CO_2 Sequestration Market Development

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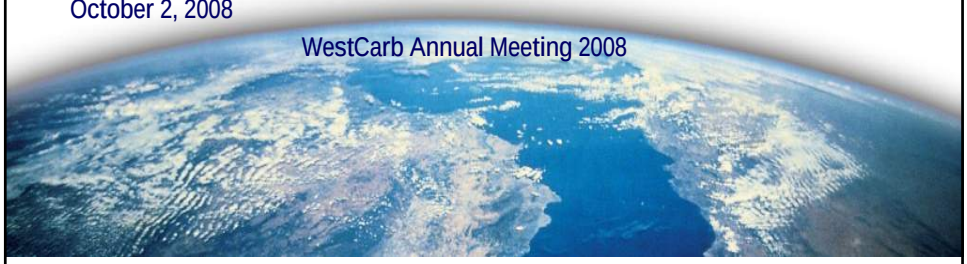

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Comparative Scope

2

- Inject 41 MtCO2/yr for enhanced oil recovery
  - Output of six 1000-Mw coal-fired plants
  - Moved safely hundreds of miles via pipeline
- 50 U.S. oilfields that produce >150,000 bbl fluid per day
  - Output of a 1000-Mw coal-fired plant
- No huge technical barriers to geologic storage of CO2
  - But…EOR experience has been focused on the oil, not the CO2
- Non-technical challenges, on the other hand, are huge

Similarities / Differences with Oilfield

3

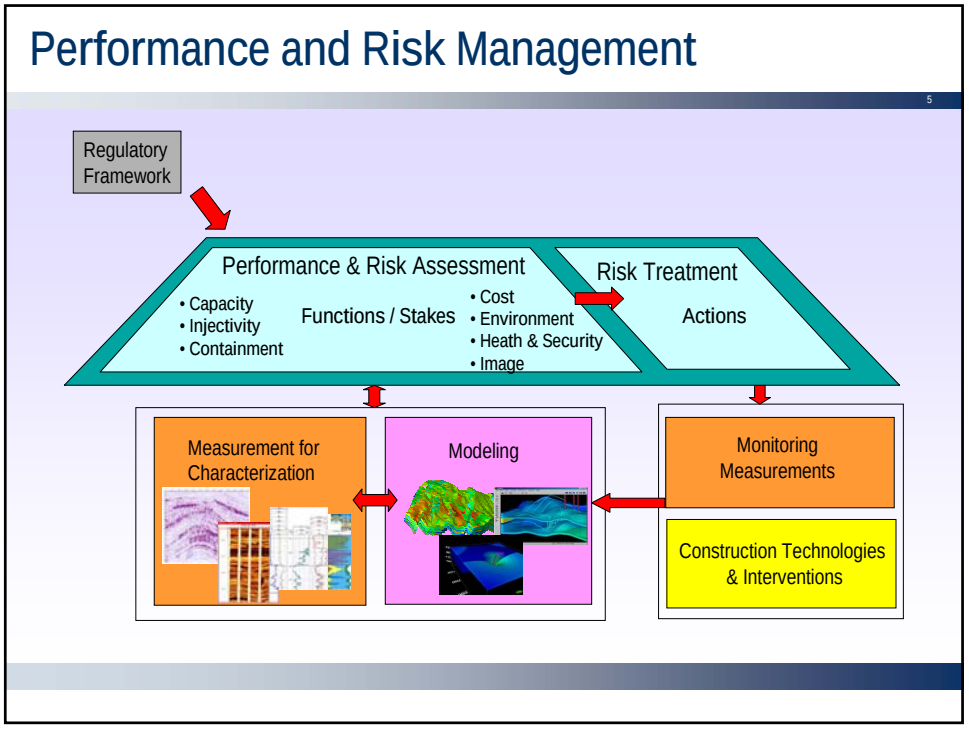
- Capacity
- Injectivity
- Containment
- Reservoir
- Seal
- Closure
- Source
- Timing
- Access

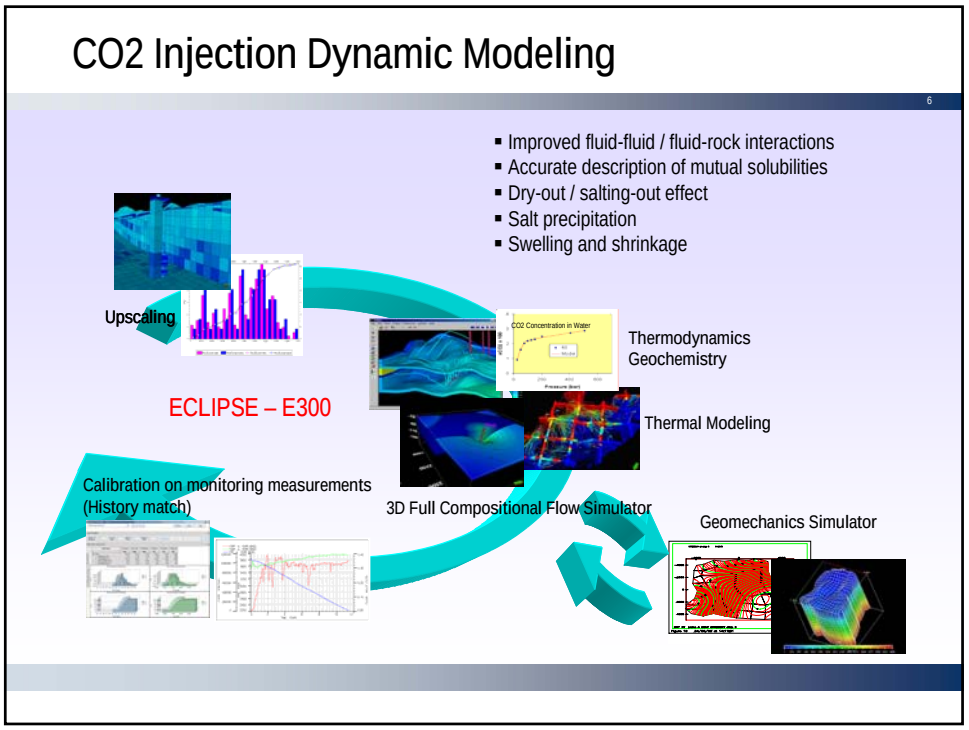
Other Similar Settings

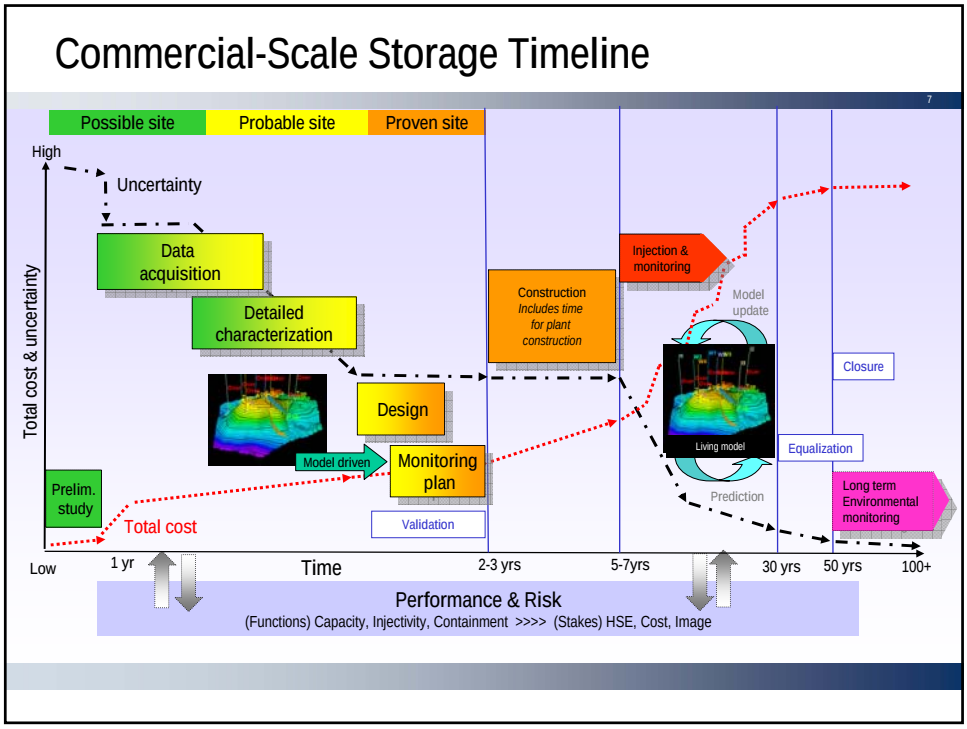
4

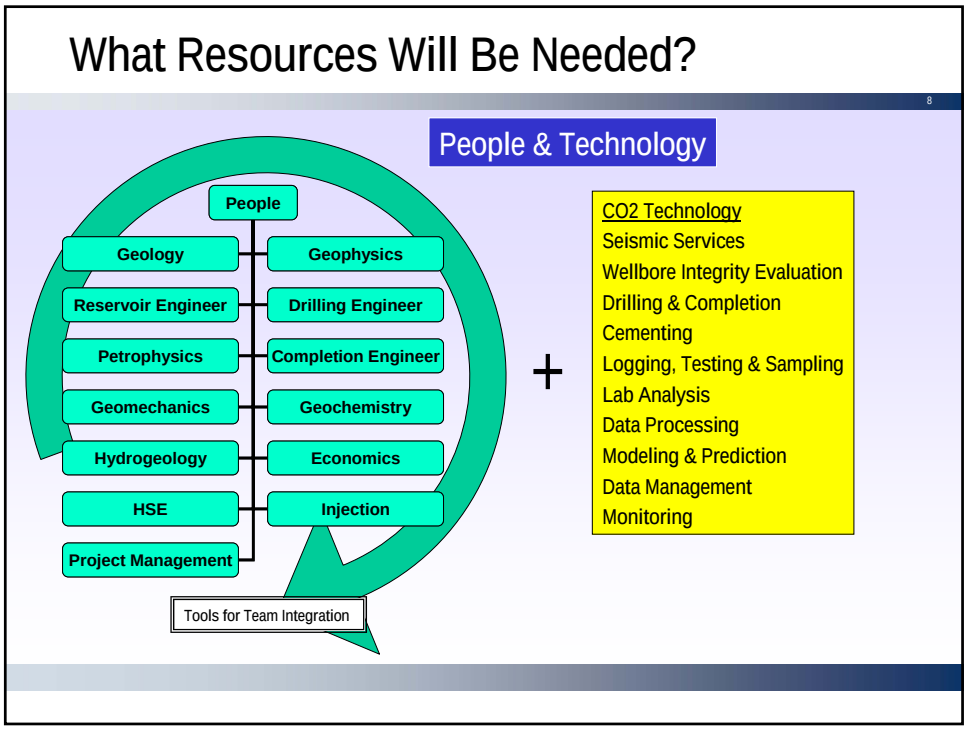
Natural gas storage
- Smaller volumes
- Shorter term focus
- Losses accepted
- Use eminent domain

UIC / Acid Gas
- Regulation built to protect potable water
- Regulated by EPA, not O&G
- No verification required
- Limited “area of influence”


Performance and Risk Management
5
Regulatory Framework
Performance & Risk Assessment
• Capacity
• Injectivity
• Containment
Functions / Stakes
• Cost
• Environment
• Heath & Security
• Image
Risk Treatment
Actions
Measurement for Characterization
Modeling
Monitoring Measurements
Construction Technologies & Interventions


CO2 Injection Dynamic Modeling
6
▪ Improved fluid-fluid / fluid-rock interactions
▪ Accurate description of mutual solubilities
▪ Dry-out / salting-out effect
▪ Salt precipitation
▪ Swelling and shrinkage
Upscaling
ECLIPSE – E300
Thermodynamics
Geochemistry
Thermal Modeling
Calibration on monitoring measurements
(History match)
3D Full Compositional Flow Simulator
Geomechanics Simulator


Commercial-Scale Storage Timeline
Possible site
Probable site
Proven site
High
Uncertainty
Total cost & uncertainty
Data acquisition
Detailed characterization
Design
Model driven
Monitoring plan
Validation
Prelim. study
Total cost
Construction
Includes time for plant construction
Injection & monitoring
Model update
Living model
Prediction
Closure
Equalization
Long term Environmental monitoring
Low
1 yr
Time
2-3 yrs
5-7yrs
30 yrs
50 yrs
100+
Performance & Risk
(Functions) Capacity, Injectivity, Containment >>>> (Stakes) HSE, Cost, Image


What Resources Will Be Needed?
People & Technology
People
Geology
Geophysics
Reservoir Engineer
Drilling Engineer
Petrophysics
Completion Engineer
Geomechanics
Geochemistry
Hydrogeology
Economics
HSE
Injection
Project Management
Tools for Team Integration
+
CO2 Technology
Seismic Services
Wellbore Integrity Evaluation
Drilling & Completion
Cementing
Logging, Testing & Sampling
Lab Analysis
Data Processing
Modeling & Prediction
Data Management
Monitoring

Non-Technical Needs

9

- Carbon value
- Pore ownership ruling
- Regulatory environment
  - Defined area of review
- Long-term liability
  - Insurance framework

Education Needs

10

- Sources
  - Comfort with the “risk” element
  - Coordinated timing on siting decisions
  - Working with PUCs
  - Parasitic load
- Public
  - What happens to the water?
  - Other long-term dangers
  - Value to them vs. cost
  - Communication methodology

Conclusion

11

- Good technology is available today
- Technology choices can impact risk
- High quality modern data sets need to be gathered prior to injection
- The integration of technologies with modeling tools is a skill
- Modeling tool selection is an important consideration

Keys to Success

12

- Pick the Right Site
  - Non-complex, depth, porosity, perm, extent, structure, caprock…
  - Some existing wells, but not too many
  - Access and capability for: 3-D seismic acquisition, logs, core, fluids, background
- Use the Right Technology
  - Proper density, resolution, noise limits, area of review
  - Value equivalent uncertainty reduction
  - Has impact on performance and risk
- Properly Integrate the Data
  - Requires an experienced, skilled, multi-disciplinary team
  - Unified modeling environment
  - Shared earth model, easily updatable - “Living”

Going Forward

13

- Non-technical factors are the key to progress
- Clear regulatory guidelines and and long-term liability protection are needed for commercial involvement
- Resource requirements will be large
- Uncertainties can be managed with technology
- Expertise and technology must be valued and respected
- Thorough assessment and baseline characterization is the key to reducing cost
  - number of wells
  - frequency of monitoring
  - public acceptance