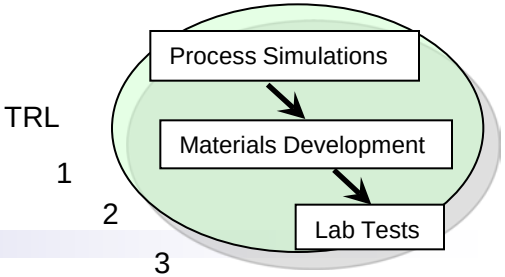
Strategic Program on Carbon Capture



Activity	*Description*
Process Simulations	Largely in-house modeling effort to (a) identify target properties of solvents, solid sorbents, and membranes for CO_2 capture (b) develop new hybrid separation schemes (c) evaluate 3rd party carbon capture processes
Materials Development	External collaborative effort to develop and test early stage, novel separation materials at laboratory scales
Bench- and Pilot-Testing	Testing of capture processes at Univ. of Kentucky (bench) and National Carbon Capture Center (bench and pilot)

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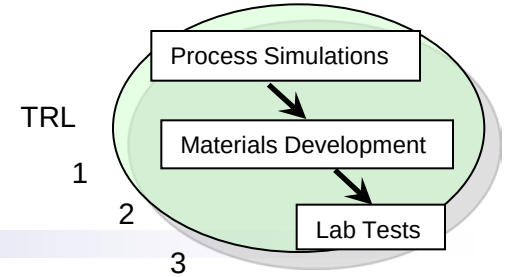
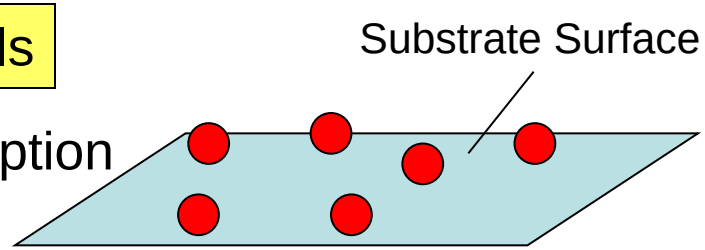
Solid Sorbent Example (Adsorption)



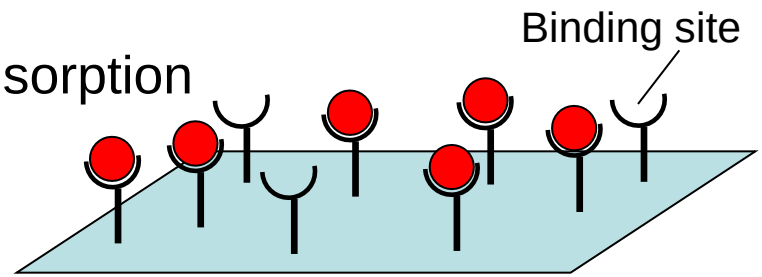
Materials

Physisorption



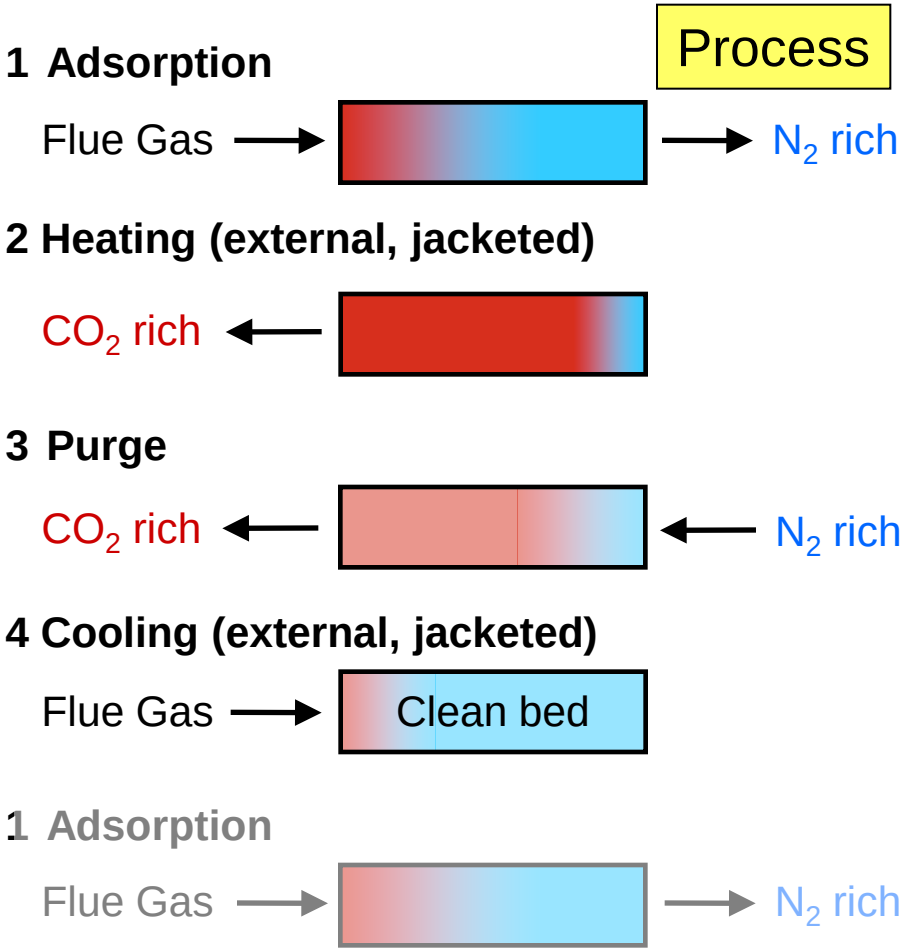
- Adsorption directly onto substrate
- Hard to adsorb/Easy to desorb (low ΔH)
- Thermal stability, low capacity, low selectivity

Chemisorption



- Adsorption onto binding sites
- Easy to adsorb/Hard to desorb (high ΔH)
- Thermal instability, high capacity, high selectivity
- Binding sites can be poisoned

Process



What materials properties and process conditions do we want?

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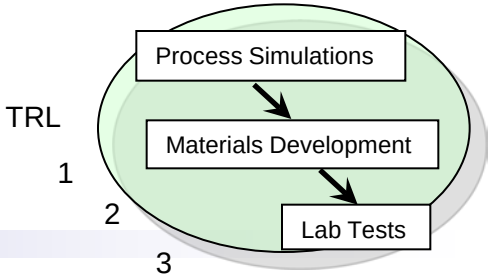
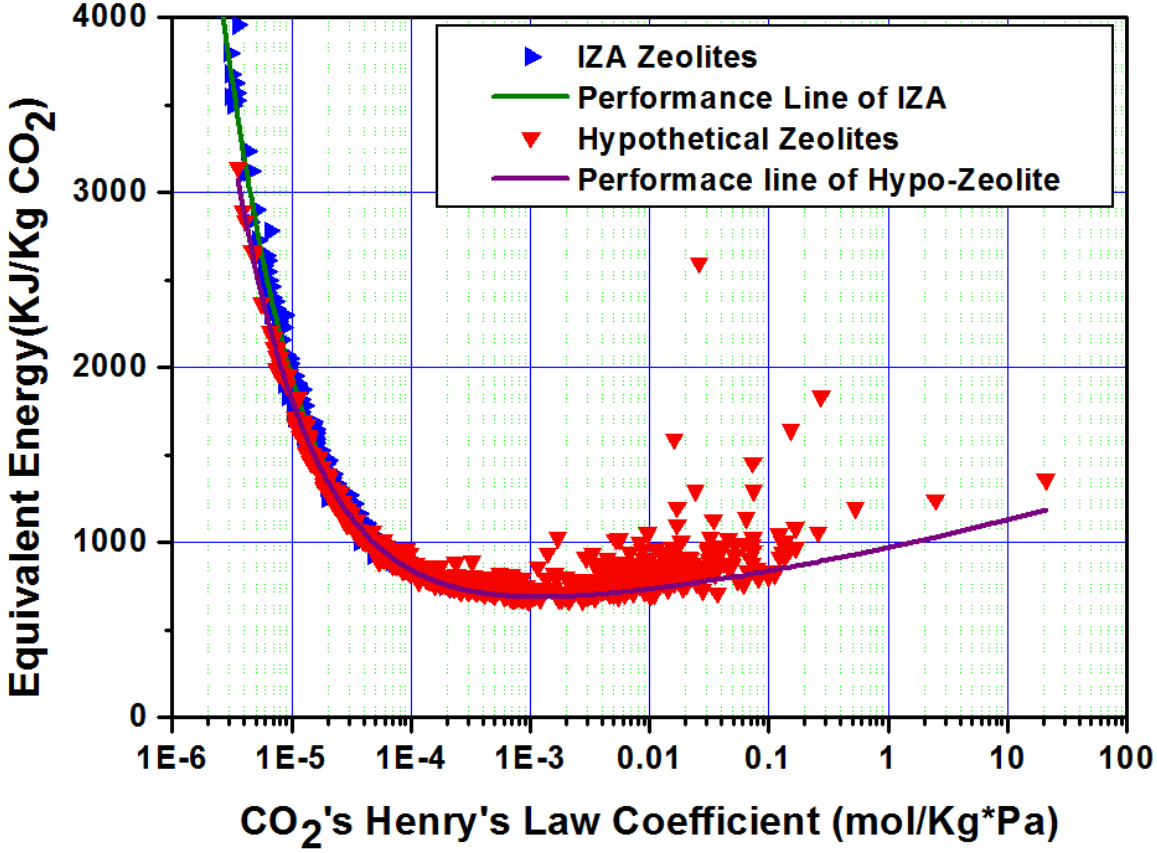
Screening of 500,000+ Zeolites





- Zeolitic Imidazolate Framework also being screened
- Metal Organic Framework will be next
- Collaboration with LBNL/UC Berkeley with DOE (EFRC, NETL, ARPA-e)

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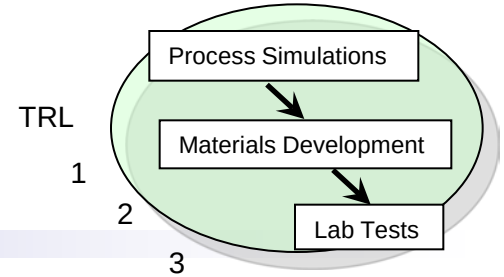
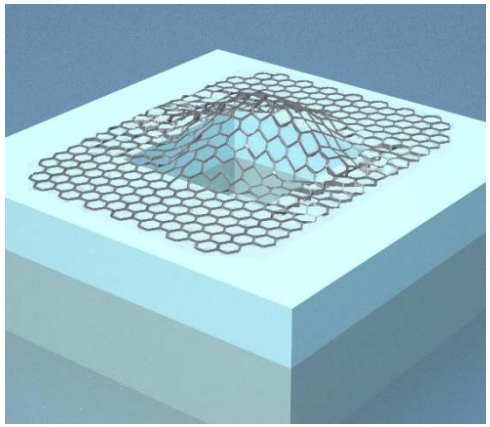
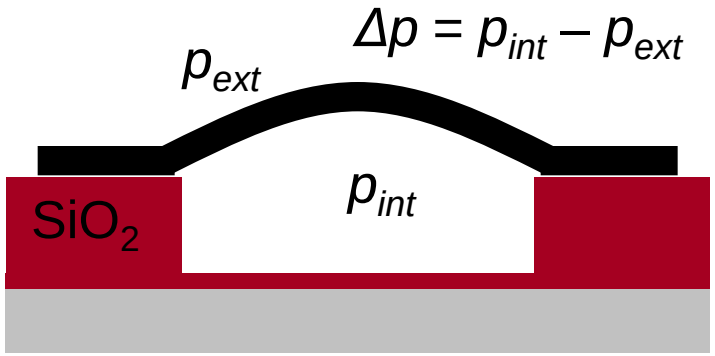
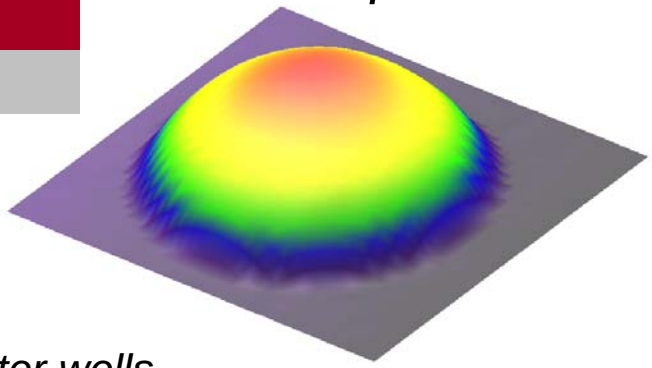
Graphene Membranes





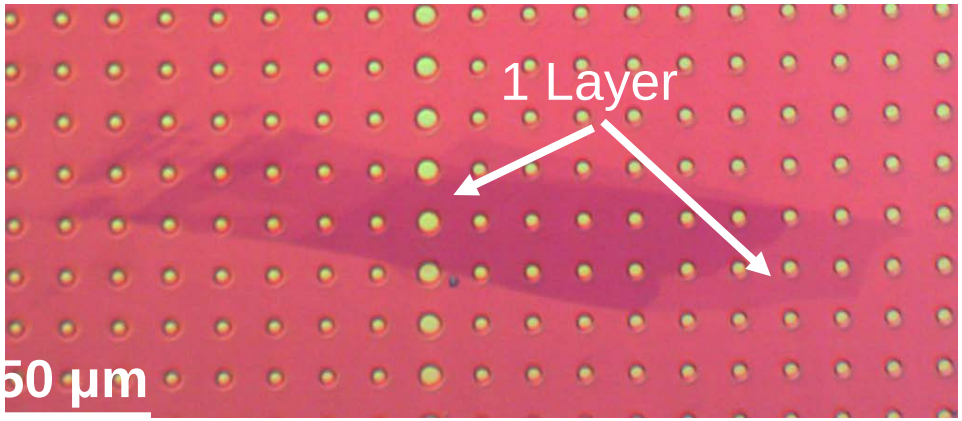


Δp = 1.3 MPa



AFM image
Pressurized graphene membrane

Exfoliated Graphene Flakes suspended over ~5 µm diameter wells



*<u>Previous Work:</u> J.S. Bunch et al. Nano Letters **8**, 2458 (2008)*

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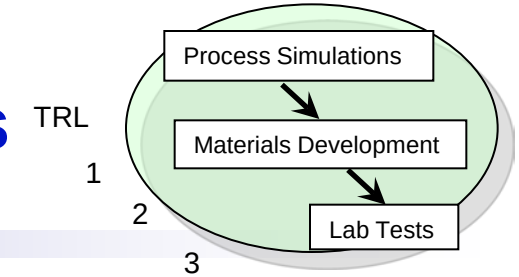
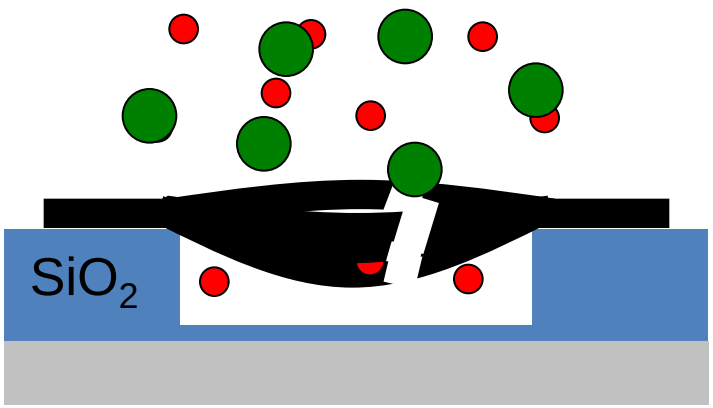
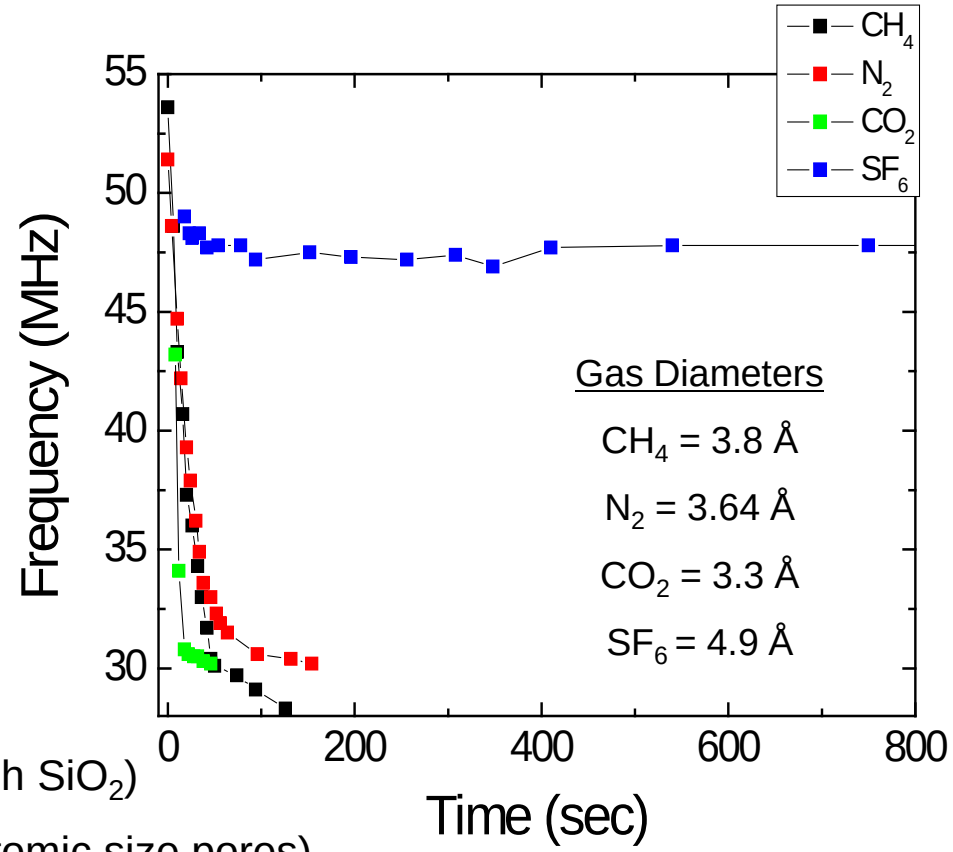
Effusion through Atomic Membranes



Etch Pores into Membrane





N_2 Leak Rates

Pristine Graphene: ~70 hours – (Diffusion through SiO_2)

Porous Graphene: ~100 sec (Effusion through atomic size pores)

Current work at U Colorado to incorporate selective flakes into polymeric membranes

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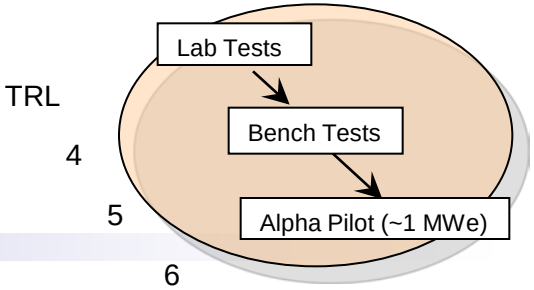
Process Evaluations And Capture Database



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Post Combustion CO2 Capture Database

Home | Carbon Capture Processes | Glossary | Technology Readiness Levels | Administration

This database contains profiles for post-combustion CO2 capture (PCC) processes currently under development and for which there is sufficient descriptive data available in the public domain. The purpose of the database is to provide Program 165 members with a single source for information about PCC technologies and to report them in a consistent and timely manner. These process profiles are created and updated by EPRI staff throughout the year. F technologies presented, EPRI has entered into a non-disclosure agreement with the developer. Accordi information contained in these profiles is limited to information in public domain or that which has been ERPI by developers as non-confidential information, or is a derivative analysis based on information fro sources.

Pertinent information about the developer and the process are reported for each process. For those whi in development, estimations are made for the total capture potential and potential application (new or re the inherent characteristics on the process relative to similar processes for which more details are know EPRI is not including profiles for capture technologies for which there is no accompanying process. This with most academic materials development work.

Carbon Capture Processes

The database contains two important elements. The first is "Carbon Capture Processes". It lists each p developer name, process name, capture method, current technology readiness level (TRL) and the data update. All of the processes can be sorted by clicking on the column headers located at the top of the ta once will sort the field by ascending order (A to Z, 0 to 9) and clicking again will sort by descending orde field of processes can also be filtered by either Capture Method and/or current TRL level. Click on any pa to bring up the profile for the selected capture technology.

Contact Us

EPRI encourages user input to report

- 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

~120 Technologies Evaluated

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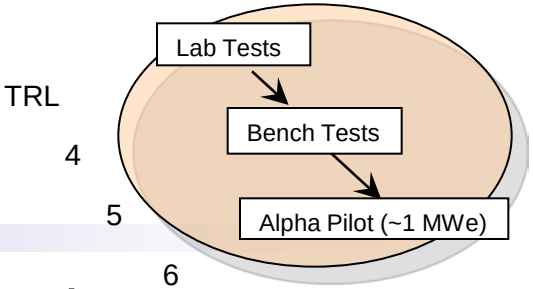
CO_2 Chain of Custody



- Many firms have "custody" of CO_2 at some point
  - Capture, Compression, Transport , Injection, Monitor, Verify, Remediate
- Few take charge of the full chain and look at how one link affects the next one up or down the line
  - Operation/design impact on constituents, conditions?
  - Impact of composition/condition on compression, phases, energy use?
  - Impact on transport design or meeting specifications?
  - Well design/ injection/ closure impacts?
  - Down hole chemistry, geology or use?
  - Liability /impacts of the material?

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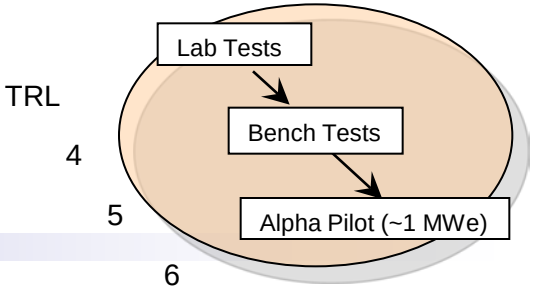
CO_2 Impurities Literature Review



- Most degradation studies are bench scale and involve the identification of products in the liquid-phase
  - The connection between experimental and pilot scale data is not well understood
- Limited pilot plant data is available
  - Currently only one study has sampled the regenerator off-gas
- For the most widely studied solvent system (MEA), physical property data is not publicly available for greater than 50% of the suspected degradation products

- Conducted a 2-day emissions workshop Aug 16-17.
  - 75 participants. Proceedings forthcoming.

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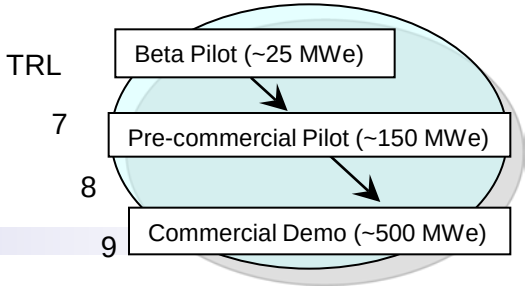
MHI KM-CDR Demo at Plant Barry



- ~25-MW_e
- Builds upon a 0.5 MW_e (10 tpd CO_2) R&D pilot in Japan
- Injection program under U.S. DOE's Southeast Regional Carbon Sequestration Partnership (SECARB) Project
- 6-8-year program envisioned: 2-4 years injection + 4 years post-injection monitoring
- Commissioning underway
- Expect injection by end 2011
  - Saline formation in Citronelle oil field 10-12 miles away

Source: MHI

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Advanced Coal Generation

Cost-effective coal-based generation with carbon capture and storage

- **Economics/Planning**
  - Technology knowledge databases
  - Economic analyses
  - Government Incentives
- **Future Assets**
  - **High efficiency** ultra-supercritical pulverized coal plants
  - IGCC design/cost improvements
  - Optimization of design and operations with CCS (post-, pre- and oxy-combustion capture)
- **Retrofit/Repower Existing Assets**
  - Economic analysis of post-combustion capture retrofits
  - Repowering strategies which maximize use of existing coal assets

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Retrofit USC PC/PCC Plant Performance Study – Based on modern USC Plant Design

	Reference USCPC	Retrofitted Plant with KS-1 PCC
Coal Feed, MW_{th}	1954	1954
Main Steam Pressure, bara/Temperature, ^oC	290/593	290/593
Gross Power Output, kW	815,220	704,920
Auxiliary Load, kW	65,218	163,678
Net Power Output, kW	750,002	541,242
Capital Cost, $/kW	2250	4800
Net Plant Efficiency, % HHV	38.4	27.7

110 MW lost due to steam for regeneration

72% of original output

1st of a Kind Cost

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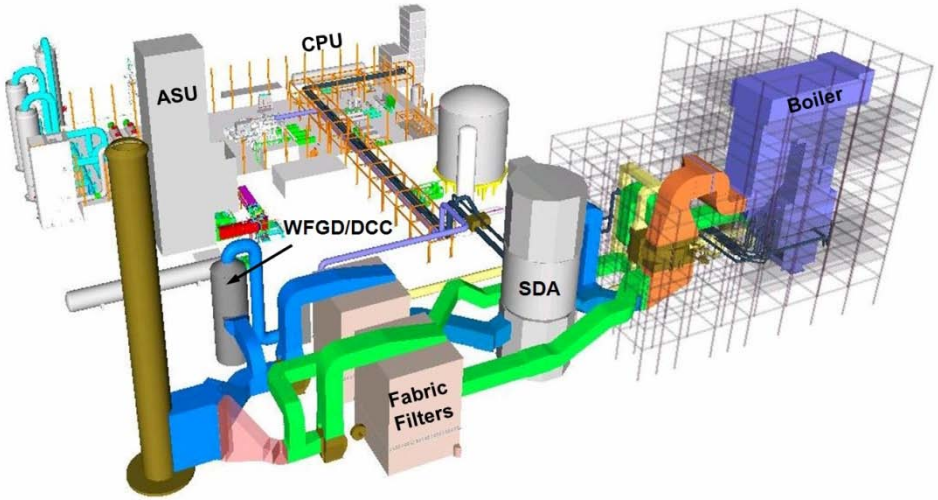
Oxy-Combustion Design Study

First Collaborative Study of a Commercial-scale Oxy-Combustion Power Plant

- B&W and URS produced the design based on EPRI's CoalFleet specifications
  - First evaluated a 650 MW PC without CO_2 Capture
  - Compared it to similar plant operating in Oxy-combustion mode



Results show that Oxy-combustion is competitive with other CO_2 Capture Options

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EPRI's R&D for Post-Combustion Capture

Absorption (Solvent)
Universities (TX, KY)
Entrepreneurs (3H, VRI, others)
Corporations (Alstom, MHI,..
…URS, ION*)

Adsorption
Universities (WY, UCB)
Corporations (ADA-ES)
Nat'l Labs (LBNL)
Informal (NUS)

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Evaluations & Analysis
Process Modeling

Membranes
Universities (NJIT, CU)
Corporations (MTR)
Nat'l Labs (LANL)

System Testing
National Carbon Capture Center

Biological / Mineralization
Corporations (Calera),
Univ. (CU, CMU)

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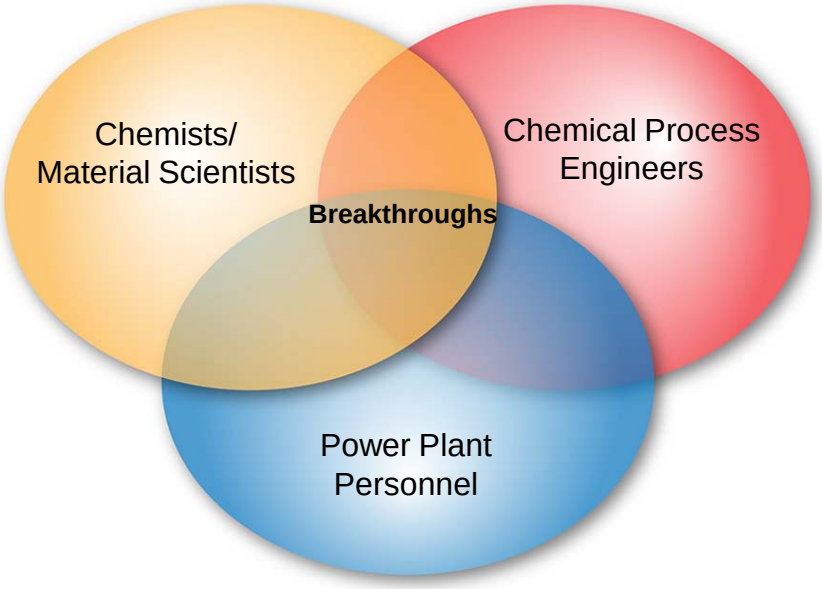
Together…Shaping the Future of Electricity



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