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Carbon Management Research:

Energy Systems Modeling, Risk Assessment and Geotechnology at Sandia National Laboratories

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Sandia National Laboratories

Presentation for

Shell

Albuquerque, NM

Wednesday, March 28, 2007

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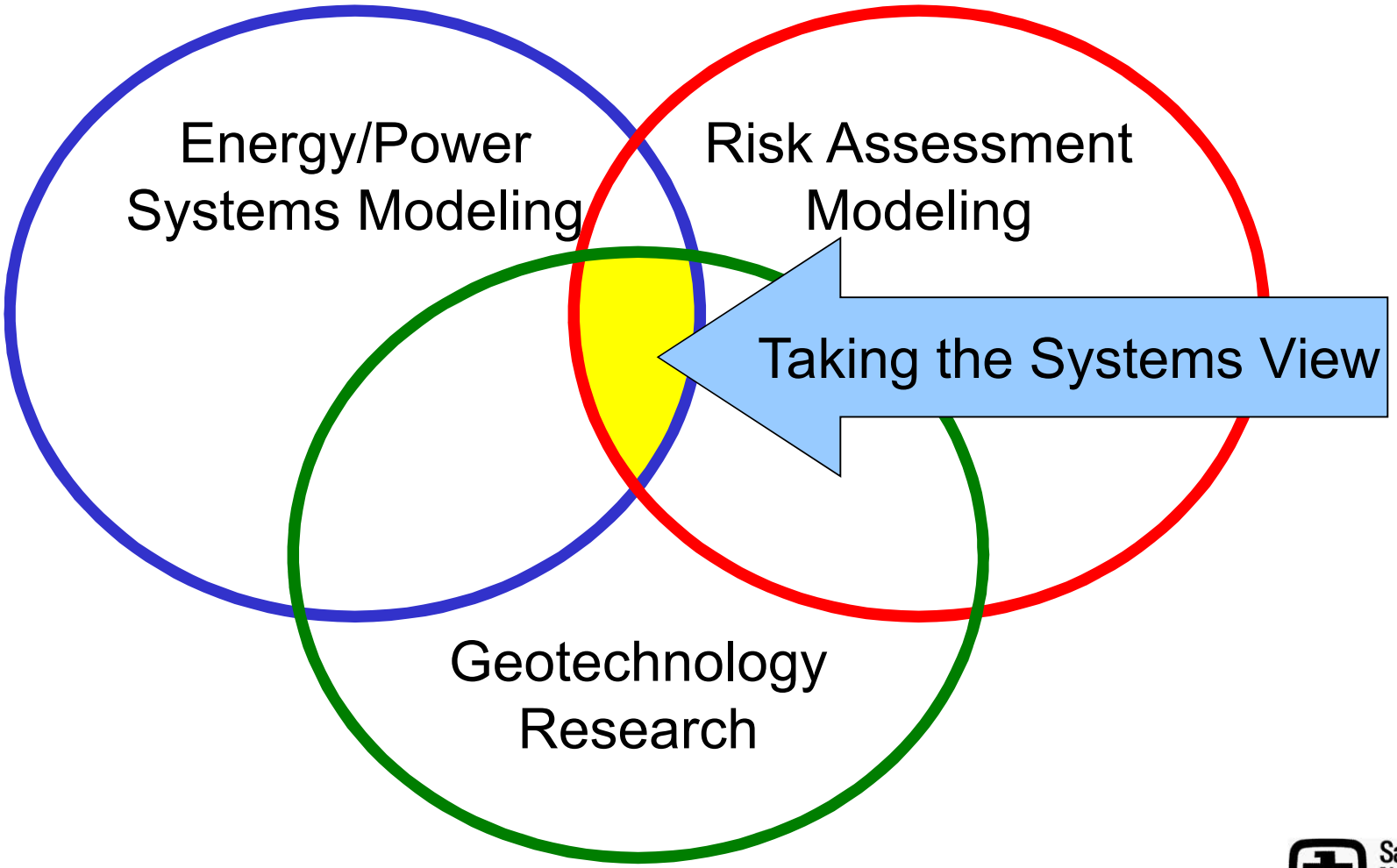
Carbon Sequestration Research at Sandia National Laboratories



The Integrated Assessment Model and 'The String of Pearls'

Sandia National Laboratories

Carbon Sequestration

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String of Pearls

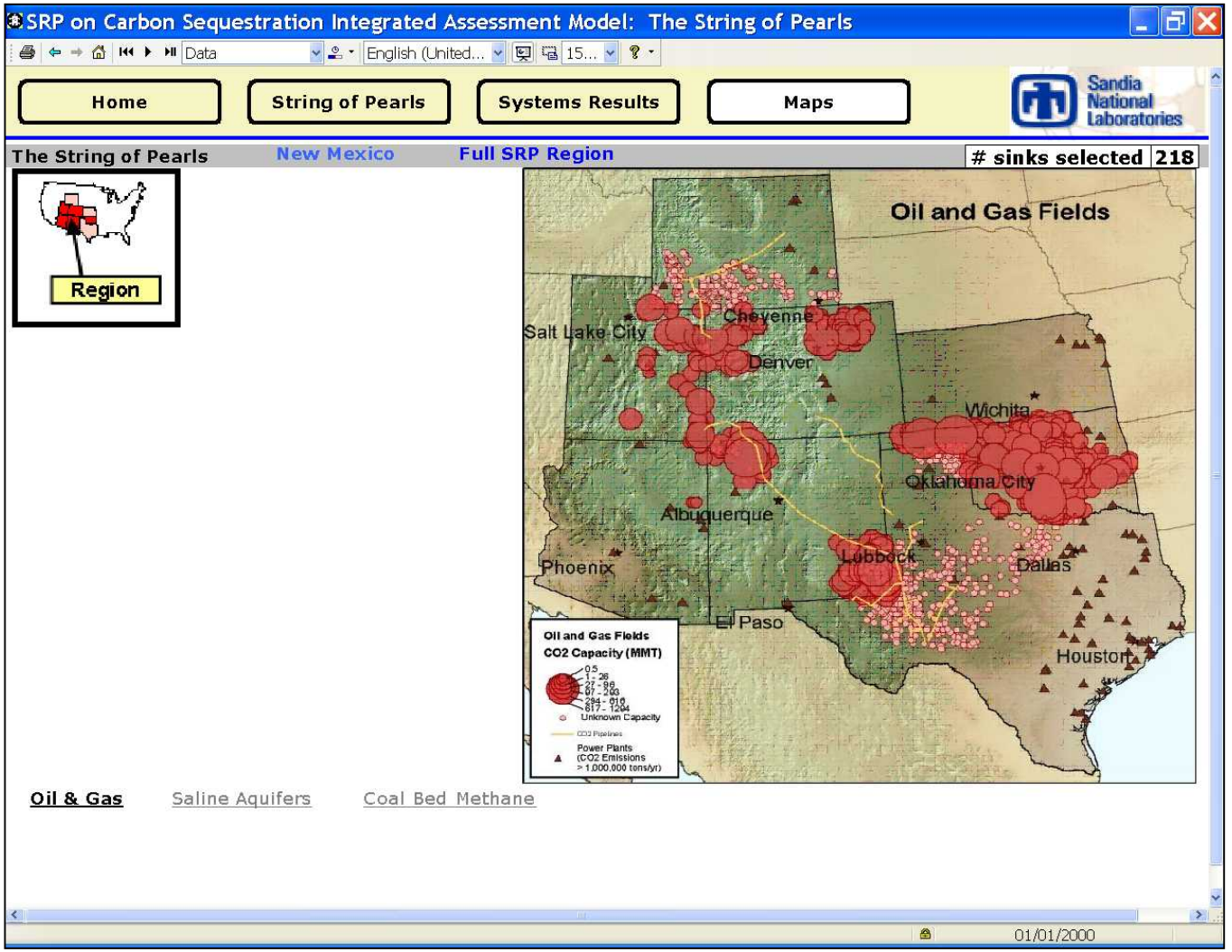
The Integrated Assessment Cost and Source-Sink Model

This research describes the 'String of Pearls' analytical model used by the Southwest Regional Partnership on Carbon Sequestration to assess potentially hundreds of carbon dioxide (CO_2) source and geological sink combinations in the Southwestern United States. The model can help decision makers (e.g., policy analysts and interested companies) determine where a power plant (or other CO_2 source) could be built given a set of planning decisions based on current power plant locations, sink availability, and existing pipeline infrastructure right-of-ways.

The working results indicate that the cost of capturing carbon dioxide is by far the majority of a project's overall capital cost. The analysis also develops overarching regional CO_2 sequestration totals and relative costs, and sink lifetimes across an initial fifty-year time horizon. The region may support anywhere from several decades to several thousand years' worth of sink capacity.

Questions & Comments | Privacy and Security
Last modified: March 1, 2007

The Partnership's Working Database: Oil & Gas CO_2 Sequestration Sites



(Database as of July 2006; Biediger, 2006)

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The Integrated Assessment Model: CO_2 Capture, Transportation and Storage

1. Characterize the physical, economic and policy requirements for a carbon sequestration project

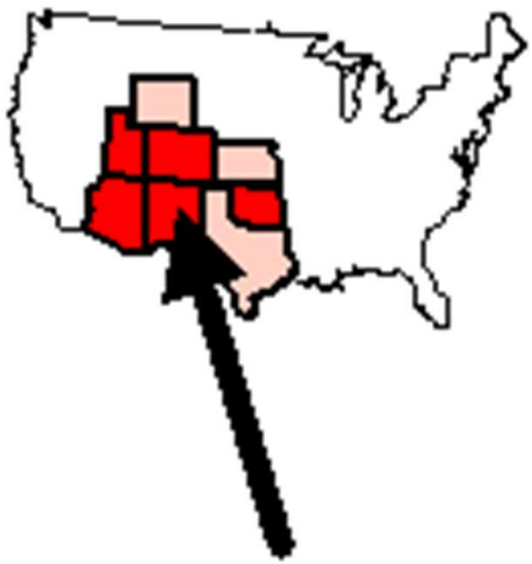
2. Develop a high-level methodological framework for analysis

3. Build an Integrated Assessment model (dynamic simulation computer model) to help interested parties understand the potential screening criteria necessary to develop such a project

4. Apply the model to the Southwestern United States, and beyond

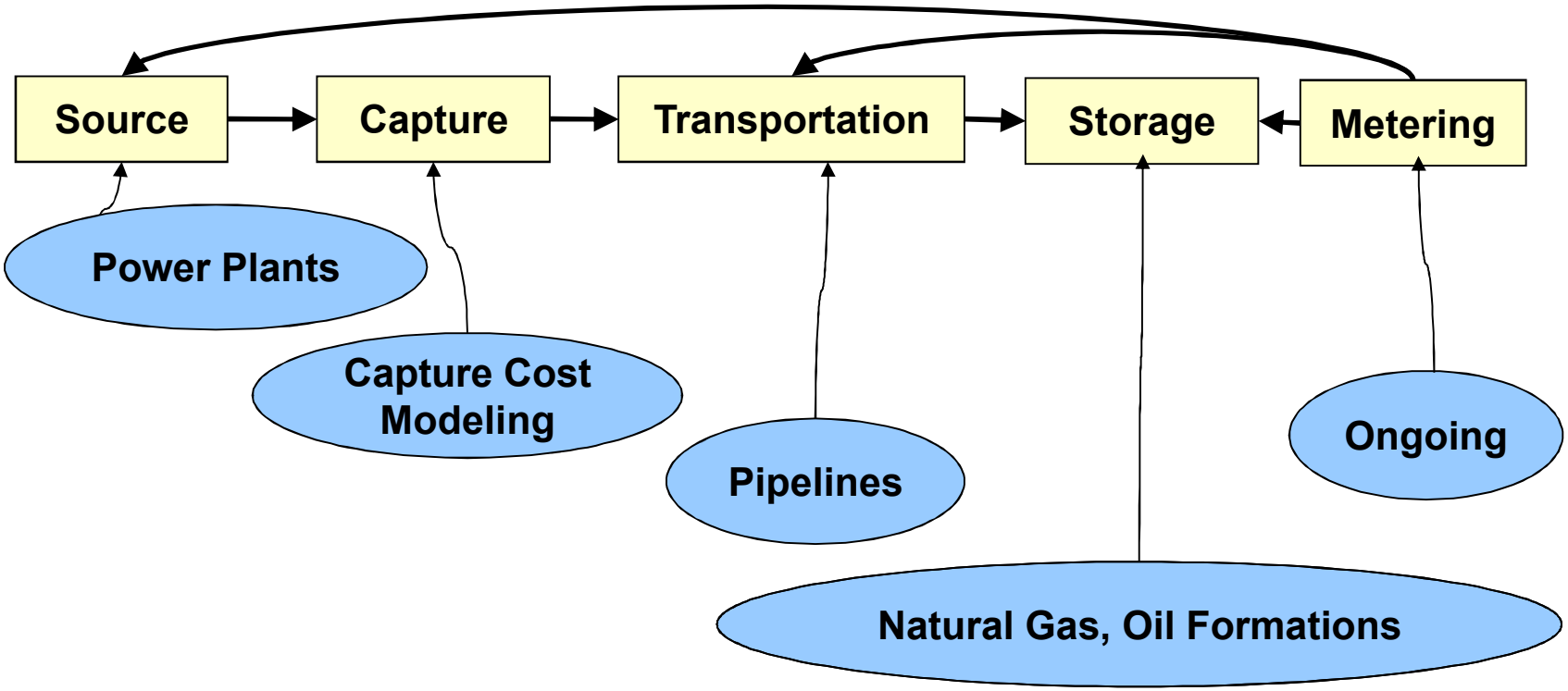
The Model is Part of a Regional Partnership

Southwest Regional Partnership for Carbon Sequestration



- **Model characterizes the screening criteria:**
  - **underground geologic storage of carbon dioxide (CO_2)**
  - **the relative size of the CO_2 flow from the source to the sink**
  - **economics associated with this system**

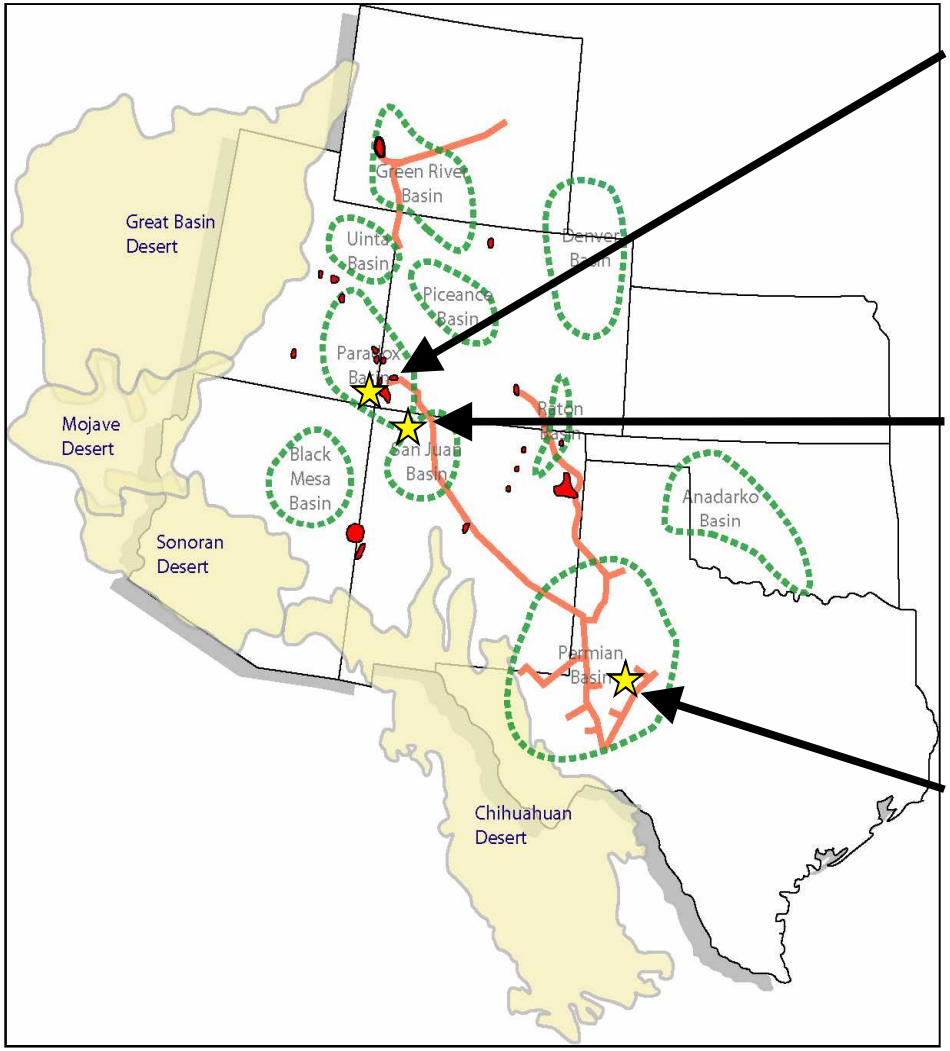
Schematic of the Integrated Assessment Model



Systems Cost =

Capture Cost $_{tCO2}$ + Pipeline Cost $_{tCO2}$ + Surface Piping and Well Costs $_{tCO2}$ + Measurement, Monitoring and Verification $_{tCO2}$

Phase II Demonstration Options: Geological Sequestration

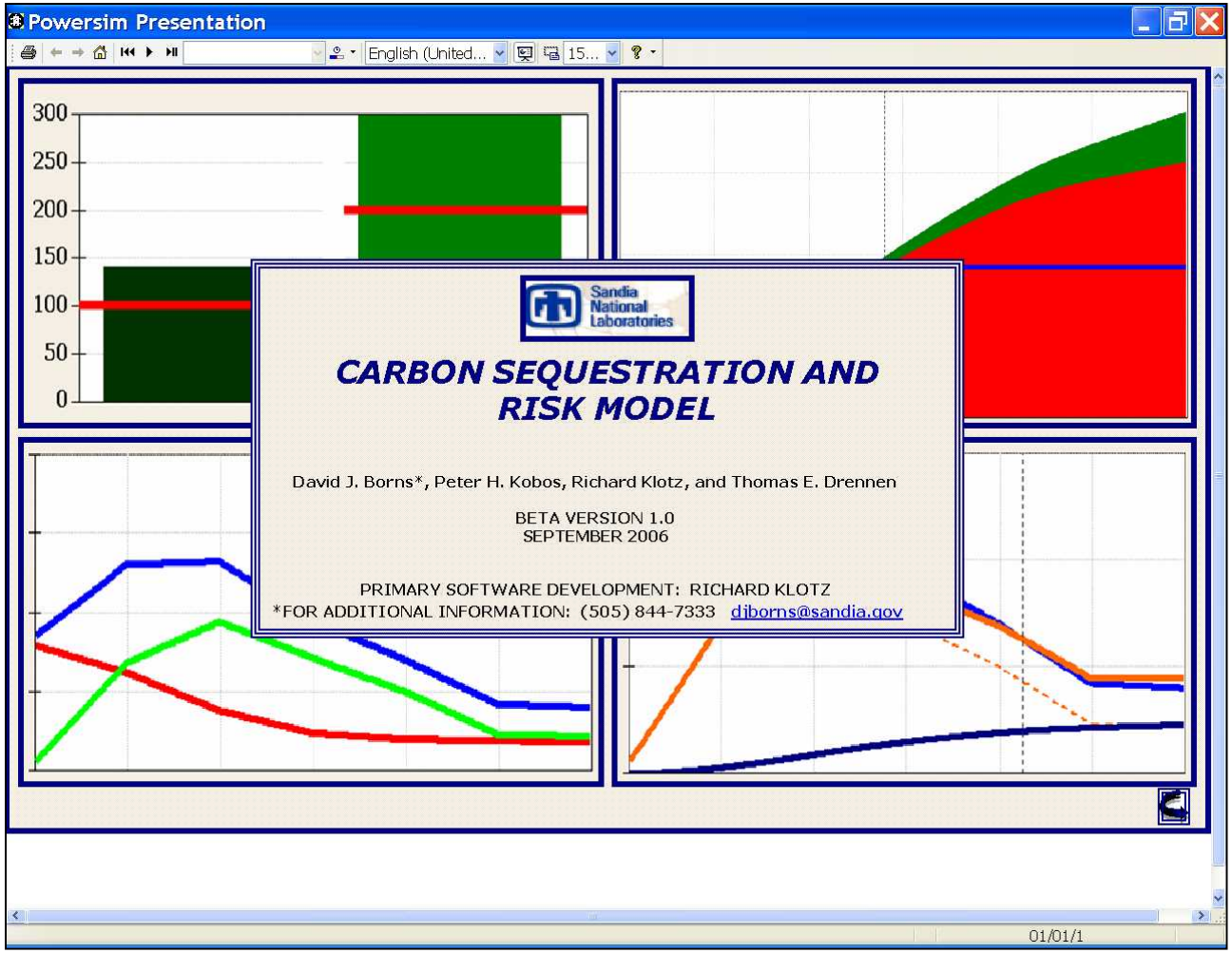


McPherson, 2005

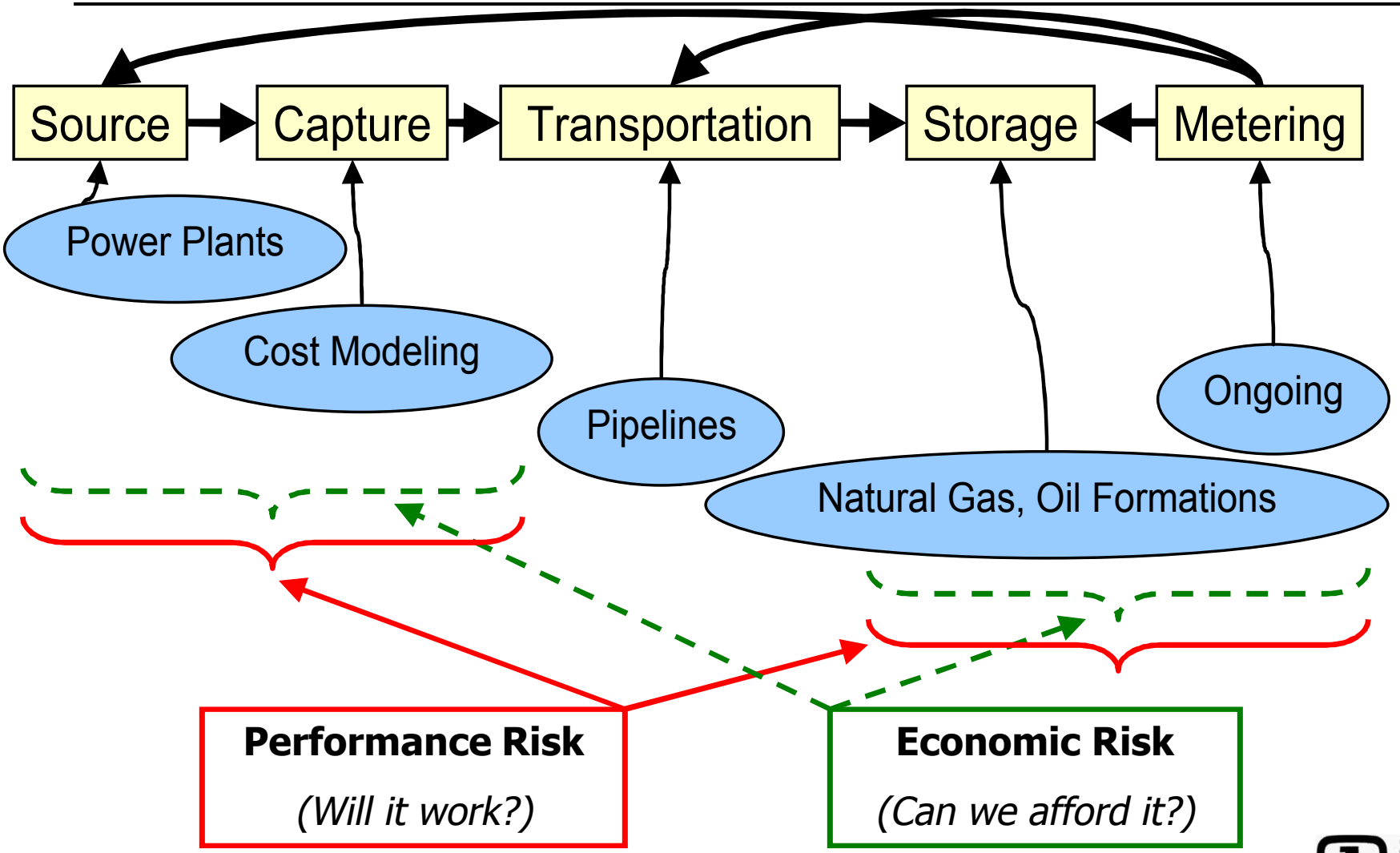
- Paradox Basin, Utah: combined EOR and deep saline aquifer sequestration pilot test *(Jim Rutledge)*
- San Juan Basin, NM: combined ECBM and terrestrial sequestration pilot test *(Scott Reeves, Joel Brown)*
- Permian Basin, TX: combined EOR and sequestration pilot test at SACROC & Claytonville *(Mark Holtz)*

Model Demonstration

Risk Assessment Modeling

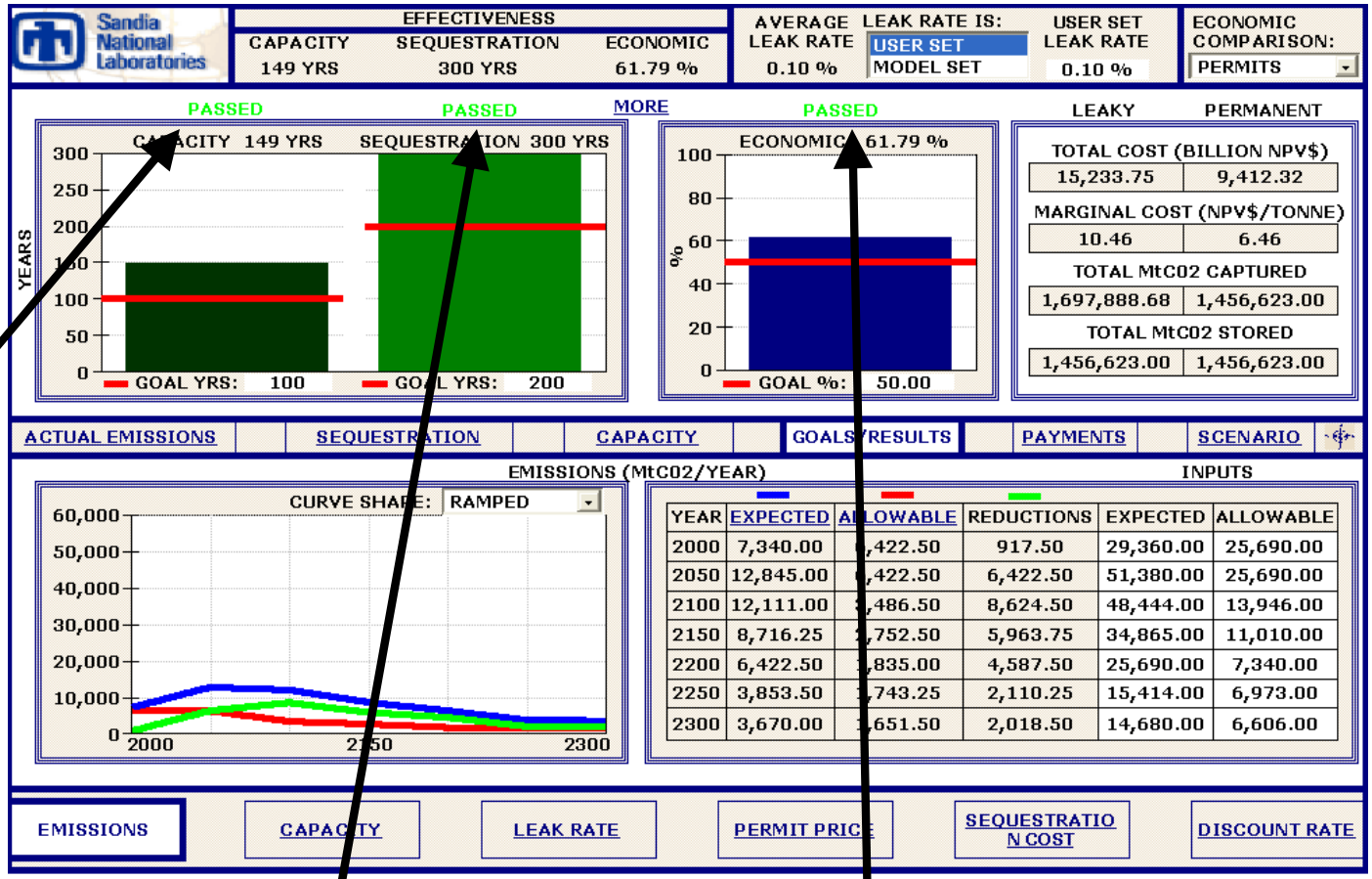


Approach: CO_2 Source to Sink Systems Analysis



Risk Assessment Modeling

Global Capacity for 150 to well beyond 300 years

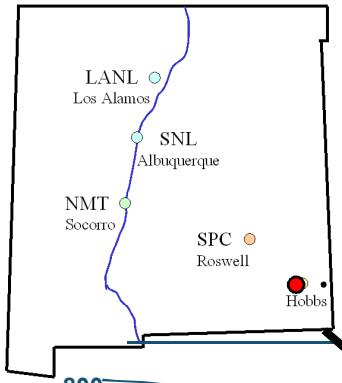


While meeting performance and economic goals

Risk Assessment Lessons / Remarks

- **The majority of the cost Share is with Capturing the Carbon Dioxide**
  - **(usually >90% of the total cost)**
  - **CO_2 sequestration will increase the cost of electricity**
- **Much of the Technology is proven**
  - **Capture ➔ Transportation ➔ Disposal**
- **The CO_2 community network has been developed (NETL, MIT, MRS, IAEE, etc.)**
- **The CSR simulation model is a perfect complement to the SW Regional Partnership on Carbon sequestration project**
  - **Begin to address performance and economic assessment based on RISK, and not arbitrary goals (e.g., picking a # of years required for monitoring)**

Geotechnology:
West Pearl Queen Field



Structure Map - Top of Queen Sand
(T. 19 S., R. 34 W.; 20' contour interval; Datum S.L.)

Strata Stivason-Fed #4
80,000 bbls produced since '89
5-30 md permeability
18% porosity
23' (net) thick (4508-4531' depth)
30° API at 105ºF
800 psi shut-in pressure
65% qtz, 25% fldsp, 5% clay
carbonate cement

Manzano producing wells (monitor production)

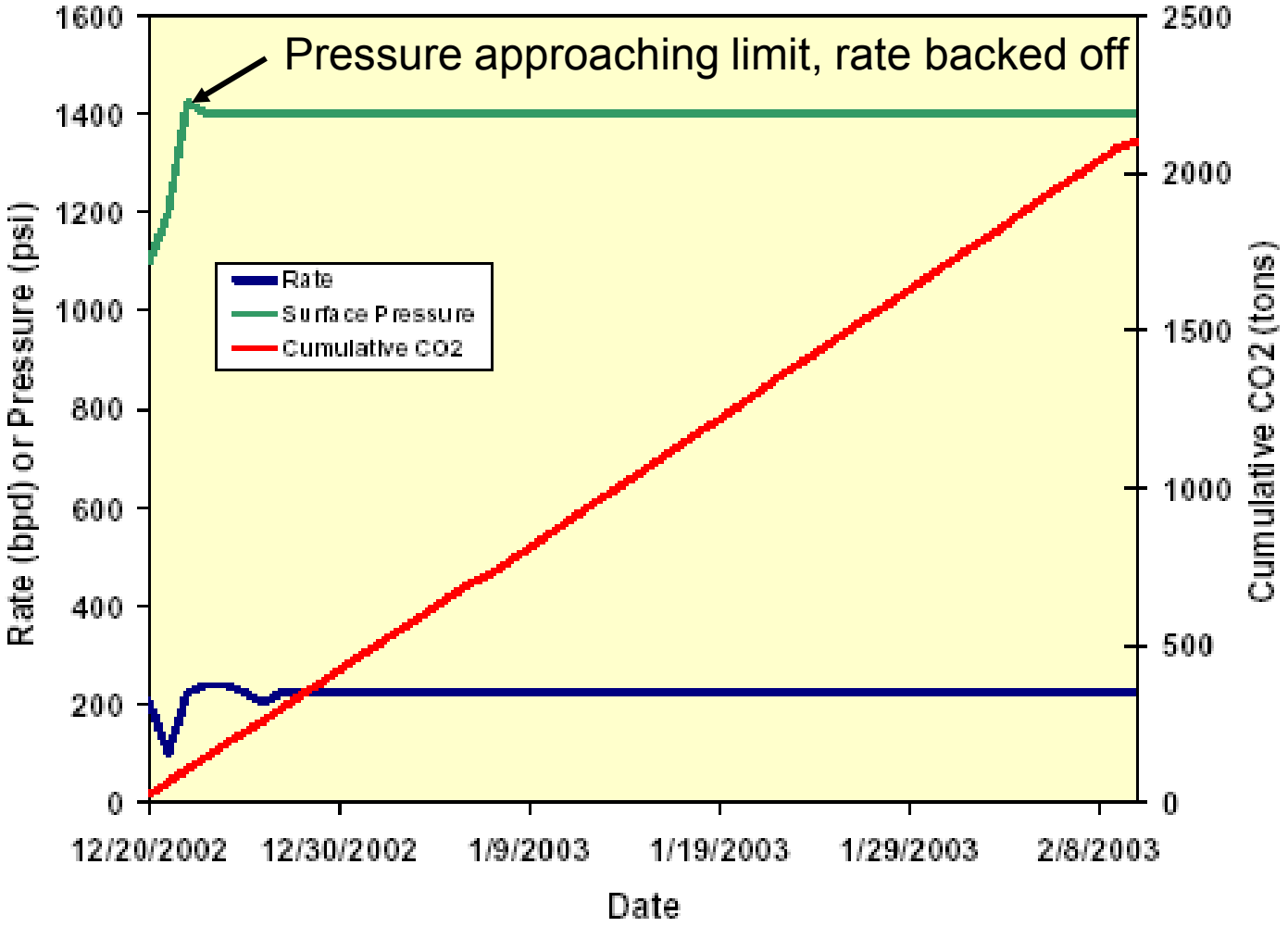
Strata Production Co. Wells
#4 CO_2 Injection & monitoring well (4.9" ID)
#5 Monitoring & producing well (4.9" ID)
#1&3 Waste water injector well (1.8" ID w. packer)
#2 Plugged well

(NETL CO2 Sequestration Field Site)

Injection:

Anticipated 500 B/d, Actual 200 B/d

West Pearl Queen Field



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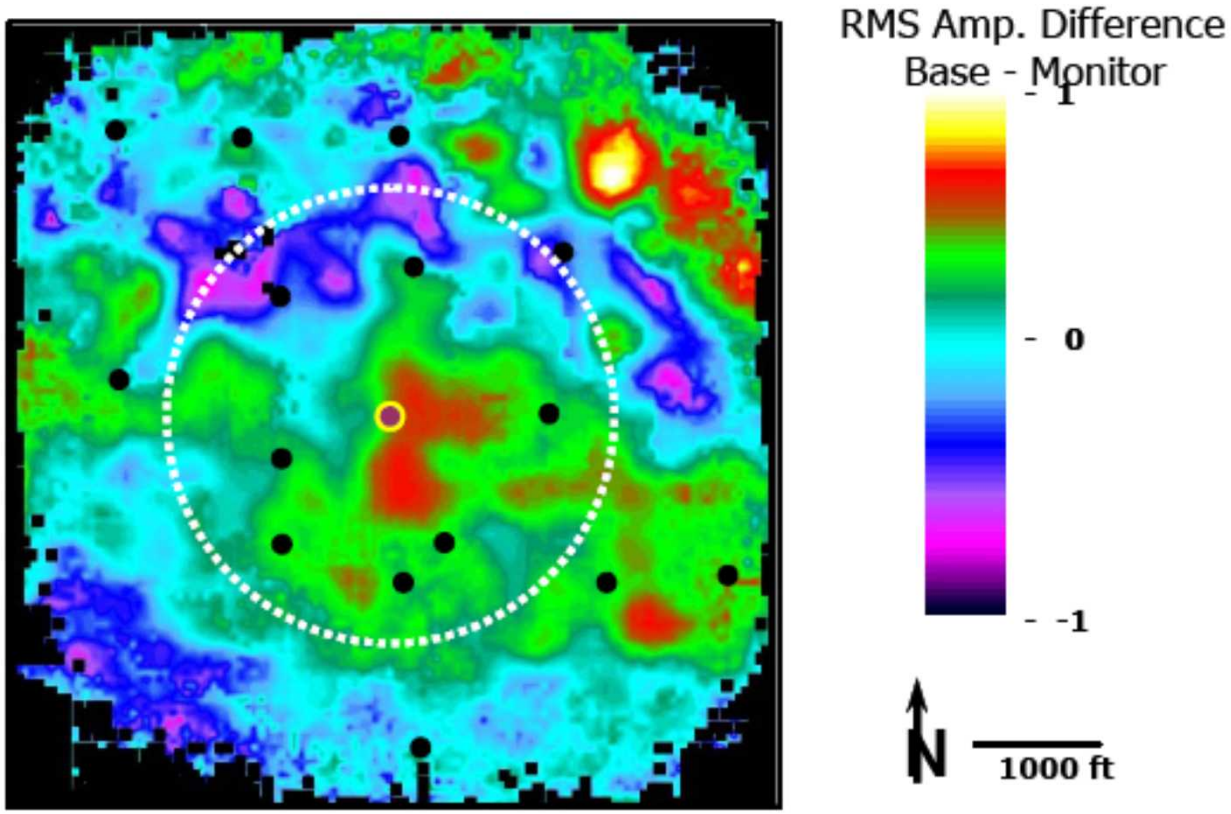
Geotechnology Research

West Pearl Queen Field

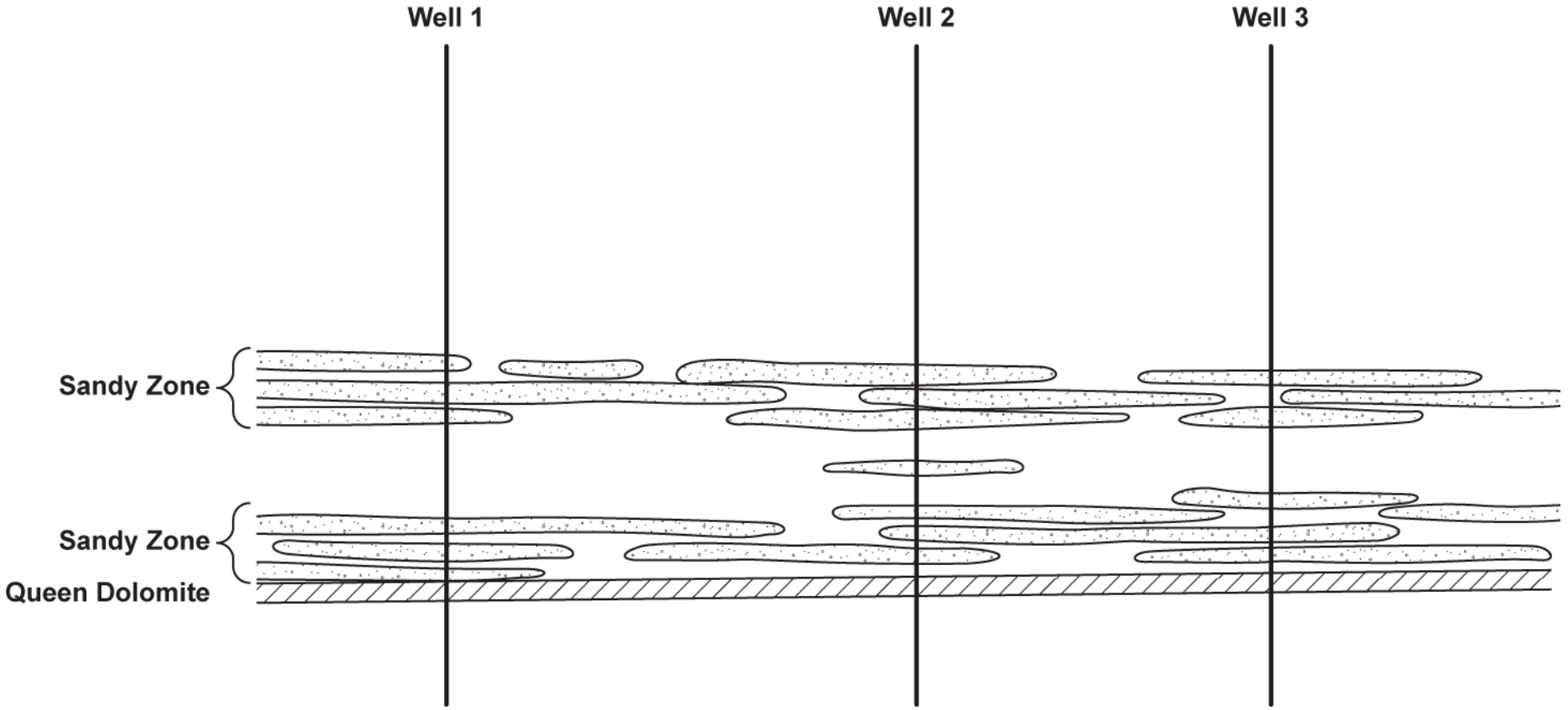


RMS reflection amplitude differences – P wave.

Interesting Results

- Excessive injection pressure
- Minimum recovery of CO_2
  - 34 MMSC injected
  - recovered only 12.97 MMSC (~43%).
- Slow CO_2 migration to adjacent wells
- No EOR effects on adjacent wells
- Localized gas plume, offset at the base of the injection well

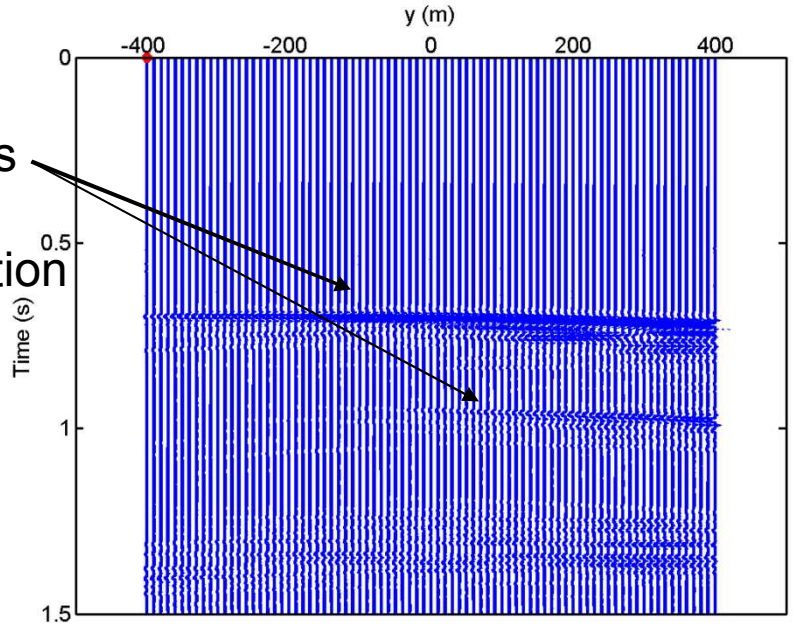
Potential reason for the results: Sandy zones correlate; individual beds do not



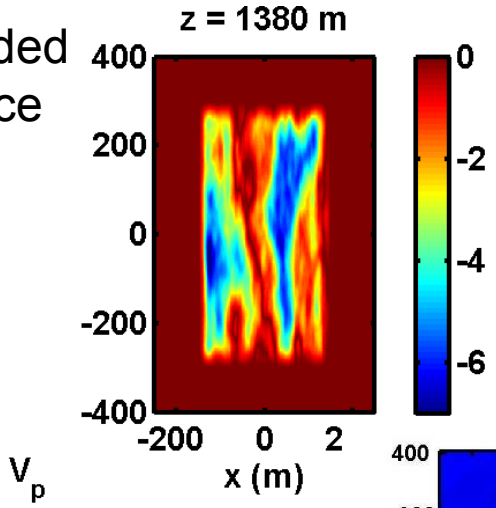
Sandstone Formations are not homogeneous

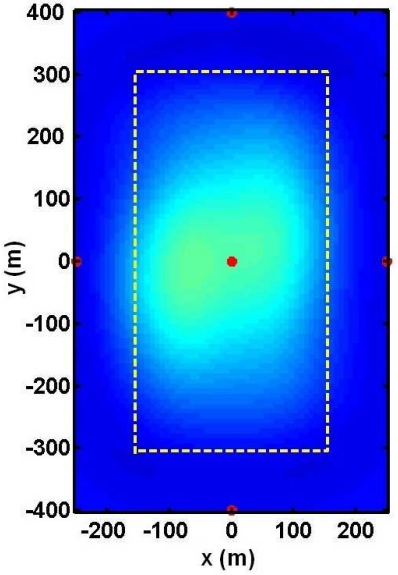
Synthetic Seismic Reflection Data Simulation

Synthetic gather of seismic traces recorded on surface (Vz particle velocity) for source located at y = -400 m.



Reflections from CO_2 sequestration zone.





Synthetic seismic data calculated with 3D finite-difference numerical algorithm appropriate for isotropic elastic media.

Other CO_2 work At Sandia

- Internal Drive to look at the value of CO_2
- Enhanced Oil Recovery
- Potential to apply energy and chemical processing technologies to capture and convert CO_2 and H_2O
  - Develop into a synfuel that is compatible with exiting fuels infrastrucure into an infrastructure compatible liquid fuel.

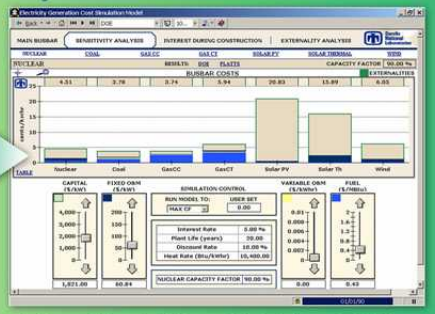
Final Slide: Other Sandia Models, Assessing Costs and Energy Options

ECONOMIC DYNAMIC SIMULATION MODELS

STRATEGIC SUPPORT FOR HIGH-LEVEL PUBLIC POLICY DECISIONS AND SANDIA PROGRAMS

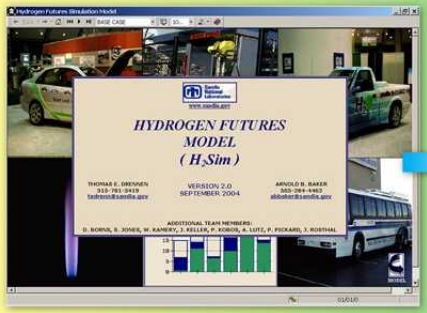
Understanding Technology Cost Options

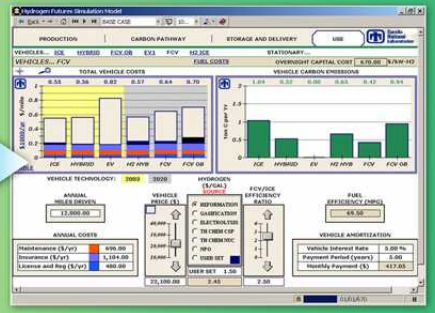
Electricity



- Calculates electricity production costs for a variety of electricity generation technologies, including: pulverized coal, gas combustion turbine, gas combined cycle, nuclear, solar (PV and thermal), and wind
- Provides sensitivity analysis for key variables, including: capital, O&M, and fuel costs, interest rates, construction time, heat rates, capacity factors, and considers externality costs and pollution control options

Hydrogen

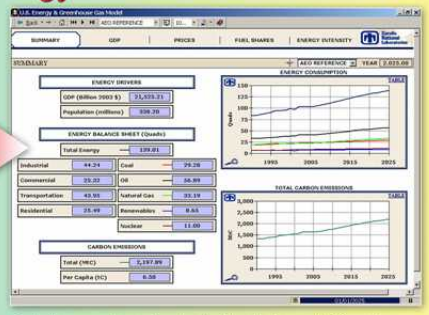




- Seeks to improve understanding of the economic viability and emission trade-offs of all stages of potential hydrogen pathways
- Calculates the production, storage, delivery, and end use costs associated with a future hydrogen economy

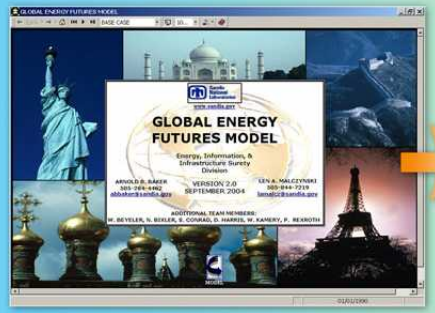
Understanding Long Term Energy & Environmental Options

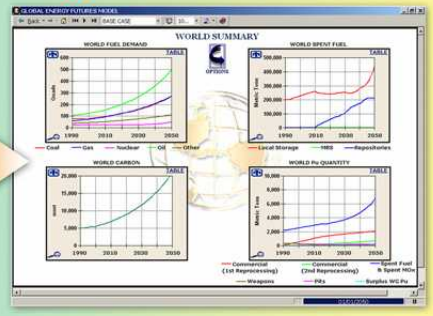
U.S. Energy



- Focuses on U.S. energy demand by economic and electric power sectors through 2025 to facilitate energy policy discussions
- Evaluates energy demand, carbon dioxide emissions, and oil import requirements, driven by gross domestic product, energy prices, energy intensities, and population effects

Global Energy





- Provides a global/regional perspective on trade-offs for economic growth, energy demand and environmental emissions to 2050, including the full nuclear fuel cycle and related materials
- Links oil, gas, coal, nuclear, and renewable energy to GDP growth, energy intensities, carbon emissions, and twelve other measures of environmental impact for five regions of the world

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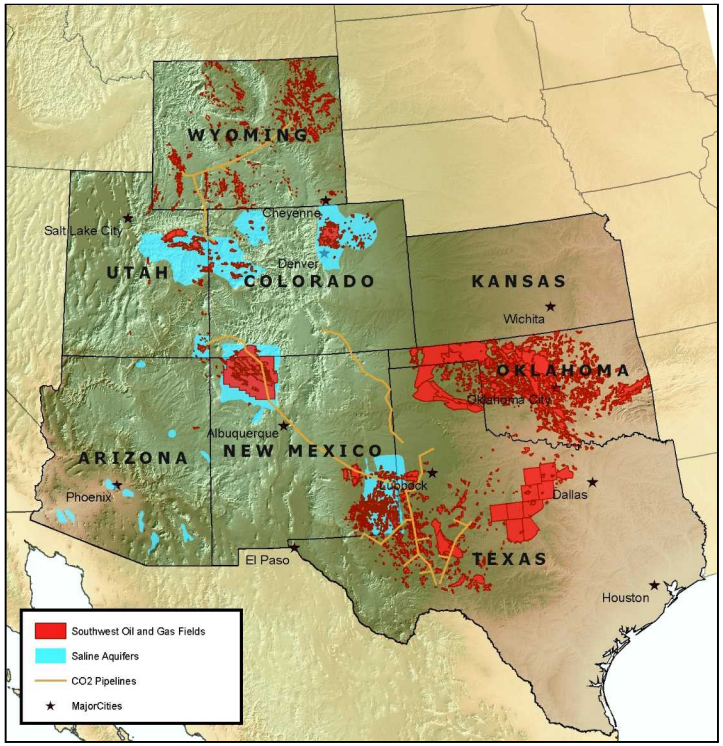
Thank You



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