

# ***The Water, Energy and Carbon Sequestration Simulation Model (WECSsim<sup>©</sup>): Using System Dynamics for CO<sub>2</sub> Management & Planning***

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2012 Carbon Sequestration Partnership Water Working Group (WWG)  
*WECSsim project supported by the National Energy Technology Laboratory*

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# Water, Energy and CO<sub>2</sub> Sequestration (WECS) Model:

**(4) H<sub>2</sub>O Treatment & Use**



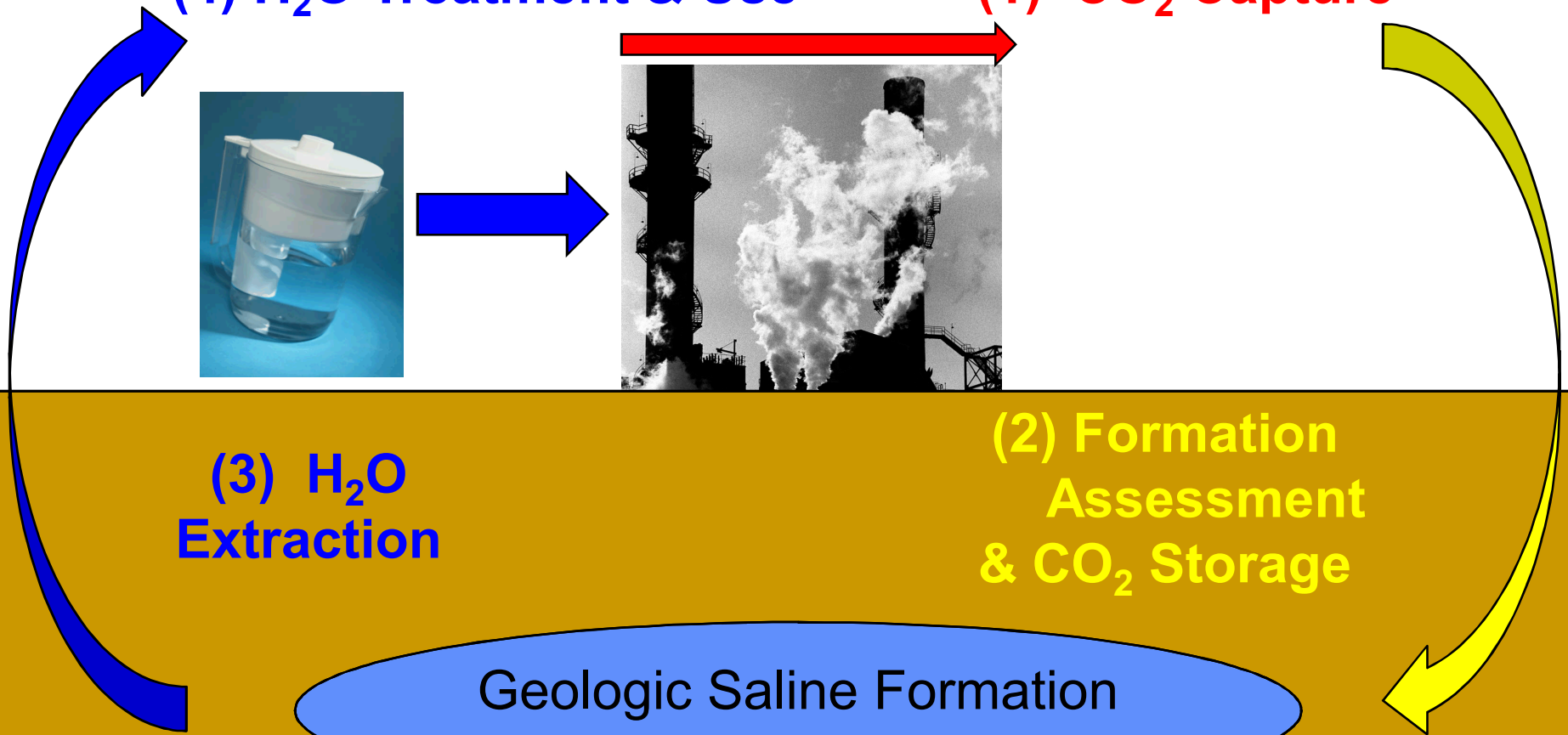
**(1) CO<sub>2</sub> Capture**



**(2) Formation Assessment & CO<sub>2</sub> Storage**

**(3) H<sub>2</sub>O Extraction**

Geologic Saline Formation



# WECSsim Modular Structure

- Plant type
- CO<sub>2</sub> generated

WECSsim - a dynamic analysis tool

Module Input Summary

Specify a Power Plant (Existing or Hypothetical):

Plant Type & Specific Plant  
 # PowerGen Gas  
 AL - Barry  
 # SSCC  
 FL - Polk  
 # NGCC  
 AL - Enbridge Mobile Bay Onshore  
 # Gas Turbine  
 AL - ABC Coke  
 # Hypothetical

Plant type  
 Capacity & Capacity Factor  
 2,675 MW  
 0.6239

CO<sub>2</sub> Generation Rate  
 1,879 lb/MWh

Latitude - Longitude  
 Lat 31°12'24.8" Long -89°0'37.1"

## Power Plant Module

- Treated cooling H<sub>2</sub>O
- Energy required for H<sub>2</sub>O extraction and treatment

- Base LCOE

WECSsim - a dynamic analysis tool

Module Input Summary

Carbon Capture Module Inputs Summary

Plant Type (Pulverized coal subcritical)  
 % Base CO<sub>2</sub> Captured (CC)  
 95 %  
 Water withdrawal demand specific to CC & compression  
 298 gal/tonne CC  
 Make-up Power (MUP) Plant Type  
 PC-Sub  
 MUP CO<sub>2</sub> Production Rate  
 5,800 lb/MWh  
 % MUP CO<sub>2</sub> Captured  
 95 %  
 MUP LCOE  
 13.1 cents/kWh  
 MUP Plant Cooling Type  
 Cooling tower  
 MUP water withdrawal rate  
 20 MGD

## CO<sub>2</sub> Capture Module

- Carbon capture & compression costs
- Parasitic energy
- Water demand change

WECSsim - a dynamic analysis tool

Module Input Summary

CCS Costs Summary Values

Power Plant Capitalization Factor  
 8.52 \$/kW  
 Saline Formation Capitalization Factor  
 8.52 \$/kW  
 Base LCOE at Plant  
 5.65 cents/kWh  
 Make-up Power LCOE  
 13.1 cents/kWh  
 CCS Costs - Select  
 7 cents/kWh  
 CCS Costs - Select  
 7 cents/kWh  
 CO<sub>2</sub> Pipeline Costs  
 0.44 cents/kWh  
 CO<sub>2</sub> Injection Well Costs  
 0.1 cents/kWh  
 H<sub>2</sub>O Extraction Well Costs  
 0.44 cents/kWh  
 H<sub>2</sub>O Pipeline Costs  
 0.13 cents/kWh  
 H<sub>2</sub>O Treatment Costs  
 0.13 cents/kWh  
 Brine Disposal Costs  
 0.13 cents/kWh

## Power Costs Module

- Carbon transport & sequestration costs

WECSsim - a dynamic analysis tool

Module Input Summary

Carbon Storage Target (NatCarb Partnership - Basin - Formation)  
 SECARB - Tuscaloosa Group - Tuscaloosa Group

Formation Centroid  
 31°41'3" N -89°53'55" W  
 Formation footprint area  
 120,490 km<sup>2</sup>  
 Formation depth  
 3,453 ft  
 Formation thickness  
 153 ft  
 Formation average porosity  
 0.23  
 Formation geometric mean permeability  
 1.9 mD  
 Formation temperature  
 44°C  
 Formation pressure  
 111.6 bar

## CO<sub>2</sub> Storage Module

- Mass CO<sub>2</sub> to be sequestered

- Extracted H<sub>2</sub>O capacity
- Extracted H<sub>2</sub>O quality

WECSsim - a dynamic analysis tool

Module Input Summary

Quantity & Quality

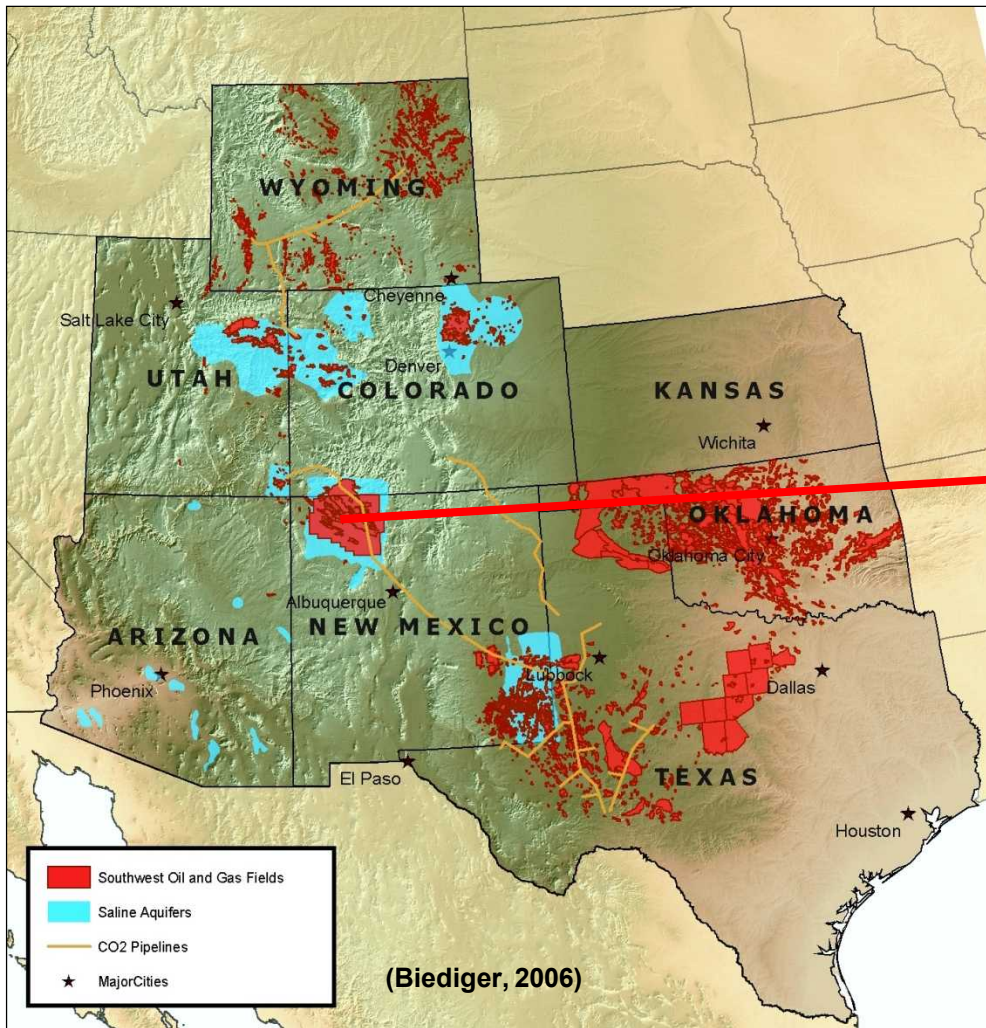
Extraction Wells  
 Water Treatment  
 Brine Disposal

Extracted Water Module Inputs Summary

Saline formation targeted  
 SECARB - Tuscaloosa Group - Tuscaloosa Group  
 Deep saline water extraction rate  
 16.03 MGD  
 Number of extraction wells  
 32  
 Extraction depth  
 2500 to 5000 ft  
 Minimum salinity threshold  
 10 ppt  
 Maximum salinity threshold  
 20 ppt  
 Average salinity of extracted water  
 21 ppt  
 Treated water stream  
 9.79 MGD  
 % new (CCS) H<sub>2</sub>O demands met  
 49 %  
 Brine disposal method  
 transport & dump

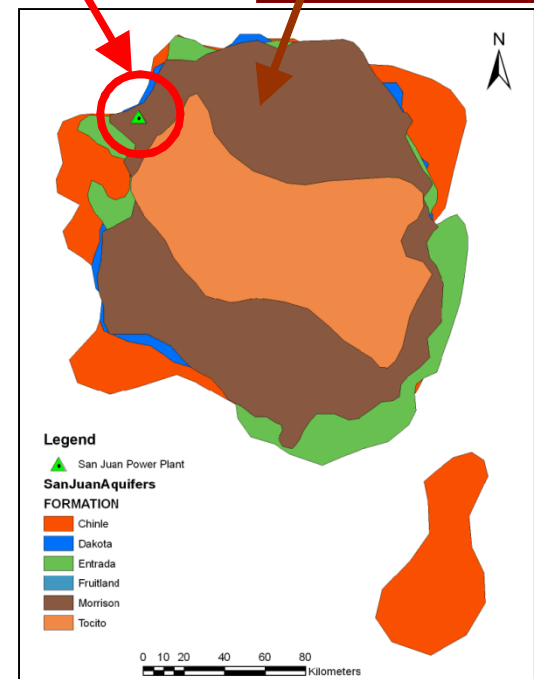
## H<sub>2</sub>O Extraction Module

# The San Juan Power Plant and Morrison Formation

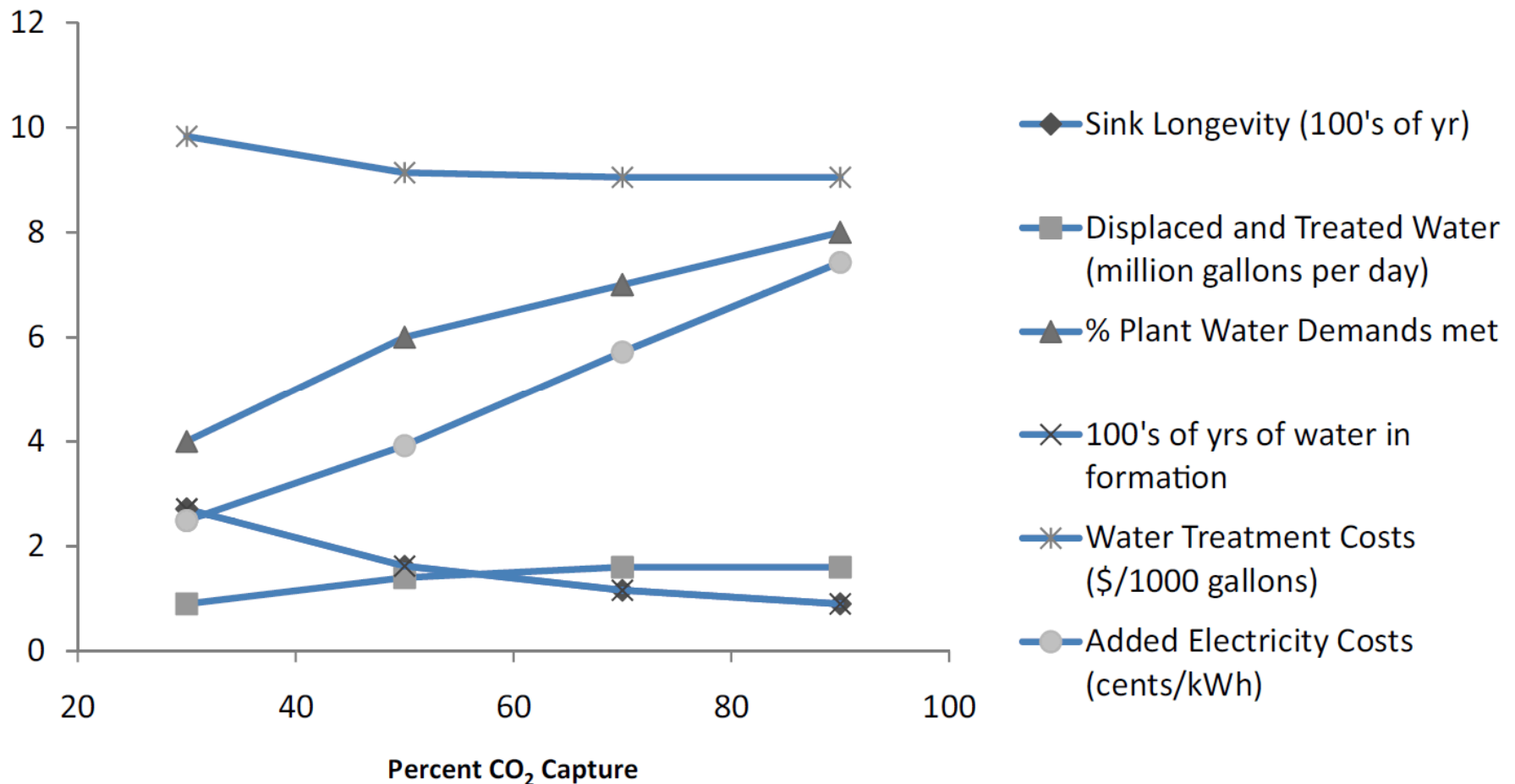


San Juan Power Plant

Morrison Formation

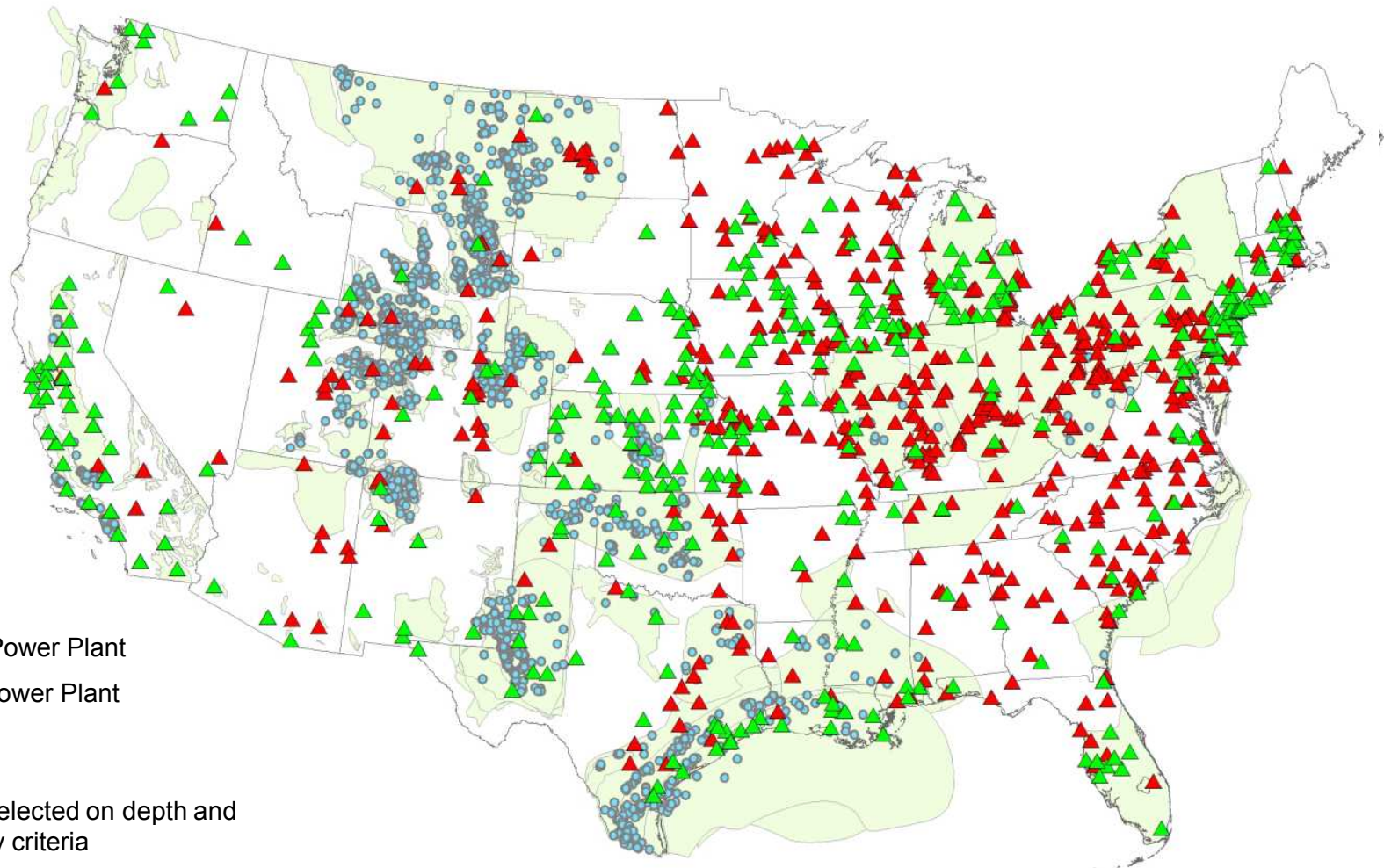


# Single Power Plant to Single Geologic Storage Site



Source: Kobos et al., 2011, Combining power plant water needs and carbon dioxide storage using saline formations: Implications for carbon dioxide and water management policies, *International Journal of Greenhouse Gas Control*, 5, 899-910.

# Geological CO<sub>2</sub> Storage Database Challenges



Coal Power Plant



Gas Power Plant



Well

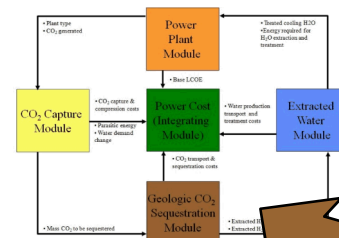
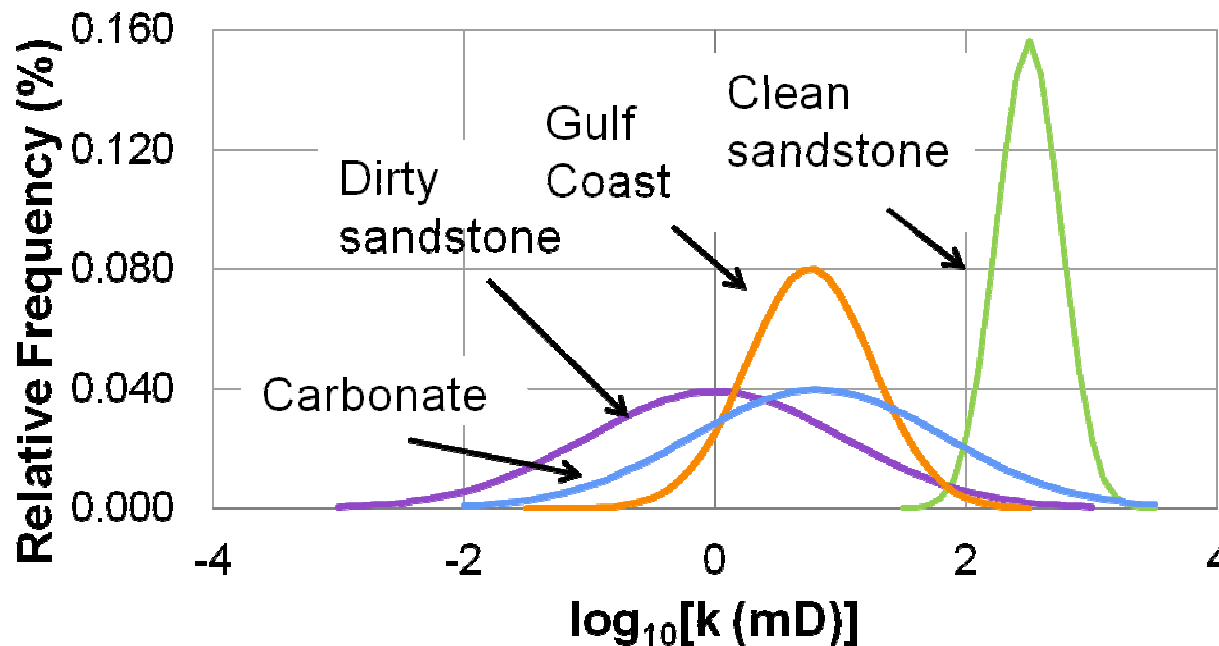


Well selected on depth and  
salinity criteria

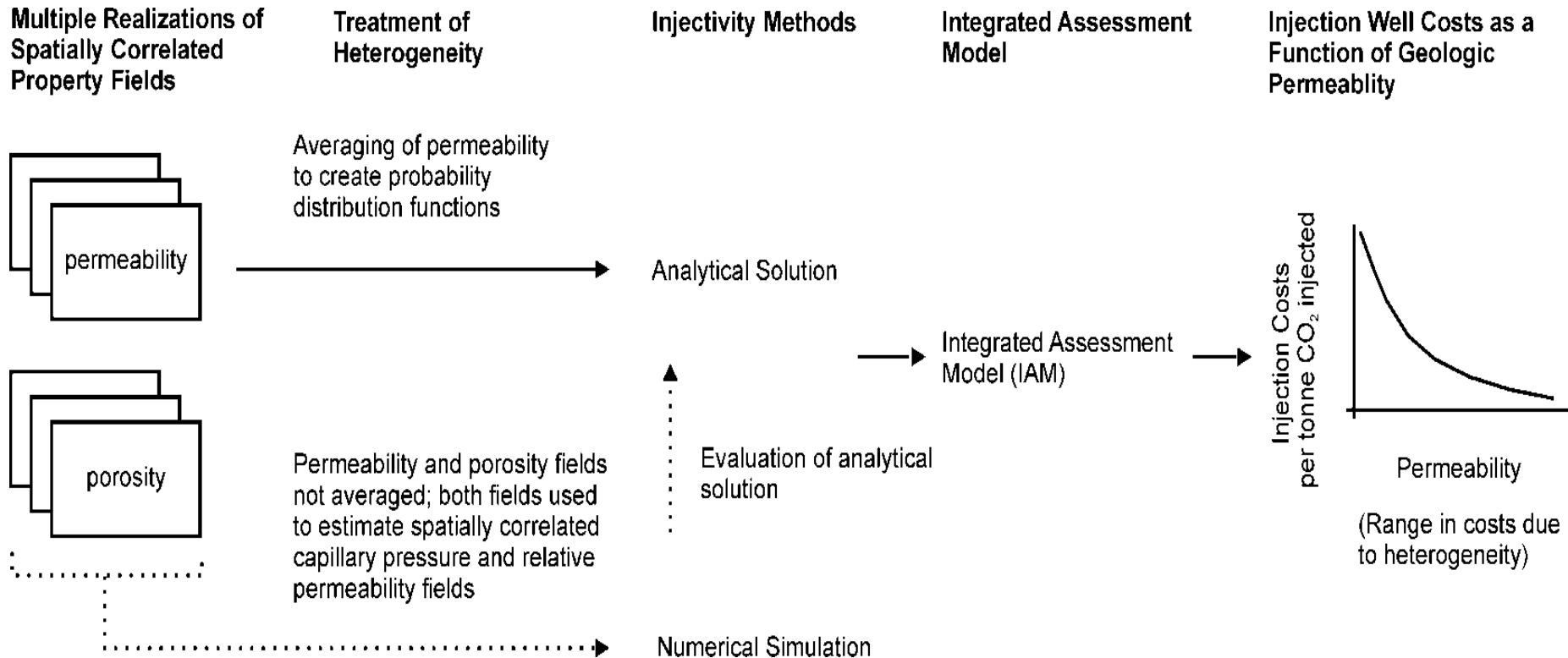
325 down selected regions  
original NatCarb Atlas data



### Injectivity equation: permeability sampled from 4 Rock Types



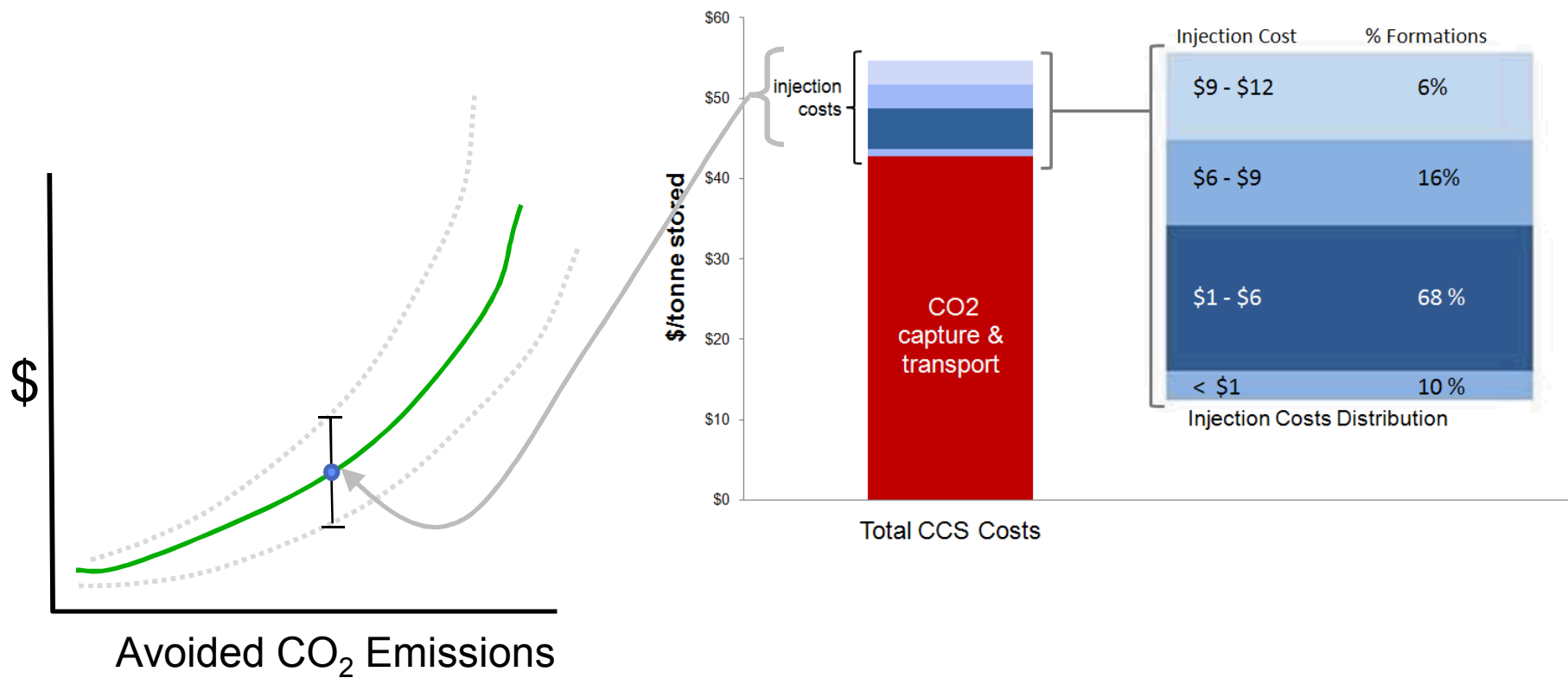
# Methods behind the Permeability-to-Cost Analysis



Source: Heath, J.E., Kobos, P.H., Roach, J.D., Dewers, T.A. and S.A. McKenna, 2012, "Geologic Heterogeneity and Economic Uncertainty of Subsurface Carbon Dioxide Storage," *SPE Economics & Management Journal*, January 32-41.

# WECSsim Results:

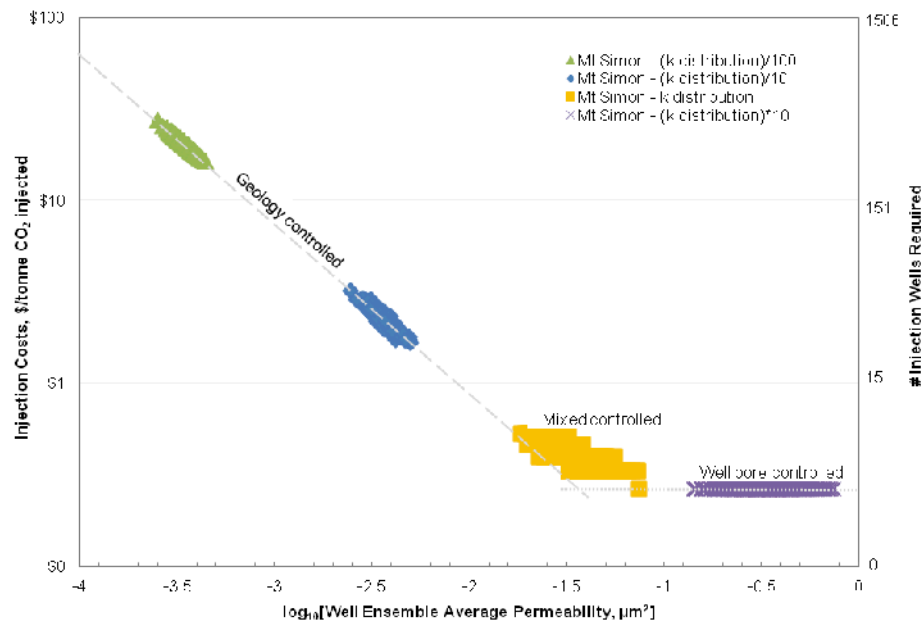
## *Similar Full Economic Analysis Underway*



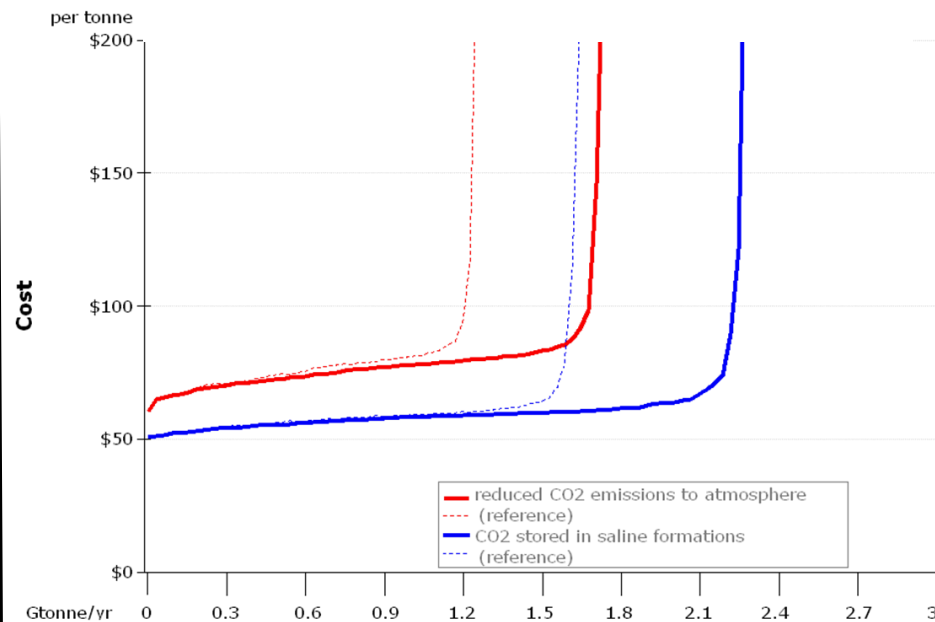
**Note: Illustrative Example at this time**

# Cost Drivers & Supply Curve: *Interactive CO<sub>2</sub> Storage Analysis*

Permeability ↑ = Well Costs ↓



## Developing a National, CO<sub>2</sub> Storage Supply Curve





# Key Messages

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## Framework for National Level Assessment

- Cost of CCS from any U.S. fossil fuel power plant to any deep saline formation
- Site-specific nature of geologic data challenge

## Impact of Geologic Uncertainty on Costs

- Low injectivity requires more injection wells and therefore higher costs
- High permeability reservoirs with low injection costs (< \$1/tonne) represent < ~10% of the 325 formations
- Scale-up challenge
- EOR adds value to CO<sub>2</sub> storage through utilization



# ***The Water, Energy and Carbon Sequestration Simulation Model (WECSsim)***

***Thank you.***

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WECSsim: a dynamic analysis tool

Summary

Power  
Plant

CO<sub>2</sub>  
Capture

Carbon  
Sequestration

Extracted  
Water

Power  
Costs



Sandia  
National  
Laboratories



## ***The National Water, Energy and Carbon Sequestration Simulation (WECSsim) Model***

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Evaluate a single  
powerplant

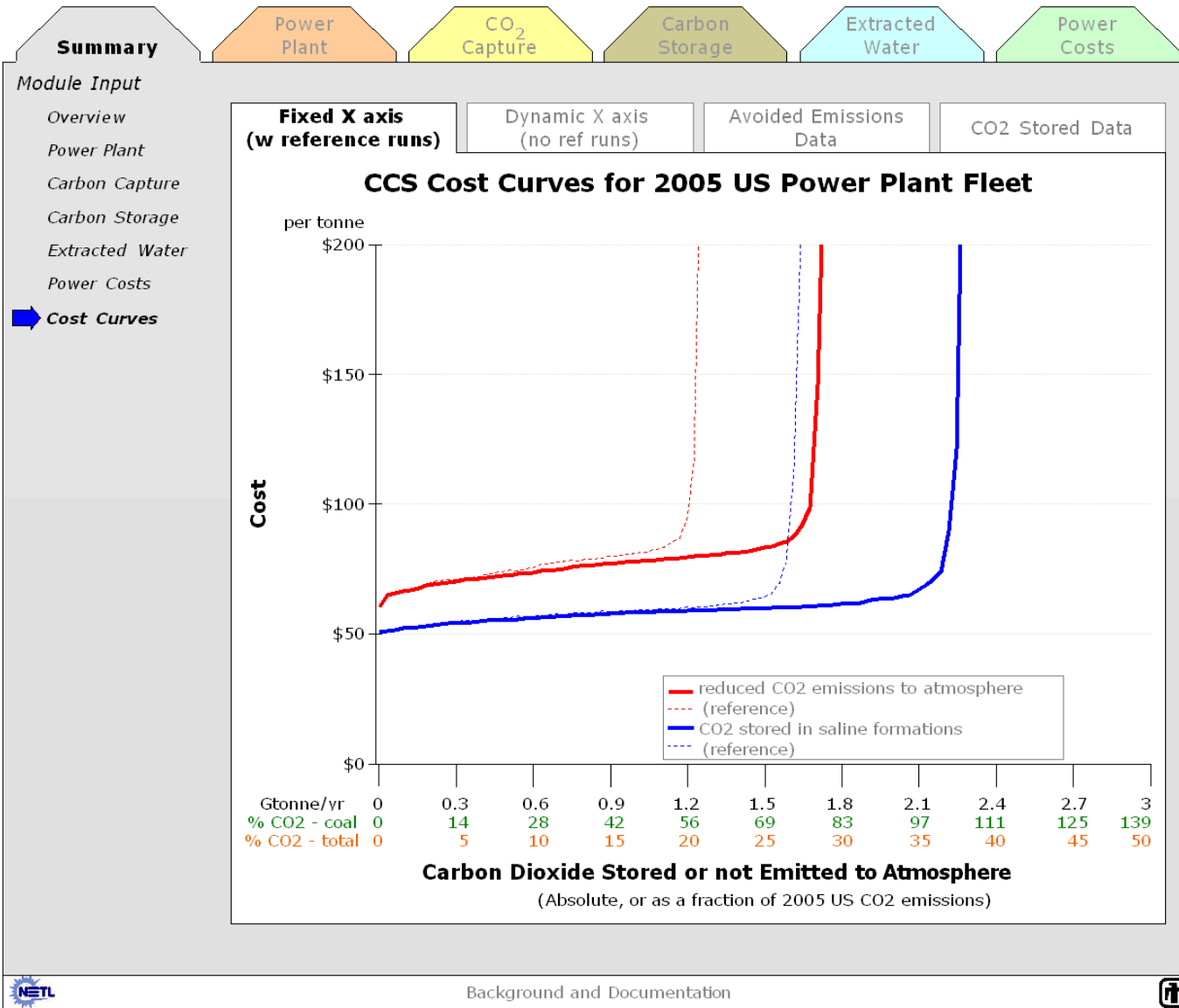
Evaluate 2005 U.S.  
powerplant fleet

**Version 1.0, September 2011; Working Version, as of 2/2012.**



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WECSsim: a dynamic analysis tool



Illustrative, working results, 2/2012.