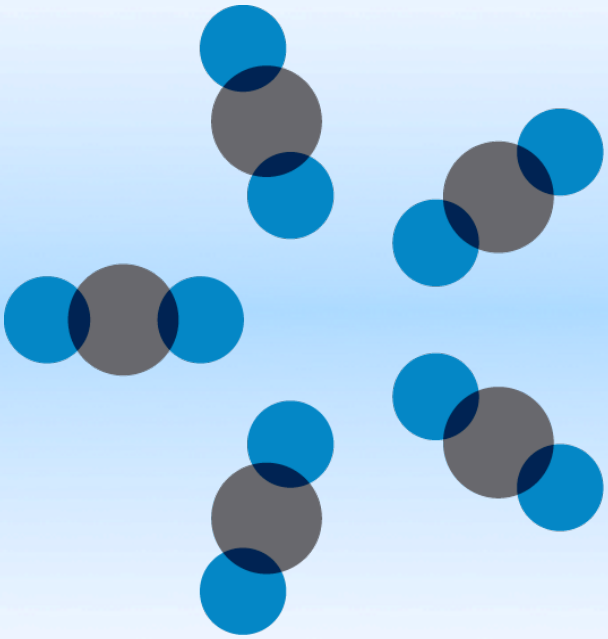


CCSI

Carbon Capture Simulation Initiative

Energy Systems Initiative
Center for Advanced Process Decision-making

6 March 2011

U.S. DEPARTMENT OF ENERGY

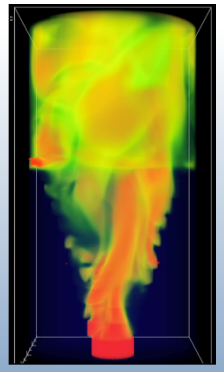
Carbon Capture Challenge

- The pathway from discovery to commercialization of energy technologies can be quite long: 2-3 decades[1]
  - Technology innovation (doing something different) increases the cost growth, schedule slippage, and the probability of operational problems[2]
- President's plan to overcome the barriers to the widespread, cost-effective deployment of CCS within 10 years[3].
- Need new approaches to take concepts from lab to power plant, quickly, at low cost
- Opportunity for simulation initiative
  - **Physics-based simulations at multiple scales → screening concepts … quantifying technical risk**

1. International Energy Agency Report: Experience Curves for Energy Technology Policy," 2000
2. RAND Report: "Understanding the Outcomes of Mega-Projects," 1988; 3. http://www.whitehouse.gov/the-press-office/presidentialmemorandum-a-comprehensive-federal-strategy-carbon-capture-and-storage

Carbon Capture Simulation Initiative






Identify promising concepts → **Reduce the time for design & troubleshooting** → **Quantify the technical risk, to enable reaching larger scales, earlier** → **Stabilize the cost during commercial deployment**

National Labs

Berkeley Lab
Pacific Northwest National Laboratory
NETL
Los Alamos National Laboratory
Lawrence Livermore National Laboratory

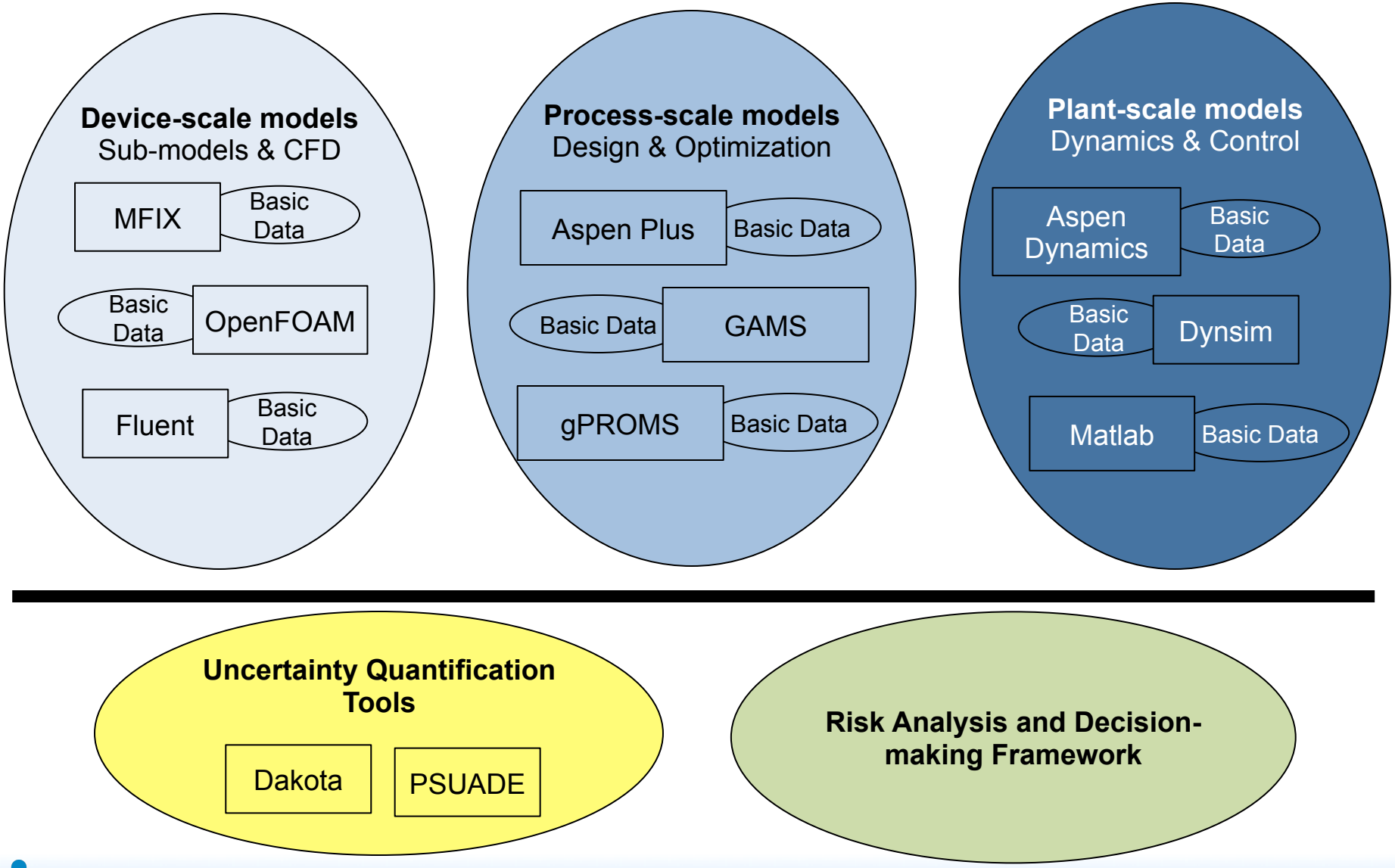
Academia

Carnegie Mellon
VirginiaTech
PennState
Princeton University
West Virginia University
University of Pittsburgh

Industry

ADA Environmental Solutions
Ameren
B&W
Babcock Power Inc.
Air Products
Alstom
Fluor
Ramgen Power Systems
AEP American Electric Power
Duke Energy
GE
PG&E
Southern California Edison — An Edison International Company — San Onofre Nuclear Generating Station
Southern Company
Chevron
Eastman
EPRI Electric Power Research Institute
WorleyParsons resources & energy
URS

Current State of Simulation Tools is Disjointed



Limited Models Available for Carbon Capture

Device-scale models
Sub-models & CFD

Limited models of specific configurations for specific technology

Very little validation of devices or sub-models

Process-scale models
Design & Optimization

Limited capability for handling complex systems (i.e., solids)

Lack of models appropriate for process synthesis, optimization, heat integration

Plant-scale models
Dynamics & Control

Minimal consideration of system dynamics and impacts on overall plant control strategies

Current models lack ability to predict solid flow dynamics

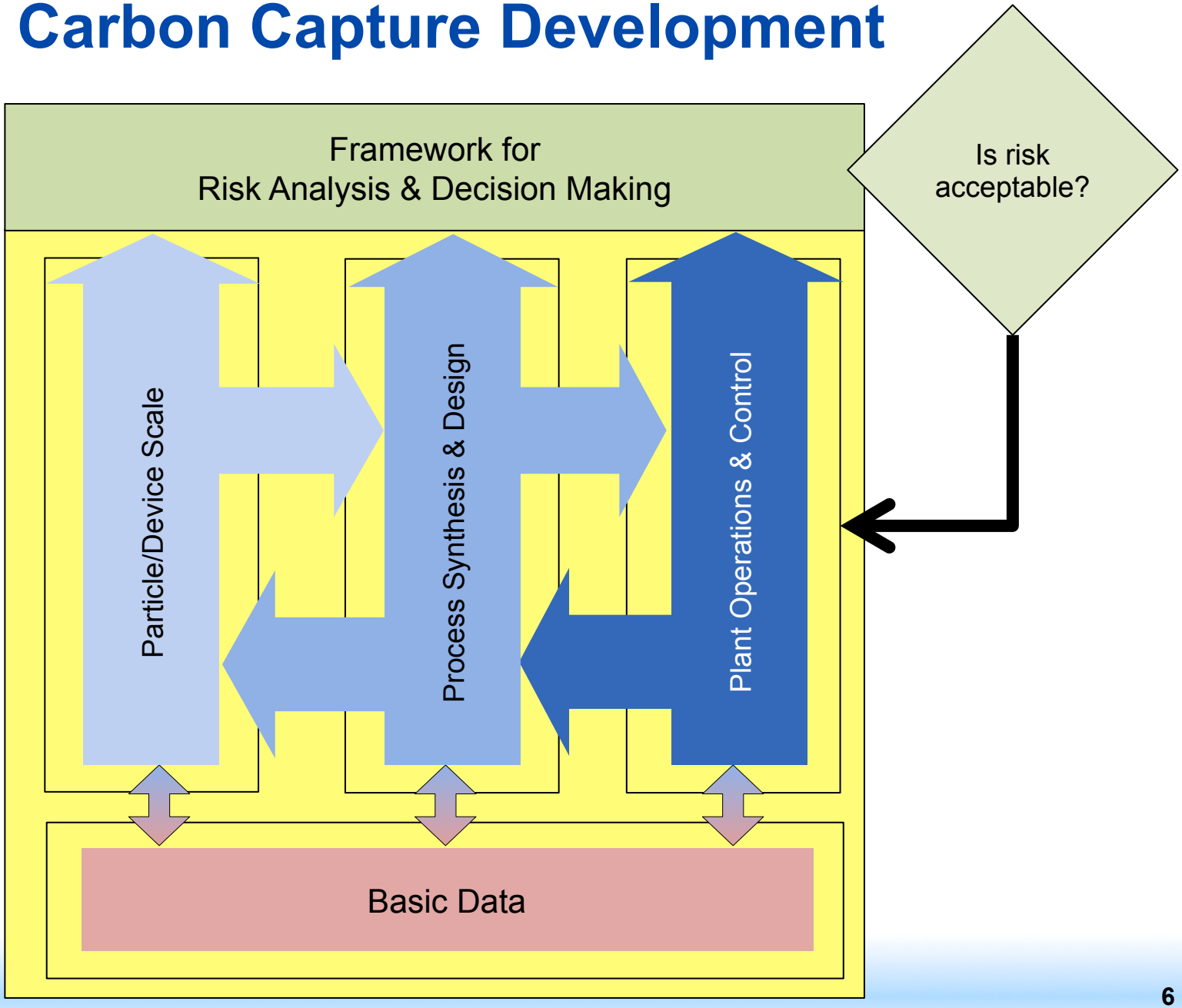
Uncertainty Quantification Tools

Not applied to current commercial simulation tools

Risk Analysis and Decision-making Framework

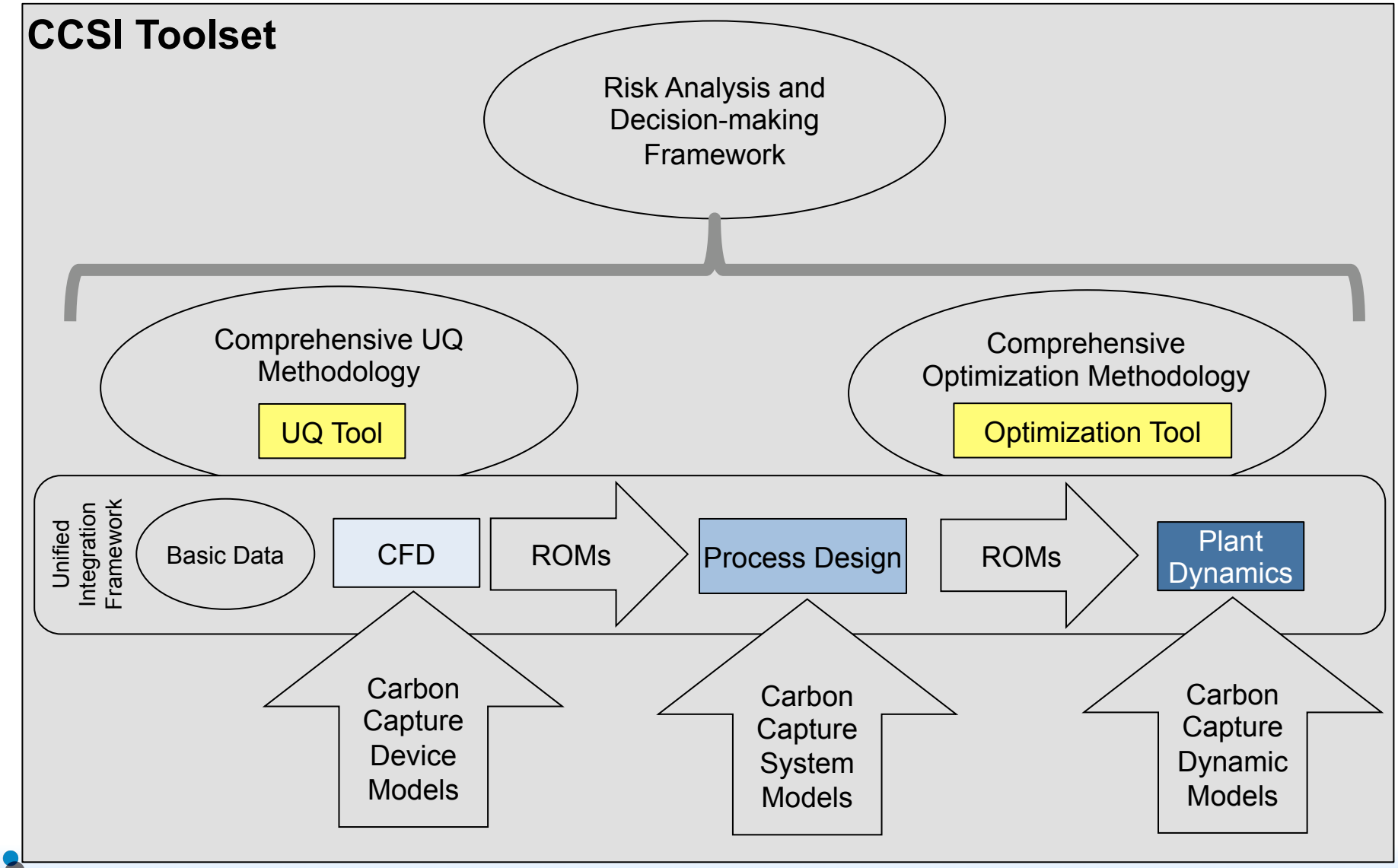
Not connected to technical simulation tools

Carbon Capture Development



CCSI
Carbon Capture Simulation Initiative

CCSI will Integrate Toolset for Carbon Capture



Technical Scope – 3 Focus Areas

Physicochemical modeling and simulation	1. *Basic Data and Models* 2. *Particle and Device Scale Models* 3. *Process Synthesis & Design* 4. *Plant Operations and Control*
Analysis and software	5. *Integration Framework* 6. *Uncertainty Quantification and Optimization* 7. *Risk Analysis and Decision Making* 8. *Software Development Support*
Industrial applications	9. *Industrial Challenge Problems* 10. *Industrial Collaboration*

Industry Partnership

Essential to accelerate commercial deployment of capture technology

- Goals
  - Industry requirements, capabilities and knowledge flow into CCSI
  - Obtain industry knowledge of key issues affecting deployment
  - CCSI Toolset used to support capture development process

- Industry Advisory Board: Decision-makers with influence over deployment of capture technology
  - Steer the overall direction of CCSI to ensure effectiveness of CCSI products in supporting capture deployment decisions

- Industry Collaborators: Industry technical leaders
  - Engage with CCSI Technical Teams on a day-to-day basis
    - IAB and CCSI Leadership identify key individuals with supportive skills
    - CCSI Task Sets identify individuals within industry with key capabilities

Industrial Challenge Problems (ICP) will Underpin CCSI Toolset Development

- **Desirable ICP Attributes**
  - Develops and uses CCSI capability for a wide range applications later
    - IGCC pressurized syngas, natural gas or industrial applications
  - Provides relevant results to problems of current interest
  - Available process and validation data
- **ICP priority: Pulverized coal plants**
  - Just two coal IGCC now, more coming later[1]
  - Approximately 280 U.S. pulverized coal plants are CCS candidates[2]

1. *Clean Coal Technology & The Clean Coal Power Initiative (2010). details available at http://fossil.energy.gov/programs/powersystems/cleancoal/index.html*
2. *Nichols, C., (2010). "Coal-Fired Power Plants in the United States: Examination of the Cost of Retrofitting with CO2 Capture Technology and the Potential for Improvements in Efficiency", DOE/NETL-402/102309*

ICP Selection - Technology

- **Different technology options for PC capture being investigated**[1]
- **ICPs ordered at right**
  - Sorbents – significant impact on reactor/process design and optimization
  - Adv. Solvents – Directly extend sorbents approach
  - Oxy-combustion adds the complexity of full plant

Capture Technology	Technology Status and Characteristics
Solid Sorbents	• Entering process development. • Pilot data/tests in progress. • System design/optimization need now.
Liquid Solvents	• Existing solvents currently in pilot and demonstration tests. • Established empirical approach for first generation scale up. • Optimization of new solvents/systems is a near-term CCSI opportunity.
Oxy-combustion	• Commercial designs exist for first generation systems, specific coals. • Dynamic operation, optimization, and new fuels is a near-term CCSI opportunity.

- **Approach to ICPs**
  - Simulation objectives established in workshops with BES, ARPA-E[2]
  - Partnership with ongoing pilot/lab testing (ADA-ES Inc., NCCC, NETL)[3]

1. *DOE/NETL Advanced Carbon Capture R&D Program : Technology Update. September 2010. available at http://fossil.energy.gov/programs/powersystems/cleancoal/index.html. See also Assessment of Post Combustion Capture Technology Developments, EPRI , Palo Alto, CA: 2007, 1012796*
2. *Carbon Capture 2020, Workshop Proceedings, October 5-6 2009 University of Maryland, available www.netl.doe.gov.*
3. *National Carbon Capture Center: Post-Combustion , NETL CO2 Capture Technology Meeting, September 15, 2010, Pittsburgh PA, proceedings available on-line at www.netl.doe.gov*

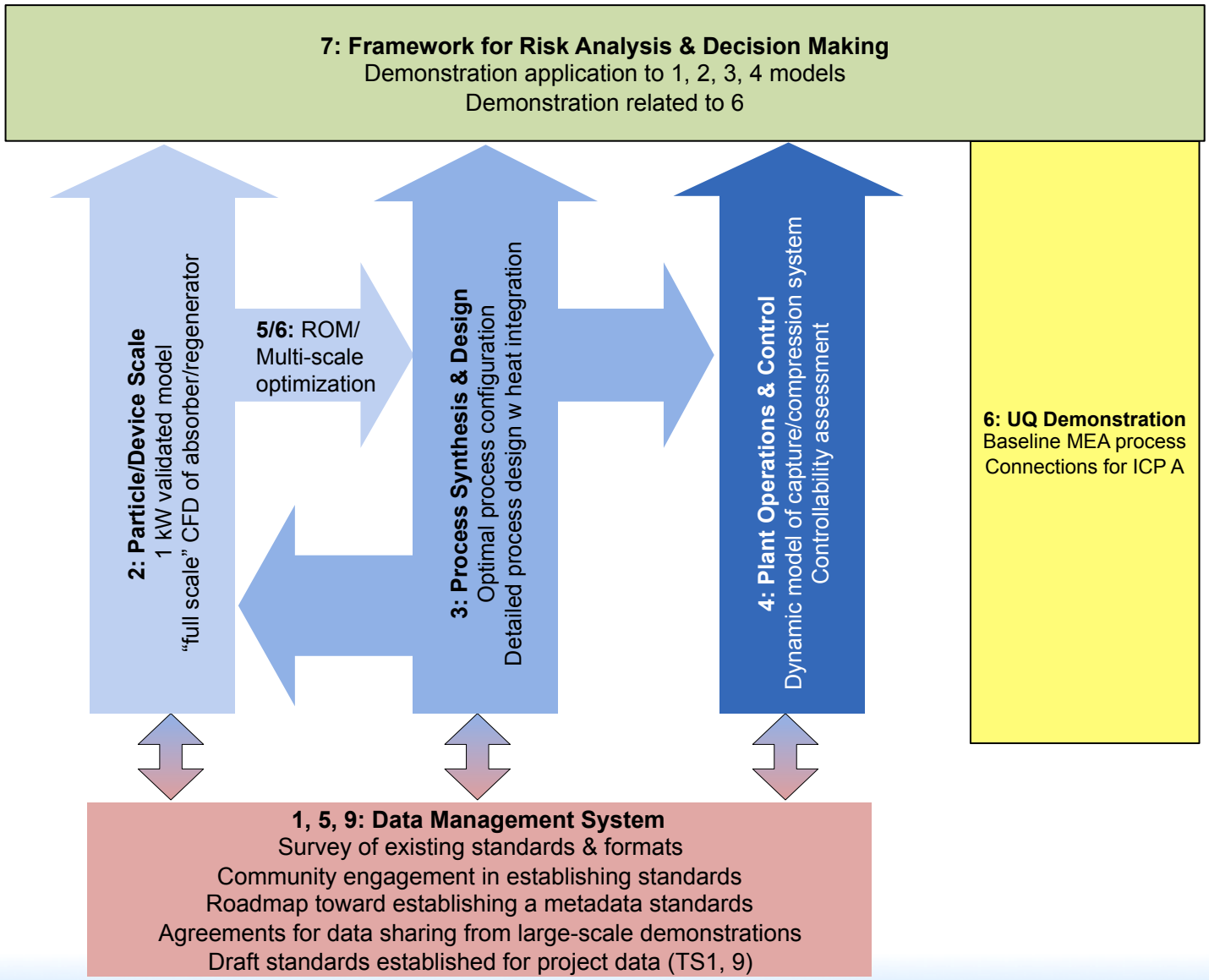
Risk Analysis and Decision Making Framework

- Risk Quantification and Risk Management
  - Technical Risk
    - Sufficient and accurate fundamental data
    - Model validation, accuracy, predictive capability
    - Process and plant design scalability
    - Plant operability, reliability, safety, waste streams
    - Construction viability and cost
  - Enterprise Risk
    - Economic feedback of energy cost at various scales
    - Operational cost considering uncertain technical risks
    - Capitalization of construction
    - Investor confidence
- *Risk Management* "Process" must support *Risk Acceptance* "Product"
  - Power generation industry has established strategies
    - Tracking technology maturation
    - Making investment decisions

Based on proven operational experience of prototype facilities

Codify and emulate established learning/ decision process to secure industry endorsement and return immediate value

Year 1 Activities (Conceptual View)



Thank you