DOE’s National Risk Assessment Partnership (NRAP)

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Regional Carbon Seq. Partnerships
- Application of existing tools for Phase III assessments
- Generation of Phase II/III field data
- Coordination via DOE Working Groups

Core R&D
- Base program research
- Other research programs (e.g., EFRCs;)
- New FOA from DOE-FE
- Other research efforts (e.g., ZERT; CCP-II)

National Risk Assessment Program (NRAP)
(part of the US-DOE Carbon Sequestration Program)

National Goals
- Assurance of Permanence, Capacity, etc.
- Best Practice Manual
- Common Assessment Framework

Site-Specific Goals
- Prediction of site performance
- Site-specific risk assessment
- Strategic monitoring (MVA)
- Mitigation strategies

Other Risk Activities
- EPA
- IEA-GHG
- CSLF
- etc.

National Labs Working Group
- LANL
- LBNL
- LLNL
- LLNL
- NETL (lead)
- PNNL
NRAP Structure

NRAP

Executive Committee

Stakeholder Group

Working Groups define and execute research to meet NRAP goals. They are responsible for coordination of research projects that cross organizations.

Wellbore Integrity
Natural-Seal Integrity
Groundwater Protection
Strategic Monitoring
Reservoir Performance
Risk Modeling

Working Group Lead

Multi-lab Working Group Technical Team
NRAP is a multi-lab risk-assessment initiative to ensure success of large-scale CO₂ storage projects.

**Outside of the Reservoir**
- Strategic monitoring for the site (during injection and post closure)
- Potential impacts of CO₂ release
- Protection of subsurface resources (groundwater, minerals, etc.)

**Seal**
- Seal characterization
- Seal & wellbore integrity
- Mitigation strategies

**Reservoir**
- Strategic site characterization
- Capacity & injectivity over time
- Plume movement in reservoir (CO₂, brine, pressure front)
- Impacts from introducing CO₂ into the reservoir

- Leverage the collective resources of national labs
  - collaborate & coordinate integration (across labs, community)
- Ensure key science base for assessment, prediction, and monitoring research directed at key gaps
  - provide link between applied needs and fundamental science
- Produce key findings that inform stakeholders and decision makers

Quantitative Risk Assessment
- 99% Permanence
- +/-30% Capacity
NRAP is developing a science-based methodology to quantify risk profiles at storage sites, using integrated assessment models to link various subsystems at a storage site.

- Storage site described by subsystems
- Subsystem behavior can be treated in detail
- Uncertainty/heterogeneity handled by stochastic descriptions of subsystems

Lawrence Berkeley National Lab
Lawrence Livermore National Lab
Los Alamos National Lab
National Energy Technology Lab
Pacific Northwest National Lab
Integrated system model allows coupling of detailed process models for subsystems while addressing stochastic factors.
Research efforts are coordinated across several interdependent working groups.

- Wellbore integrity & natural-seal integrity
  - open/close conditions of pathways; effective permeability
  - methods to identify potential pathways
  *goal*: quantitative estimate of potential release; best practices wellbore design/evaluation?

- Strategic monitoring
  - optimization tied to risk assessment
  - dynamic integration of monitoring and prediction
  - quantification of reservoir stress
  *goal*: update(s) to best practices

- Ensuring protection of groundwater
  - comprehensive assessment of potential impacts (CO₂/O₂/…)
  - identification of early signals for strategic monitoring
  *goal*: ensure protection by early detection; MVA best practices

- Validation through field opportunities
  - RCSPs; other DOE projects; international tests
  - analog field sites
  *goal*: validate predictive models used for assessment; expand scenarios for field-validation of MVA

- Systems
  - using inputs from each of the other working groups, develops science-based risk profiles
  *goal*: quantitative, science-based risk profiles; validated methodology for calculating site-specific risk profiles
A successful storage project will require predicting the site’s performance beyond the injection phase.

Schematic description of risk assuming probability of CO\textsubscript{2} release relates to reservoir pressure and phase-distribution of CO\textsubscript{2} (Benson, 2007).
NRAP Goal: Develop quantitative site-specific risk profiles to calculate residual liability for long-term stewardship.

1. pH (function of CO₂ only)
2. TDS (function of both brine & CO₂)
3. return of CO₂ to the atmosphere
4. reservoir stress

- identify parameters that are proxies for various risk components
  - based on risk framework
- predict curves for generic, idealized sites using simulation
  - determine effect of permeability, heterogeneity, lithology, wellbore distribution, fracture density, open/closed system, ...
  - evaluate magnitude of uncertainties
  - evaluate impact on profile from other sites within a basin
- confirm predictions using analog case studies
  - natural analog sites; anthropogenic sites; etc.
- develop risk profiles for field demo sites
- develop best-practice methodology for risk profile
  - includes identification of key site characterization and monitoring data needs
Example: To calculate potential impact in a GW system, one must estimate potential release through wellbores.

Viswanathan et al., 2008; Stauffer et al., 2008
For predicting movement of CO$_2$ in wellbore at the system level, we could relate that to wellbore permeability over time.

Could represent flow by Darcy’s law (Norbotten et al., 2005):

$$Q_\alpha = - \left( \pi r_{\text{well}}^2 \right) \left( k_{\text{well}} \lambda_\alpha \right) \frac{p_{\text{upper}} - p_{\text{lower}}}{D} \left( \rho_\alpha g \right)$$

Possible scenarios for wellbore fate:

i. wellbores degrade rapidly
ii. wellbores degrade slowly
iii. wellbores improve over time
iv. wellbores are unaffected by CO$_2$+brine

If so, we must know: (1) starting permeability & (2) evolution of permeability

(1) Vertical interference tests? Other measures? Potential range for “typical” wells?

(2) How might permeability change over time in a CO$_2$ reservoir?

- Single-time-point measurements: e.g., Crow and Carey (2008) found effective wellbore permeabilities for a CO$_2$-exposed wellbore of 0.5–20 µD based on a VIT.

- Other formulations? Bounding limits?
Thank You!

• Questions?
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Multi-Year High-Level Tasks outline

Year 1

• identify proxies for risk components
• complete first-generation predicted curves (risk profile) for generic, idealized sites
• prioritize key uncertainties in predictions that require improved scientific understanding and/or improved treatment in methodology
• identify analog case studies to be used for validation; initiate field studies

Year 2

• initiate focused research on high priority uncertainties
• intensive field and case studies to develop validation data and/or to develop data for high priority uncertainties
• initiate validation of predictive models and methodology
• complete second-generation predicted curves for generic idealized sites with refined prioritization of uncertainties
• initiate risk profiles for field demonstrations
• develop first version of best-practice methodology for development and validation of risk profile
• identify key monitoring needs that lower risk profile
• identify key mitigation needs based on key risks

Year 3…n

• continue focused research on high priority uncertainties (as necessary)
• continue field and case studies for validation (as necessary)
• continue development of risk profiles for field demonstrations (as necessary); refine/validate profiles based on field monitoring
• develop nth generation of predicted curves for generic idealized sites (as necessary)
• prepare nth generation of best-practice methodology for development and validation of risk profiles
Integrated Assessment Model Approach for Storage Site

Potential Receptors or Impacted Media

Release and Transport

Storage Reservoir
Potential Proxies for Risk Profiles

- CO2 volume delivered to potential receptor or medium (groundwater, pore-space not under deed, subsurface reservoir, surface or subsurface structure, confined or poorly ventilated space, atmosphere, etc.)
- change in aquifer chemistry (e.g., TDS, metals, etc.)
- return of CO2 to the atmosphere

- released CO2 as a function of effective wellbore permeability
- released CO2 as a function of effective seal permeability

- footprint of CO2 at reservoir-seal interface
- reservoir pressure (or delta from hydrostatic?)
- mobility rate of CO2 (or brine)
- size of pressure front
- deviation/magnitude of subsurface relative to initial pressure
- mineralization to reduce permeability (inverse)
- mass of free CO2 vs. dissolve/ppt CO2
Outline for Multi-Year High-Level Tasks

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U.S. EPA’s Vulnerability Evaluation Framework (VEF)

NRAP research efforts are coordinated across several interdependent topical areas.

**Systems Modeling for Risk Assessment**
- quantification of site-specific risk profiles
- identification of key uncertainty drivers to direct research

*goal*: validated, science-based methodology for risk profiles

**Ensuring protection of groundwater**
- comprehensive assessment of potential impacts (CO₂/O₂/…)
- identification of early signals for strategic monitoring

*goal*: ensure protection by early detection

**Wellbore integrity & natural-seal integrity**
- open/close conditions of pathways; effective permeability
- methods to identify potential pathways

*goal*: quantitative estimate of potential release

**Strategic monitoring**
- optimization tied to risk assessment
- dynamic integration of monitoring and prediction
- quantification of reservoir stress

*goal*: risk-based monitoring protocol
NRAP Overview

Provide scientific underpinning for risk assessment with respect to long-term storage of CO₂ (i.e., post-closure), including assessment of residual risk associated with a site post-closure.
Integrated system model allows coupling of detailed process models for subsystems while addressing stochastic factors.

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