
Energy, Water and CO₂:

Using Integrated Assessment Modeling for Performance Mapping and Collaborative Scenario Development

Peter H. Kobos, Jesse D. Roach

and the larger team including Geoff Klise, Tom Dewers, Jim Krumhansl, Brian Dwyer, Jason Heath, Dave Borns, Andrea McNemar (NETL), Len Malczynski, Vince Tidwell, and many more

Collaborative Workshop, SNL & NETL

April 2010

*Kobos and Roach are the PI and Lead Analyst for the Water, Energy and Carbon Sequestration (WECS) model, respectively.

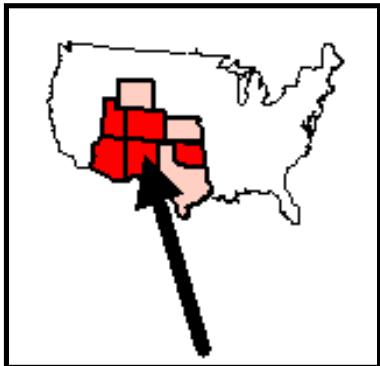
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.
Working Results as of early 2010.



SNL and NETL Collaborative CO₂ Systems Analysis Projects

- The ‘String of Pearls’ model for the Southwest Regional Partnership on Carbon Sequestration (completed)
- The Water, Energy and Carbon Sequestration (WECS) project and regional water stress assessments (ongoing)
- Developing collaborations with the Energy, Power and Water Simulation Model (EPWSim) (ongoing)
- Other Potential Efforts

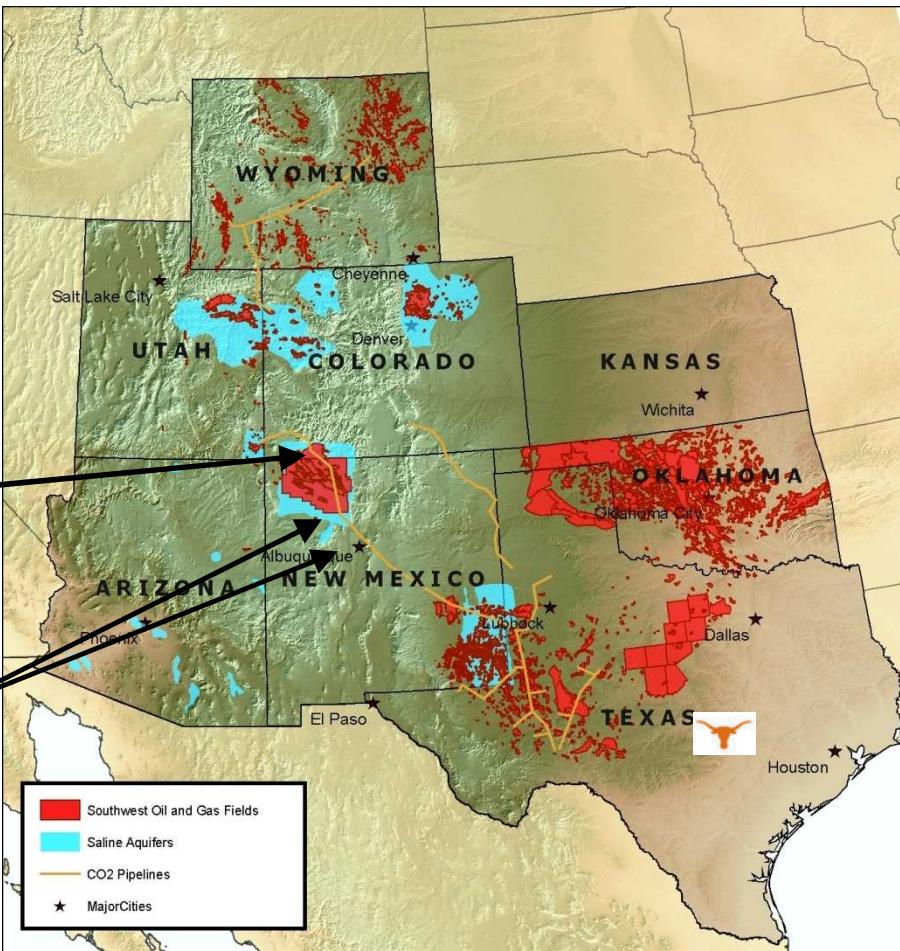
The Southwest Regional Partnership on Carbon Sequestration (SWP): *The String of Pearls*



CO₂ pipelines in NM, TX, CO, WY, UT

Potential Sequestration:

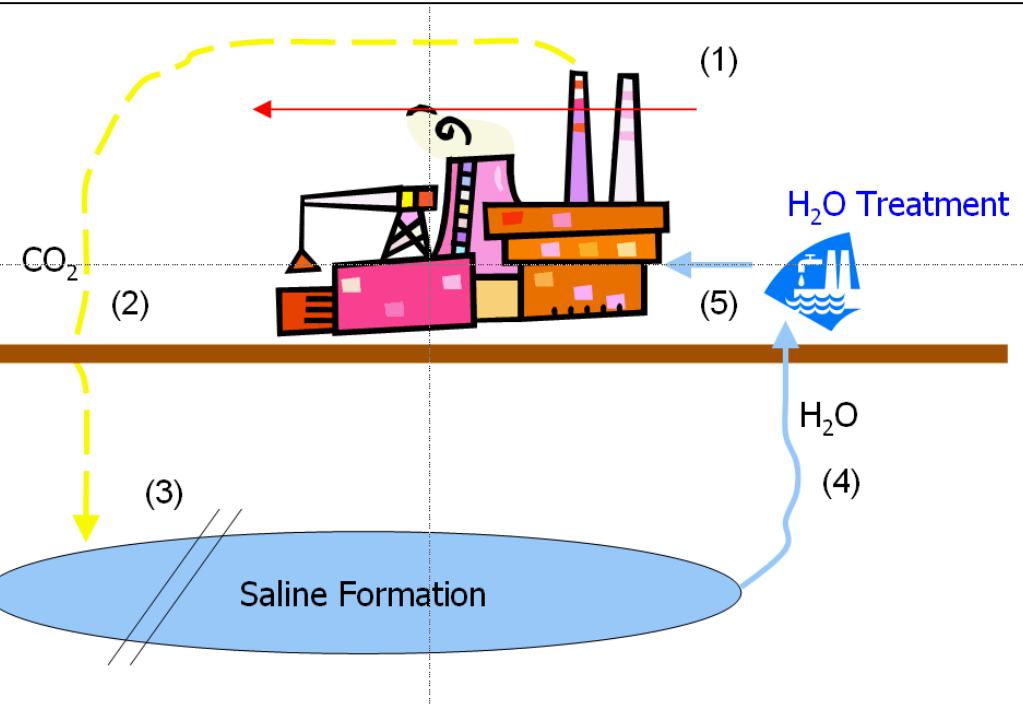
- Oil Fields
- Natural Gas Fields
- Saline Formations



- **One of seven** regional partnerships throughout the U.S.
- Evaluating **available technologies** to capture and to reduce CO₂ emissions
- **Source to Sink** matching (Power plants to Geological Formations)
- String of Pearls Model **'Tells the Story'** for the SW Partnership
 - Technology
 - Economics
 - Scale of the Issues

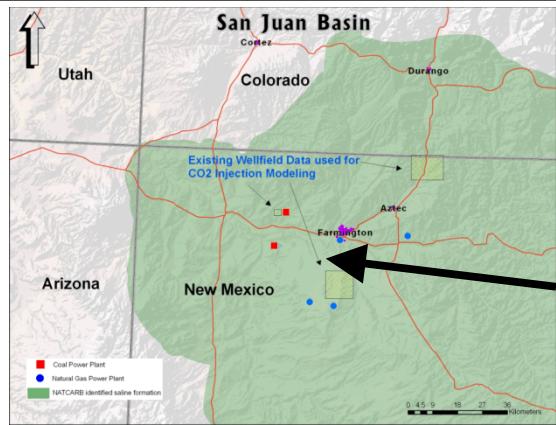
Water, Energy & Carbon Sequestration (WECS) Model:

Energy-Economic Modeling Conceptual Layout of the Project



Central Tasks:

1. CO₂ power plant emissions
2. CCS Potential
3. Saline Formation CO₂ sequestration potential
4. Pump Saline Formation for use at the power plant
5. Desalinate water for use at the power plant



San Juan Basin in NW New Mexico

Note: Carbon Capture and Sequestration (CCS)

Water, Energy and Carbon Sequestration (WECS) model interface, version 1

7 Evaluating Saline Formations for Combined Carbon Sequestration and Power Plant Cooling Water Needs

Main Page CCS Assumptions CO2 Sink Water Treatment Sandia National Laboratories

i Saline Formations for Combined Thermoelectric Power Plant Water Needs and Carbon Sequestration at a Regional-Scale

Input Options

Input

Output

cents / kWh

15
10
5
0

Base Cost Base Cost + CCS+WT

Base Cost Carbon Capture and Sequestration (CCS) Water Treatment (WT)

Input Variable

Power Plant Emissions (CO2)	13,165,665 tonne/yr
% CO2 Sequestered	50 %
Formation Depth	4,725 ft
Formation Size	1,069 mmt
Power Plant Water Demand	6.90 (cf/s)/boiler 18 MGD

High-Level Results

CO2 Sink Longevity	162 yr
Potential Displaced Water	2.2 MGD
Potential Treated Water	1.4 MGD
% of Annual Plant Demand Met	8 %
Years Worth of H2O in Formation for Plant	13 yr
Years Worth of H2O based on CO2 disp.	103 yr
Plume Migration Distance	10,320 m
Electricity Cost	4.50 cents/kWh
Water Treatment Costs	7.94 \$(/1000 gal/yr)
Electricity Cost, CO2 Seq & H2O Treatment	8.96 cents/kWh

San Juan CO2 % CO2 Captured Geological Formation Wells % H2O Recovery San Juan Water Demand Base Cost of Electricity

tonne/yr
20,000,000
10,000,000
0

90%
70%
50%
30%
0%

Morrison 1

well
6
1

100%
0%

MGD
20
0

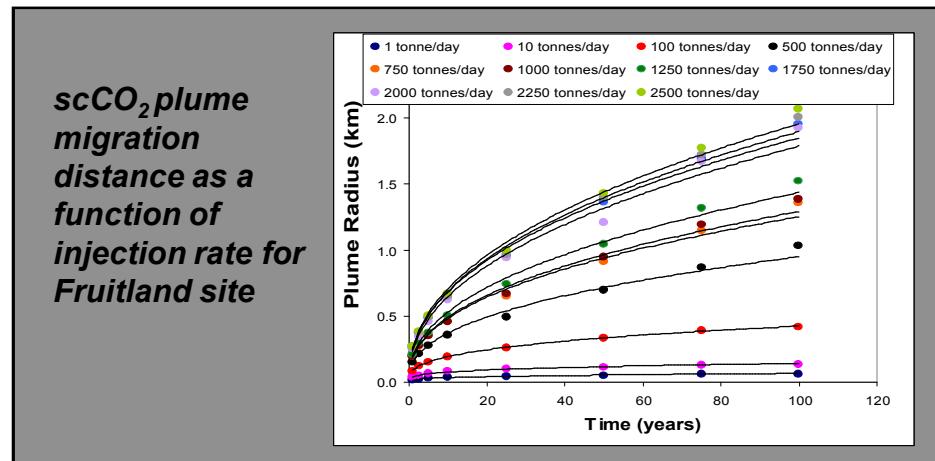
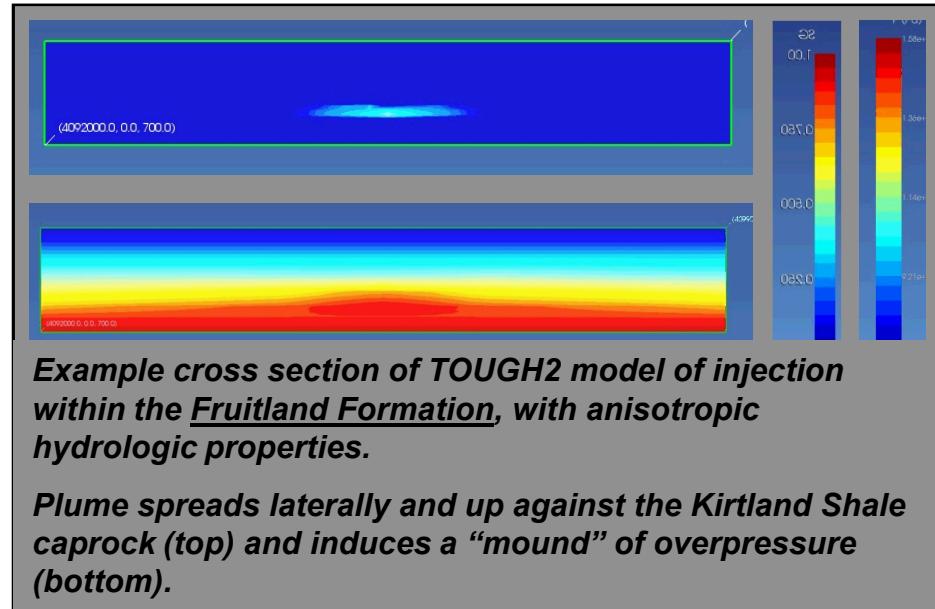
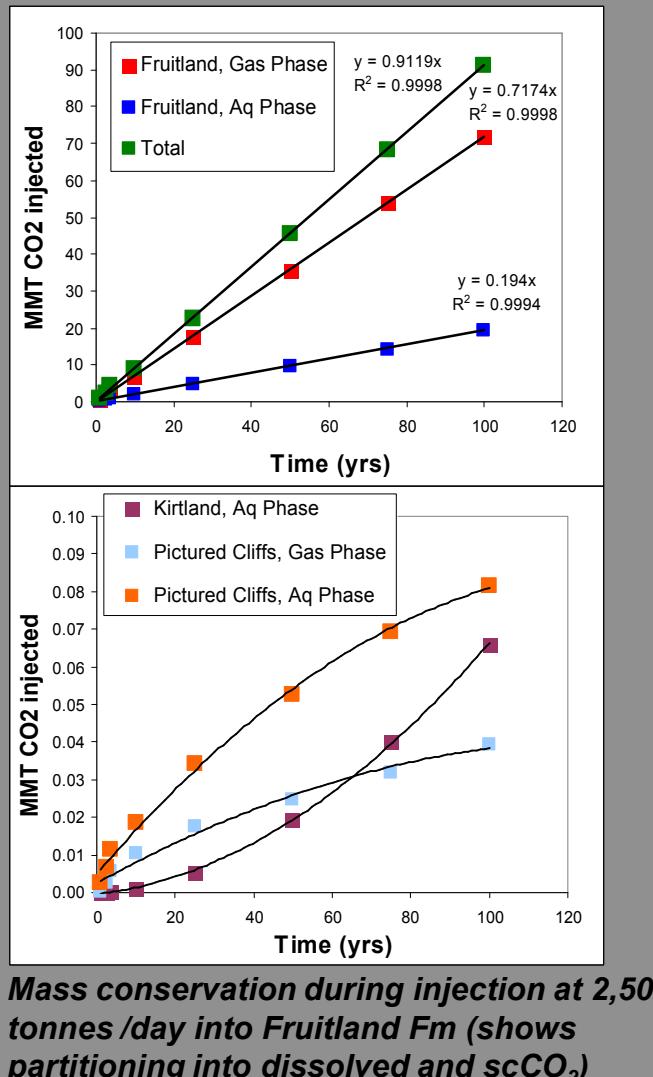
cents/kWh
20
0

13,165,665 tonne/yr 50 % 8 well 30 % 17.84 MGD 4.50 cents/kWh

06/01/2049

i Sandia National Laboratories

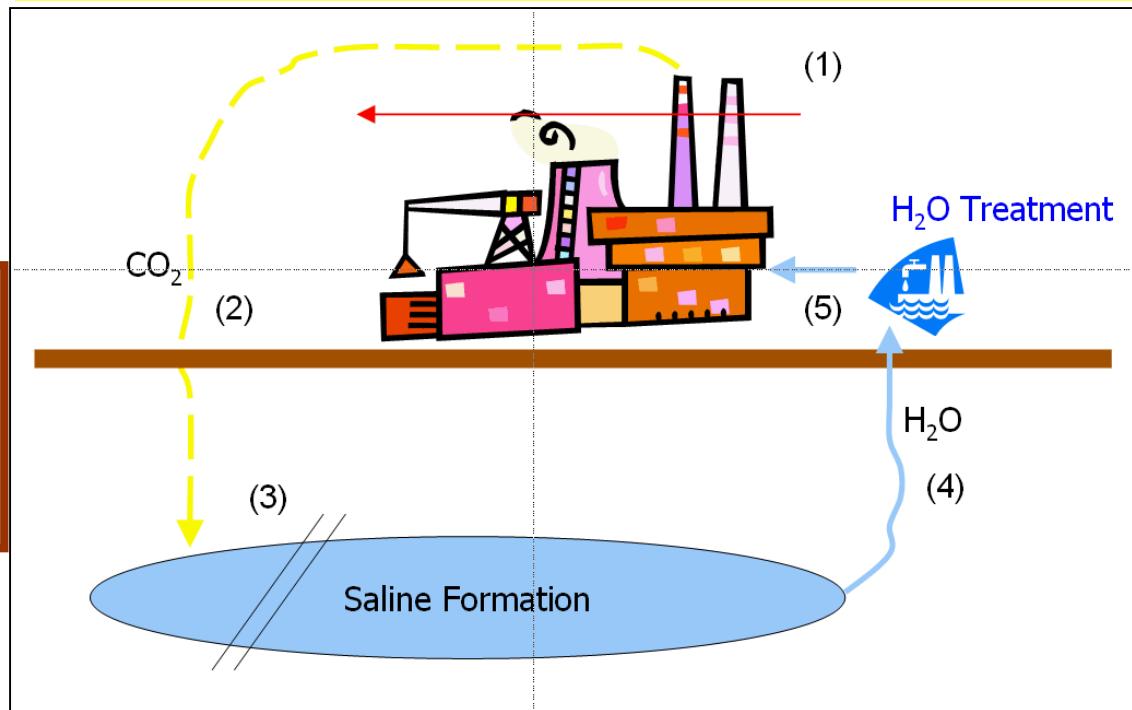
Geostudies (Geomodeling): Modeling Supercritical CO₂ injection into San Juan Basin Saline Formations – Providing Insight for Plume Migration



WECS (v1) Highlights

(1) Carbon Capture and Sequestration (CCS),
20%+ Energy Penalty ↑ costs ~100%, ↑H₂O demands

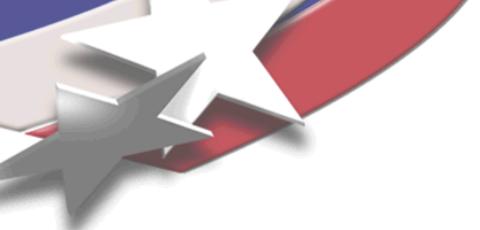
(2) CCS, 50% capture and sequestration, ~4 mmt/yr



(5) Produced Water Treatment, ↑ costs ~10%, meet potentially a portion of Power Plant's annual H₂O demand

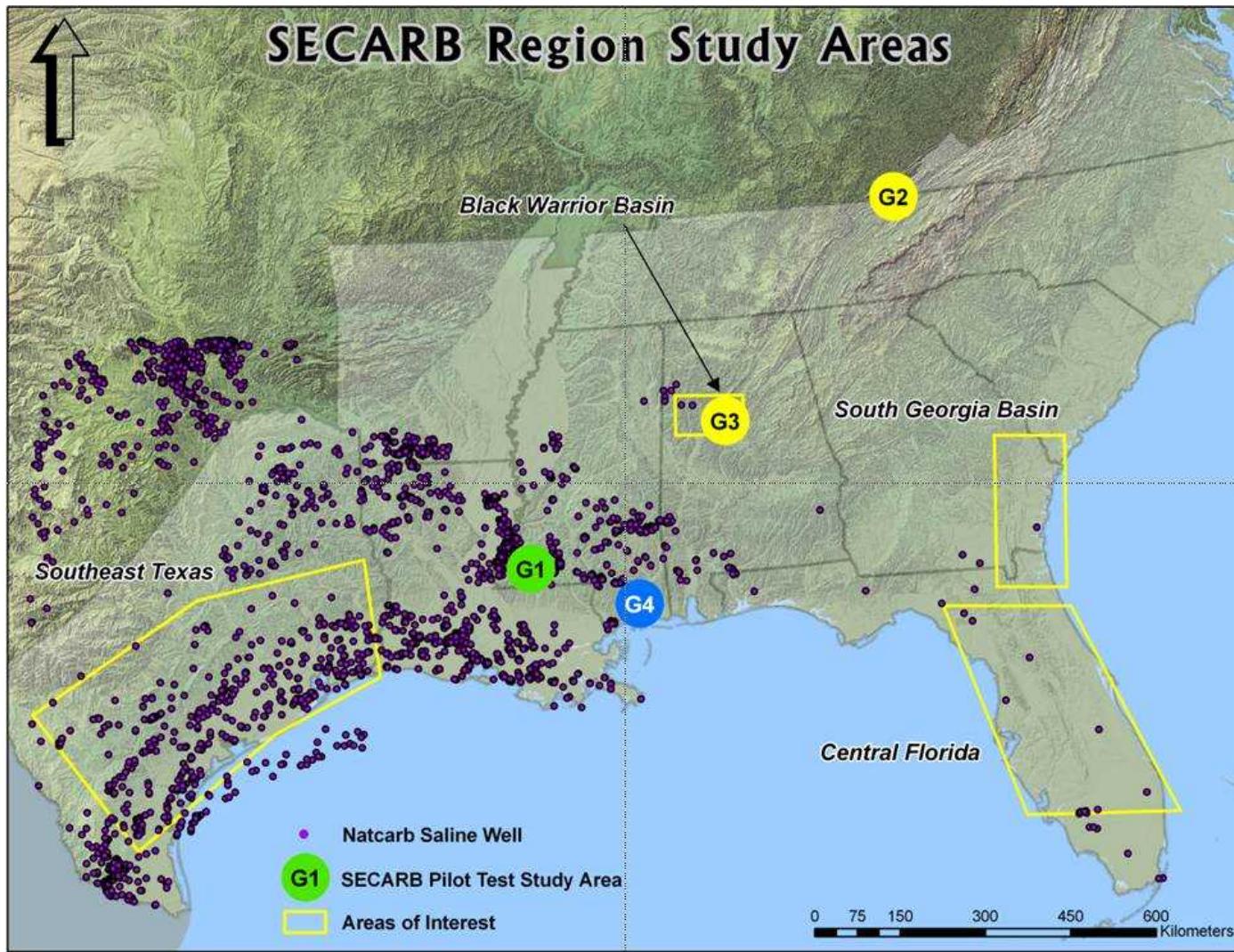
(3) Morrison Formation, 3,000+ mmt, 100s yrs. worth of CO₂ sequestration capacity

(4) <1 - 4 Million Gallons per Day for ~50-100s yrs., Assuming 30% recoverable water potential



Regional Water Stress Project:

Focusing on the SECARB region as a comparison to the San Juan Basin in the initial WECS Model





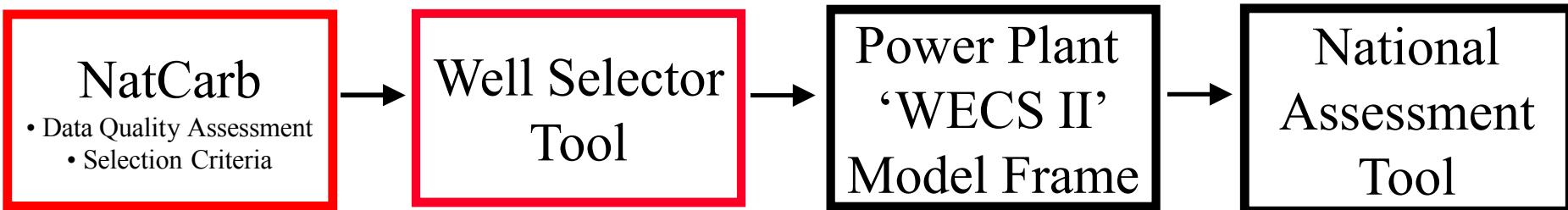
National-Level Modeling Effort:

Expanding beyond single regions into a larger, National-Level Modeling effort “WECS II”

Number of sources (power plants)

Number of CO ₂ sinks (saline formations)	One Source	Many Sources
One Sink	WECS project and model	
Many Sinks	Generic Power plant model	<p><u>Phase1:</u> National retrofit scenarios</p> <p><u>Phase2:</u> National retrofit and build scenarios</p> <p><u>Phase 3-5:</u> Refining the model for release</p>

WECS II: Progress Schematic



NatCarb well records query tool

Input criteria

Select NatCarb well records with the following criteria:
(Click on numbers in blue to change with keyboard, or use buttons for more options.)

Latitude (N): 25° to 71°

Longitude (E): -163° to -70°

Well depth (ft): 2,000' to 30,000'

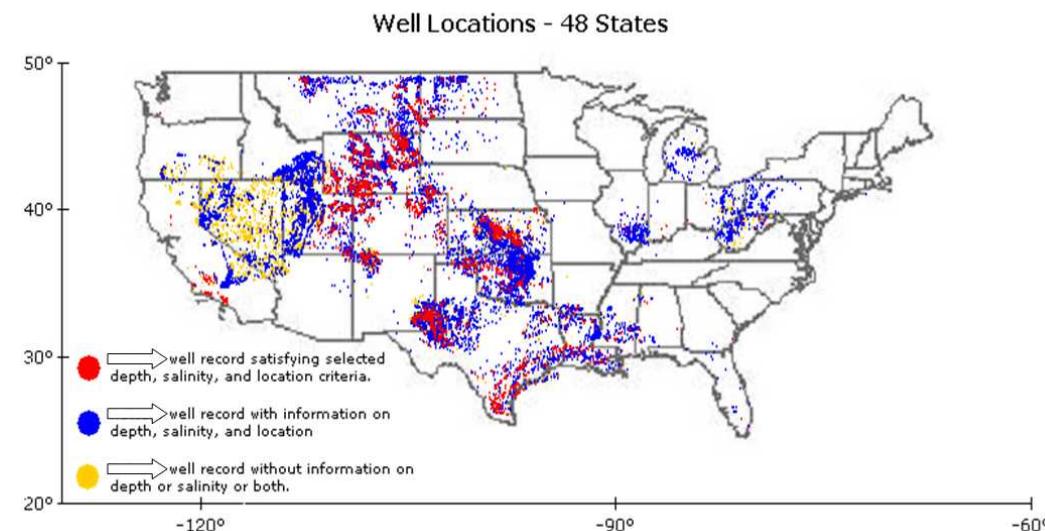
Water salinity (TDS): 10,000 ppm to 35,000 ppm

In 51 U.S. states (which can include D.C.)

Output

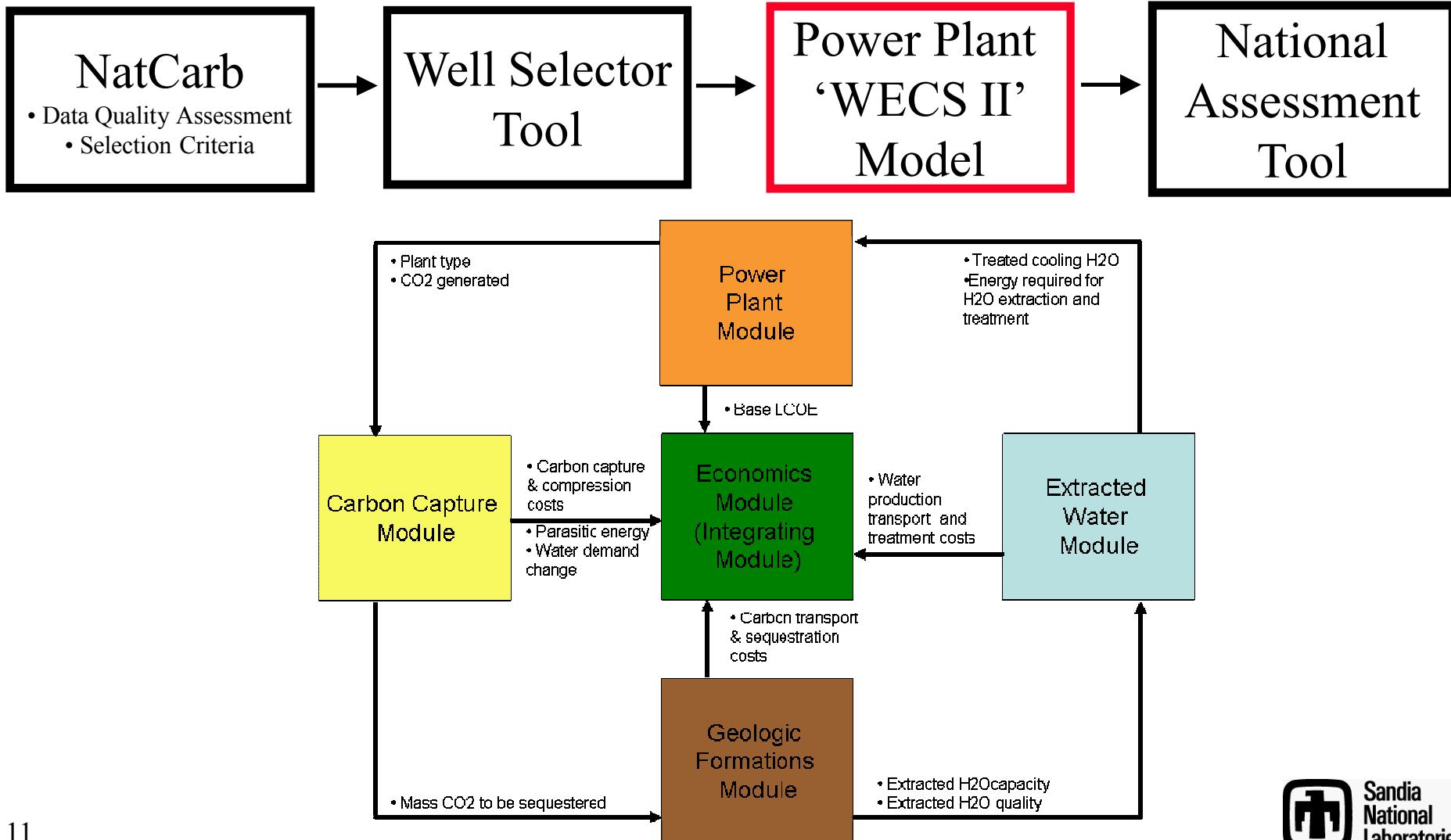
Statistics of wells satisfying input criteria:

- 10,949** well records fit selected criteria
- 9.2 %** of wells in selected area meet the depth and TDS criteria ([histograms](#))
- 8.8 %** of all NatCarb well records fit selected criteria
- 107,218** well records eliminated by TDS criteria
- 72,494** well records eliminated by depth criteria
- 5,983** well records eliminated by latitude/longitude criteria
- 0** well records eliminated by State location criteria
- 125,066** total unique NatCarb well records





WECS II: Progress Schematic



WECS II: Progress Schematic

Power plant generated carbon sequestration in saline formations
a dynamic analysis tool

Power Plant Specs:

Power Plant Type

- Pulverized coal subcritical
- Pulverized coal supercritical
- Integrated gasification combined cycle
- Natural gas turbine
- Natural gas combined cycle

Power Plant Location

(click #s to change) Latitude: 30° Longitude: -94°

Installed Capacity

0 1,000 2,000 3,000 4,000 MW

1,848 MW

Capacity Factor

0.0 0.2 0.4 0.6 0.8 1.0

0.72

CO2 Production Rate

<input checked="" type="radio"/> Use default:	1,900 lbs/MWh
<input type="radio"/> Use custom: (click # to change)	2,200 lbs/MWh

Default based on Exhibit ES-2 in NREL 2007/1281

Expected Year Online and Offline

	Start Yr	End Yr
<input checked="" type="radio"/> Existing plant	NA	2040
<input type="radio"/> New plant build (click # to change)	2010	2040

Cooling Technology

- Once through
- Cooling tower(s)
- Cooling pond(s)
- Dry cooling

Base Water Use Rates

	Withdrawal	Consumption
<input checked="" type="radio"/> Use default	670 gal/MWh	520 gal/MWh
<input type="radio"/> Use custom (click # to change)	670 gal/MWh	520 gal/MWh

Defaults based on Tables D-1 and D-4 of NREL 400/2008/1339, and Figure 4-2 and B-1 of NREL 402/080108

Power Plant
'WECS II'
Model

National
Assessment
Tool

Base Levelized Cost of Electricity (LCOE)

	Total	Fuel Costs	Cooling	All Other	\$ Year:
<input checked="" type="radio"/> Default:	6.7 cents/kWh	= 2.1 cents/kWh	+ 0.3 cents/kWh	+ 4.4 cents/kWh	2010
<input type="radio"/> Custom: (changeable)	6.4 cents/kWh	= 2 cents/kWh	+ 0.2 cents/kWh	+ 4.2 cents/kWh	2007

Defaults based on Exhibits ES-2, 3-29, 3-62, 3-95, 4-12, 4-33, 5-12 in NREL 2007/1281 and Figure 13 of Tawney, Khan, Zachary, Journal of Engineering for Gas Turbines and Power, April 2005, Vol. 127

Output

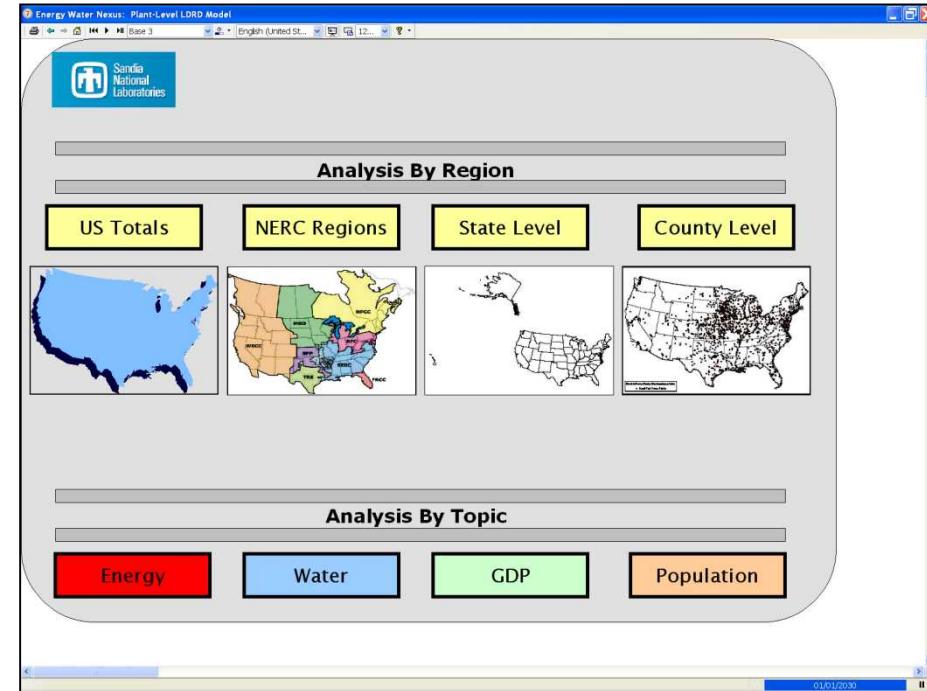
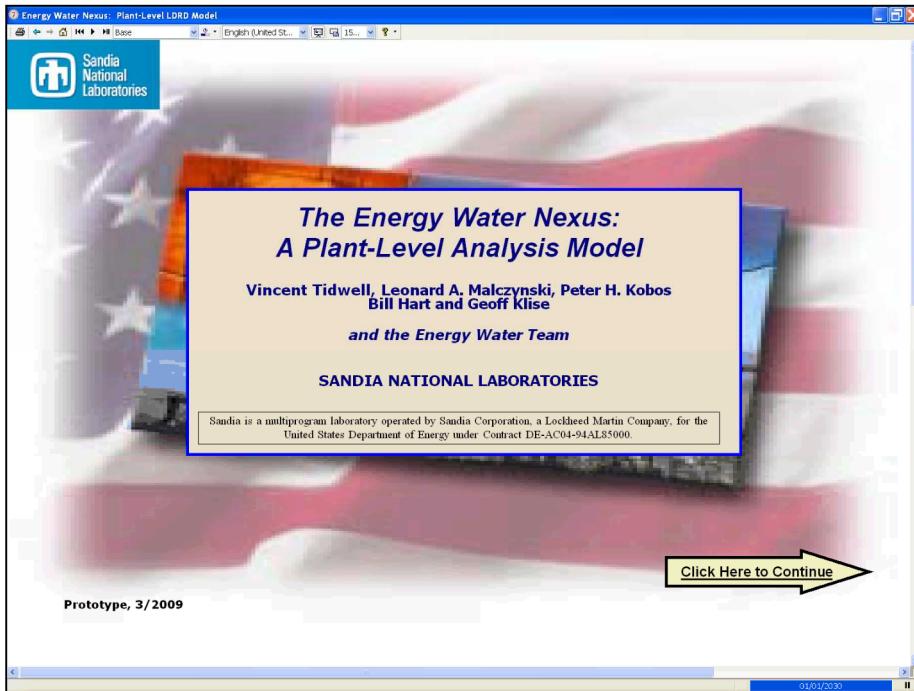
Annual electricity generation: 11.5 TWh/yr
Annual CO2 generation: 9.9 Mmt/yr
Annual H2O withdrawals: 7.7 billion gal/yr
Annual H2O consumption: 6 billion gal/yr

This plant would generate more electricity than 97 % of all plants in the U.S. in 2005.
This plant would generate more CO2 than 96 % of all plants in the U.S. in 2005.
This plant has a capacity greater than 96 % of all plants in the U.S. in 2005.
This plant has a capacity factor greater than 75 % of all plants in the U.S. in 2005.
This plant has a CO2 emission rate greater than 26 % of all plants in the U.S. in 2005.

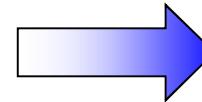
NETL

Background and Documentation

Integrated Water-Energy Planning: Energy, Power and Water Simulation Model (EPWSim)



Integrated Water-Energy Planning:
“Plant-Level Analysis Model”



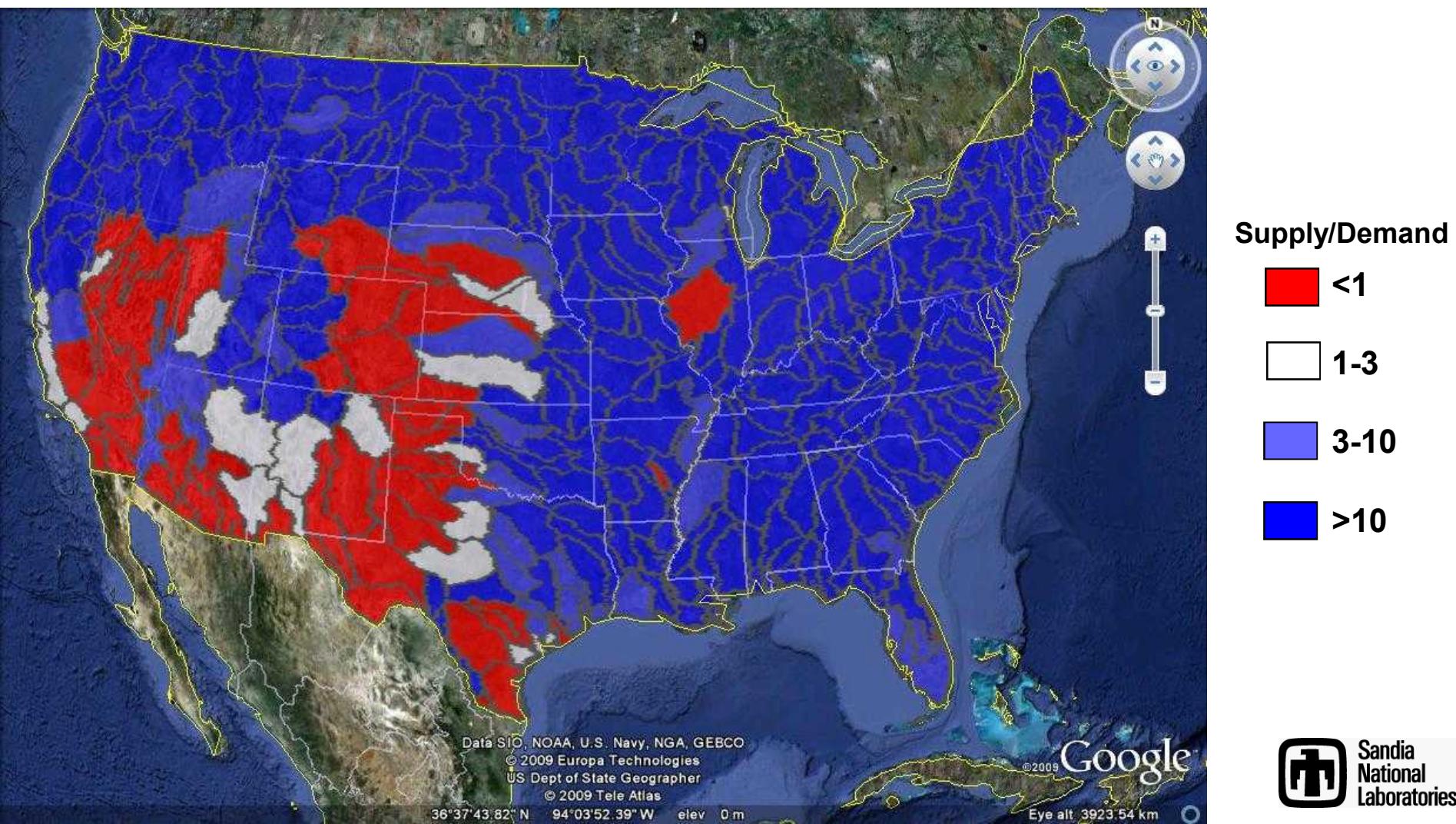
Water Demand by Sector

- *Summaries and Detail: from the National Level to the Power Plant*
- *GDP, Population Growth Changes*
- *Technology Deployment Scenarios*

Exploring the Energy-Water Nexus:

Ratio of Sustainable Recharge to Groundwater Demand

- National to Local Watersheds
- Availability of Uncommitted Water
- Energy & Water Issues





Energy, Water and CO₂:

*Using Integrated Assessment Modeling for Performance Mapping
and Collaborative Scenario Development*

Thank You

April 2010