SAND2014-3487P

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

Integrating Geoscience, Power Plants and CO_2 Sequestration Infrastructure in the U.S.

Peter H. Kobos,

David J. Borns, Geoff T. Klise, Jason E. Heath, Len A. Malczynski,

and many others

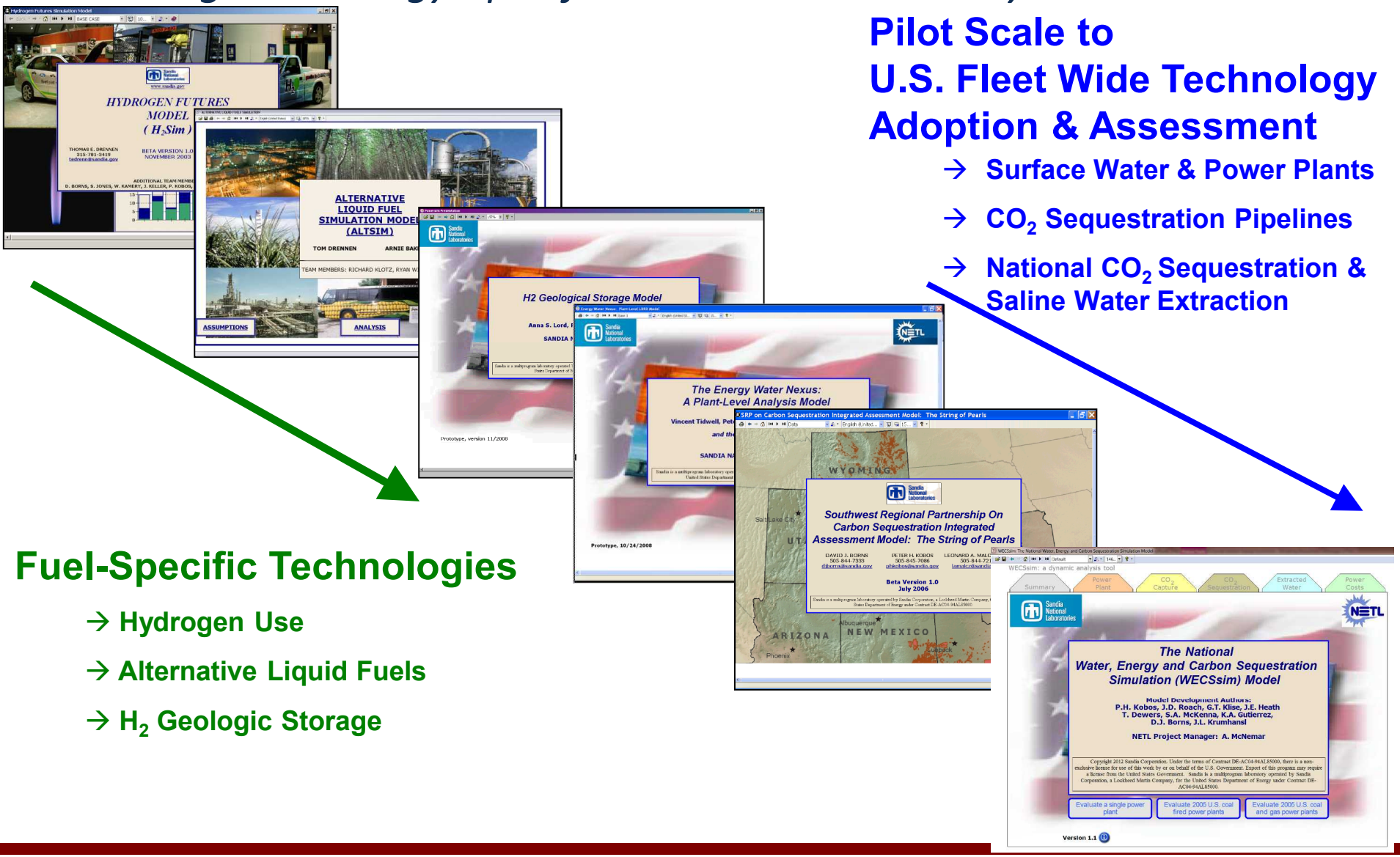
U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.
Thanks go to Jesse D. Roach for his contributions to WECSsim and NETL for their support. Working Results.

Integrated Assessment Models:

Addressing Technology-Specific and Fleet-Wide Analysis



Pilot Scale to U.S. Fleet Wide Technology Adoption & Assessment

- → Surface Water & Power Plants
- → CO_2 Sequestration Pipelines
- → National CO_2 Sequestration & Saline Water Extraction

Fuel-Specific Technologies

- → Hydrogen Use
- → Alternative Liquid Fuels
- → H_2 Geologic Storage

Water, Energy and CO_2 Sequestration Simulation Model (WECSsim) Model:

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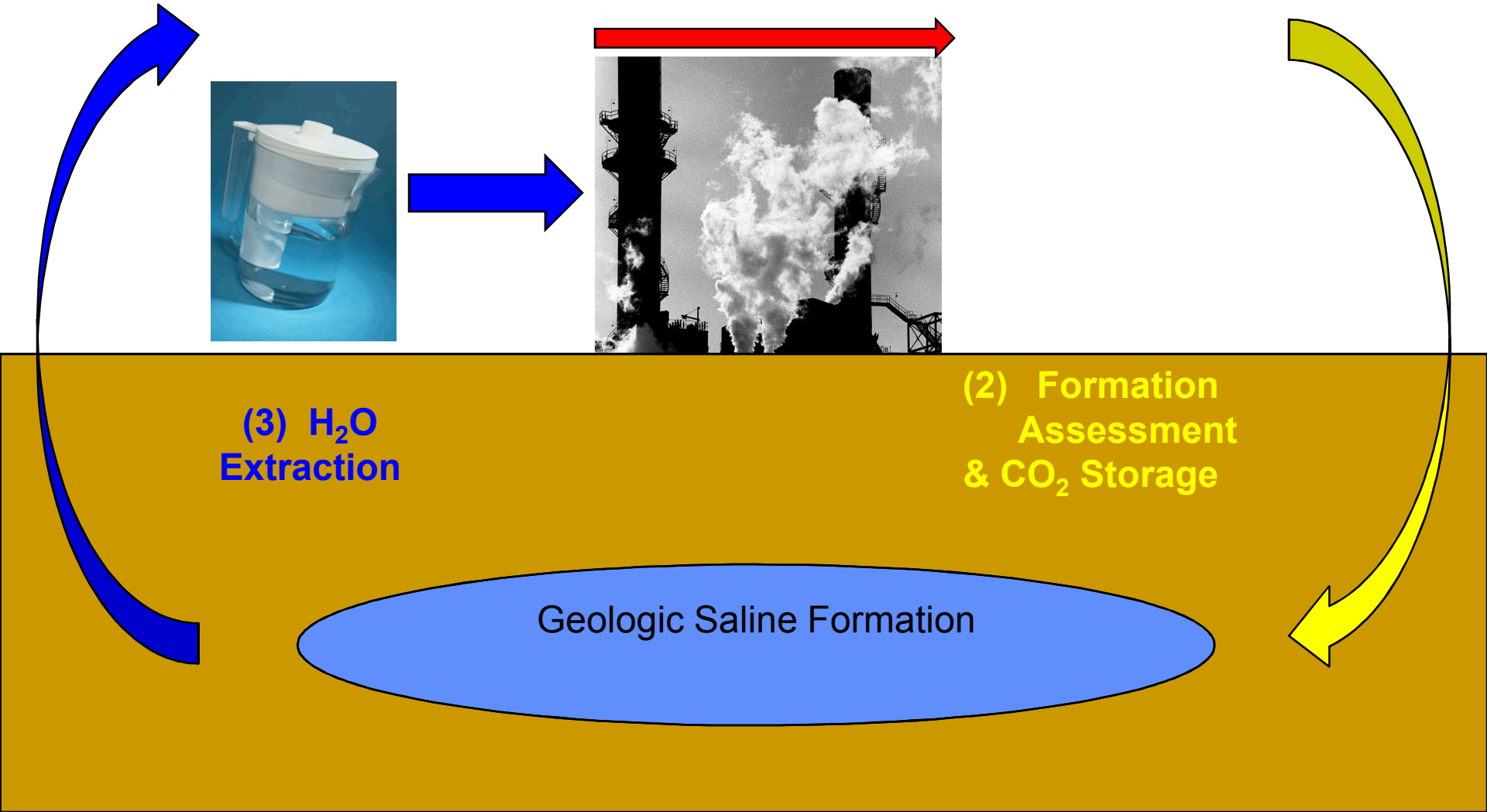

CO_2 Storage Systems Modeling (U.S.)

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- Power Plant Technologies
  - Coal and Natural Gas Electricity
    - Retrofit CO_2 Capture Technology
    - More efficient future water cooling technologies
- CO_2 Sinks
  - U.S. Department of Energy NatCarb Database
  - Geologic Storage sites (large focus on geologic saline aquifers)
- Geomodeling
  - TOUGH2 integrated within WECSsim
  - Probability Distribution Functions
- Pipeline network development
  - Cost reductions
  - Competition for Sinks

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NETL

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

Model Development Authors:
P.H. Kobos, J.D. Roach, G.T. Klise, J.E. Heath
T. Dewers, S.A. McKenna, K.A. Gutierrez,
D.J. Borns, J.L. Krumhansl

NETL Project Manager: A. McNemar

Evaluate a single power plant | Evaluate 2005 U.S. coal fired power plants | Evaluate 2005 U.S. coal and gas power plants

Version 1.1

WECSsim Modular Structure

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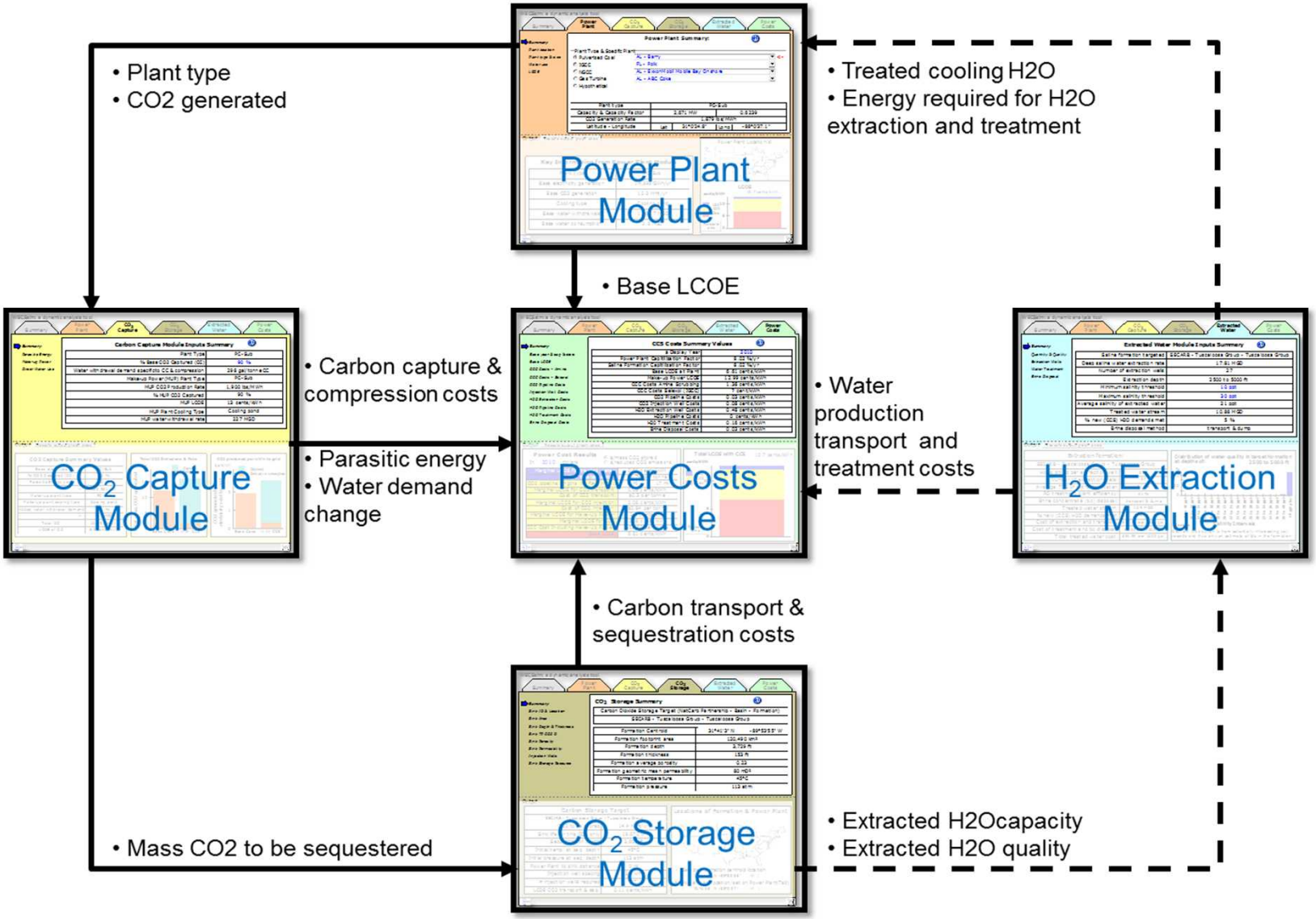

U.S. CO_2 Saline Formation Sinks

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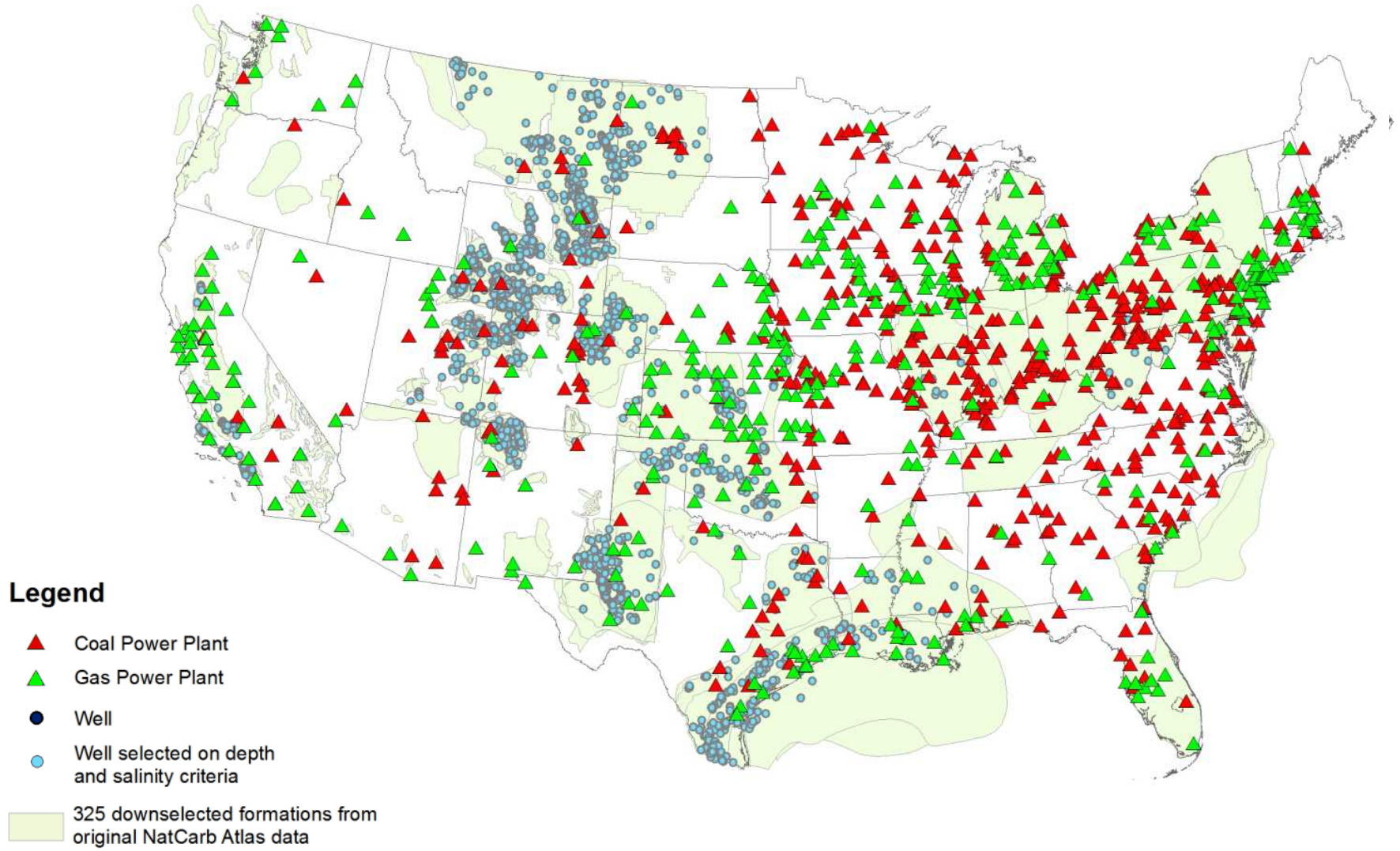
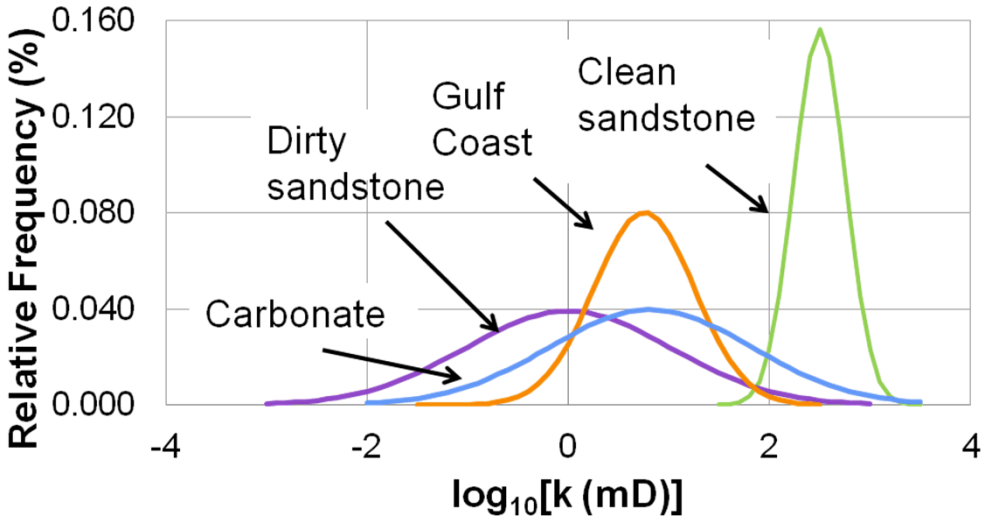


Methods behind the Permeability-to-Cost Analysis

Injectivity equation: permeability sampled from 4 Rock Types
(all storage targets defined as some mixture of these 4 Rock Types)

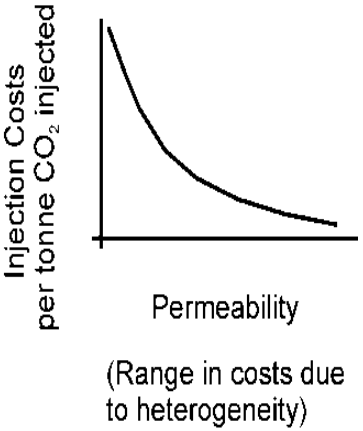


Integrated Assessment Model

Integrated Assessment Model (IAM)

(WECSsim)

Injection Well Costs as a Function of Geologic Permeablity



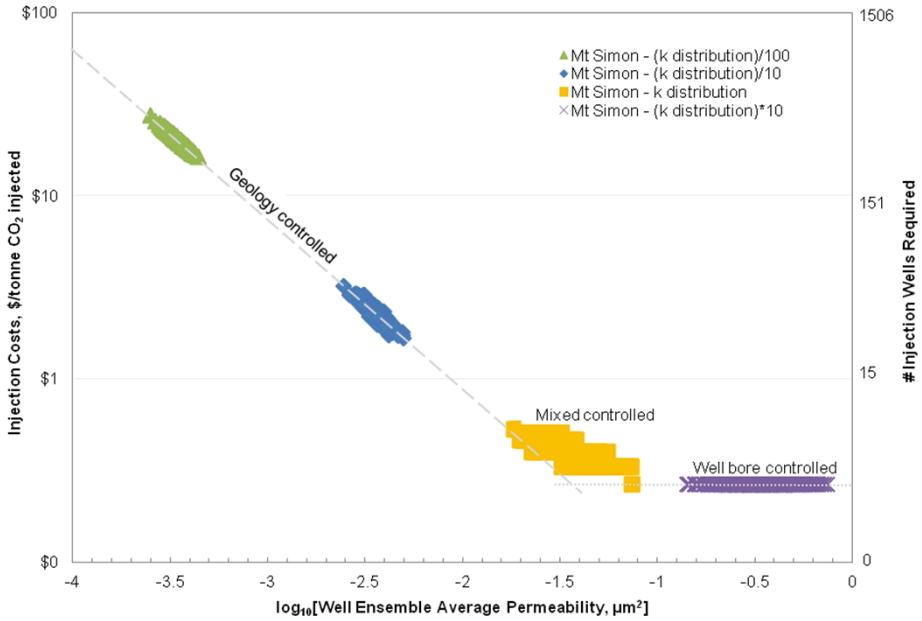
(Range in costs due to heterogeneity)

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.

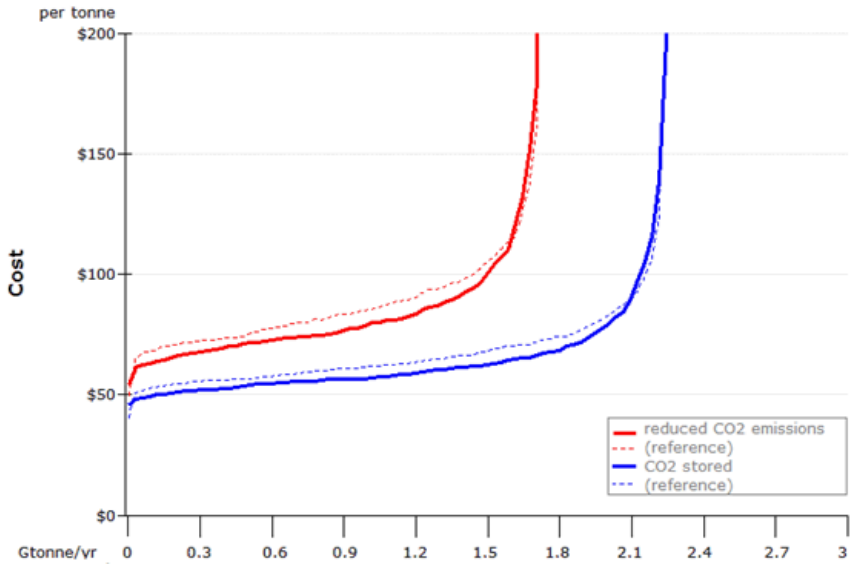
Cost Drivers & Supply Curve:

Combining TOUGH2 Geotechnical Modeling & System Cost Modeling

Permeability ↑ = Well Costs ↓



Developing a National, CO_2 Storage Supply Curve



Adapted from 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.

Uncertainty Analysis: *Geology, Water & Costs*

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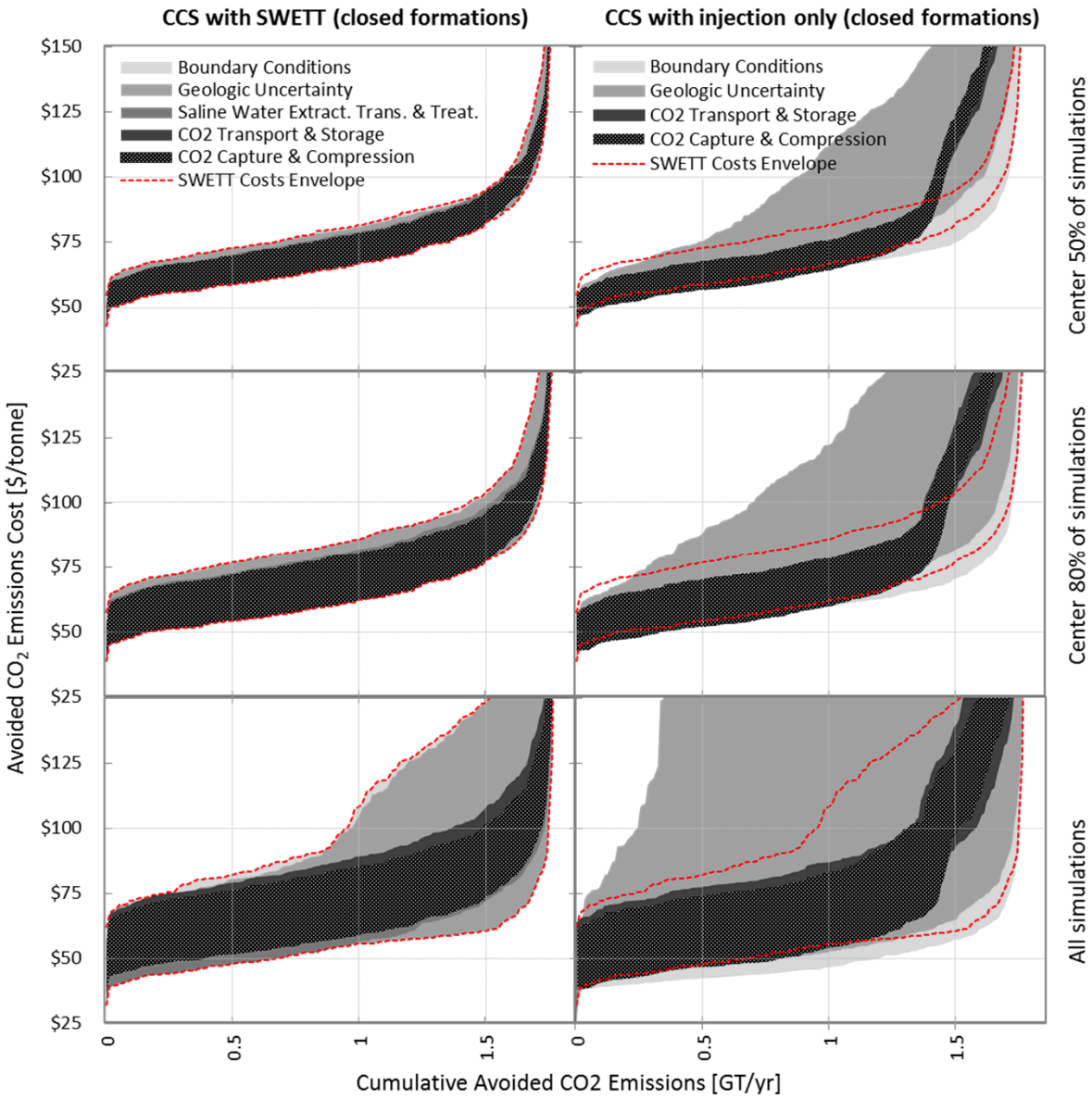
Saline Water Extraction Transport and Treatment (SWETT):

- Reduces Geologic Uncertainty
- Improves Cost Envelope Certainty
- Provides Cooling Water for Power Plants



Source: Roach, J.D., Heath, J.E, Kobos, P.H. and G.T. Klise, *in press*, System-level benefits of Extracting and treating saline water from geologic formations during national-scale carbon capture and storage, *International Journal of Greenhouse Gas Control*, DOI: 10.1016/4.ijggc.2014.04.012.

Power Plant Cooling Requirements:
SWETT can offset new water demands from CCS

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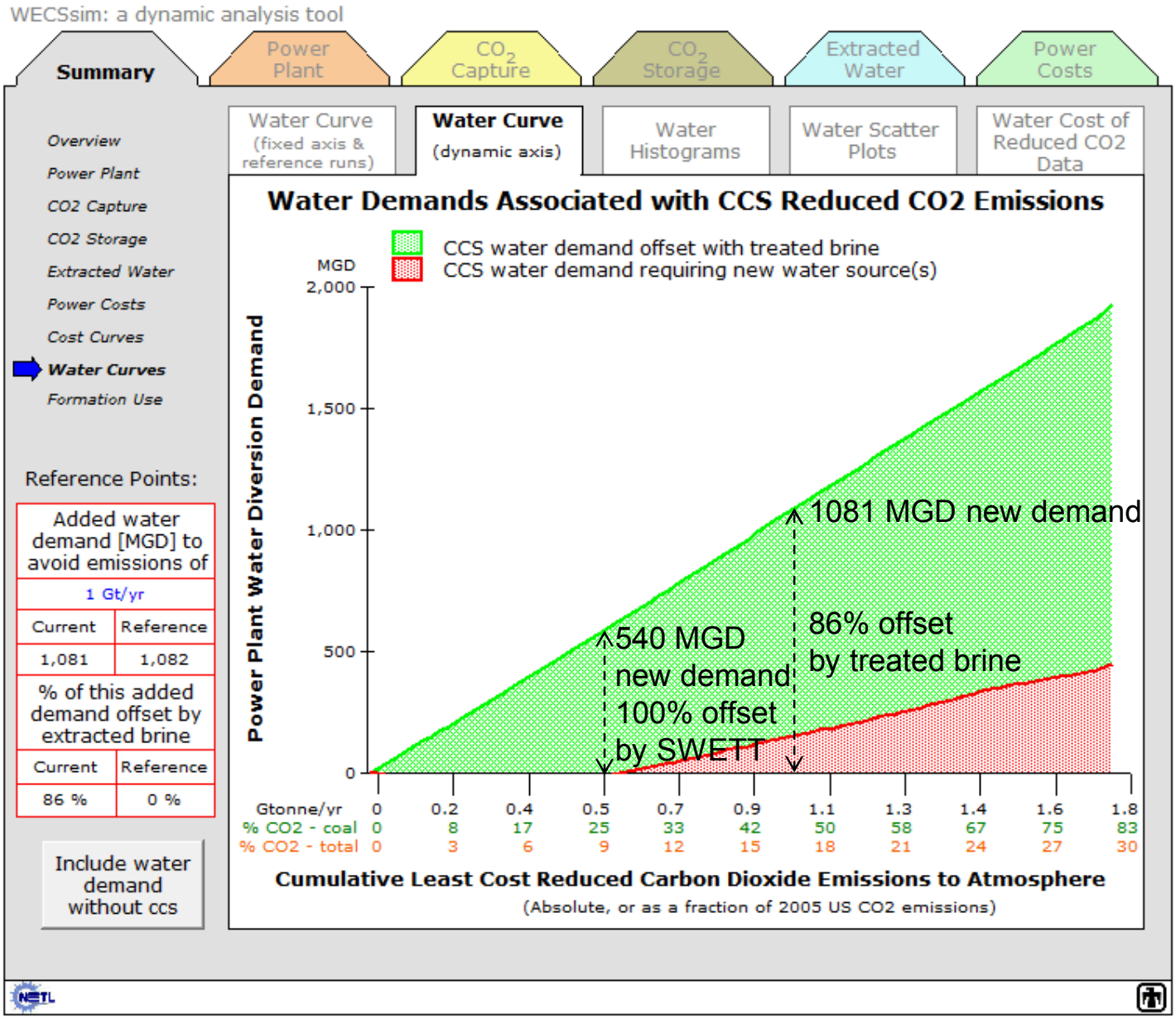
At 1 Gt/yr reduced emissions, SWETT offsets 86% of the 1081 MGD new demand

SWETT offsets all new water demands up to 0.5 Gt/yr reduced emissions

(Scenario assumes NGCC MUP cooled with towers)



Power Plant Capture & Formation Storage:

SWETT Increases Efficiency of Storage Space Use

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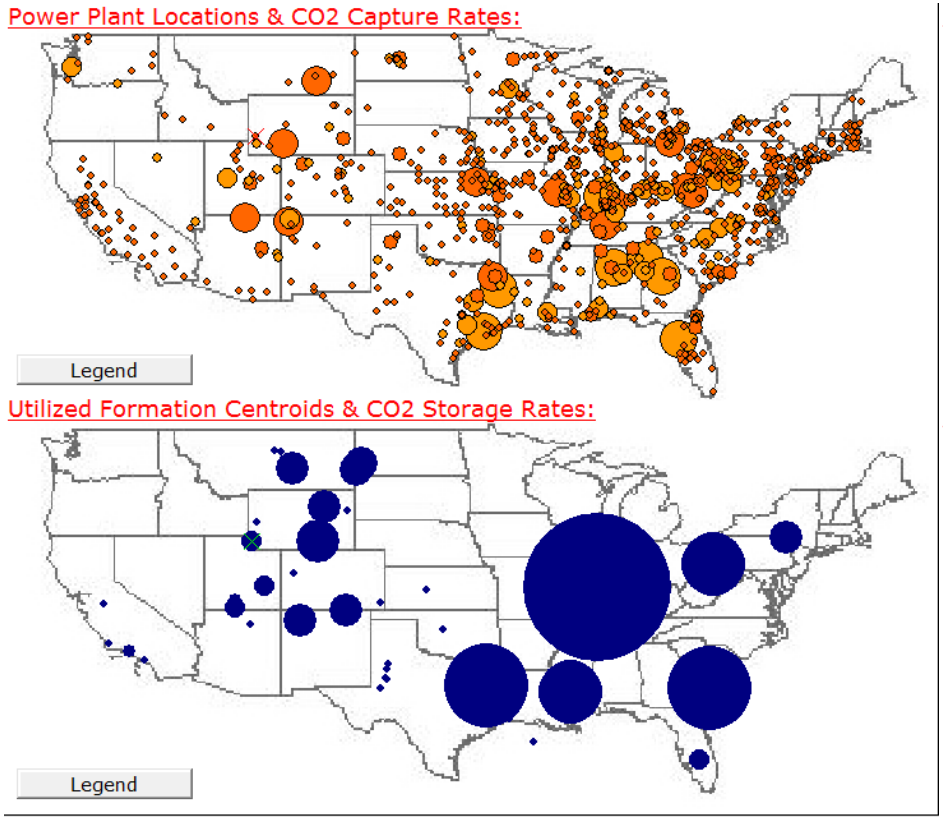
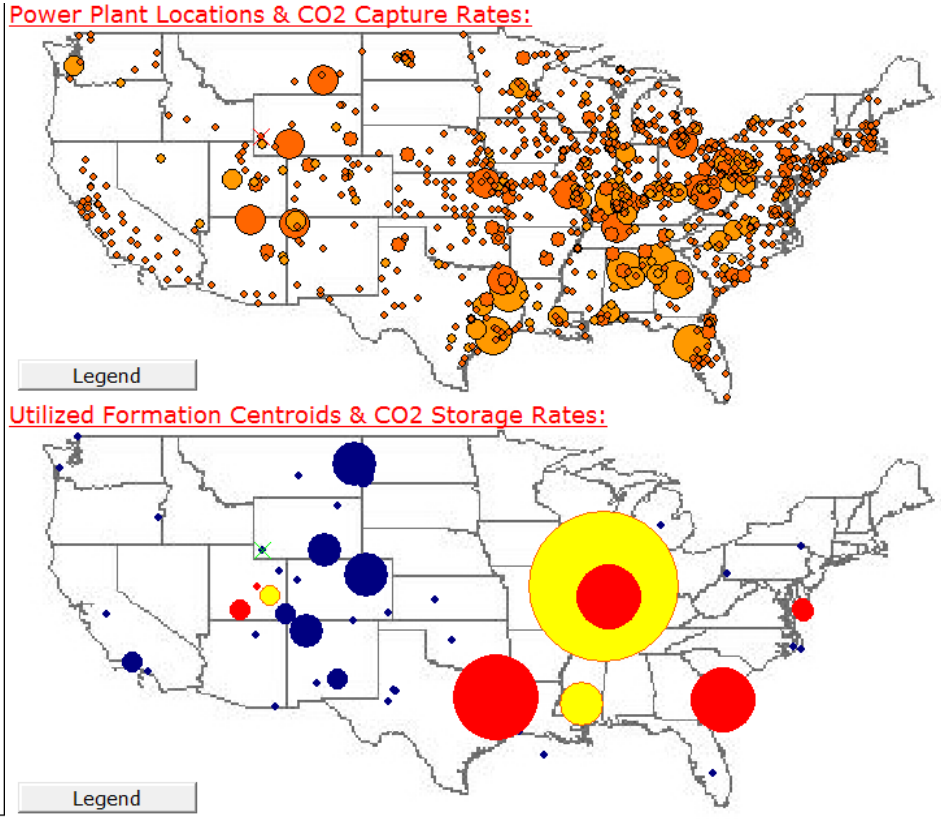
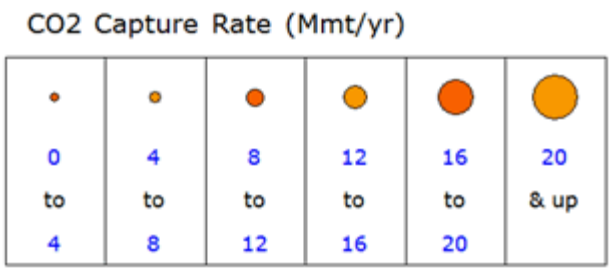
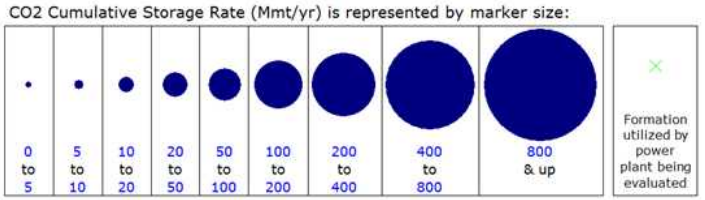
With CO_2 injection & SWETT

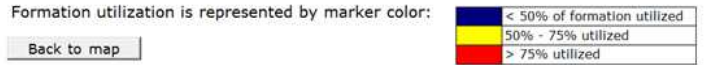


With CO_2 injection only









The Top 5 Saline Formations in the Lower U.S.: *storage potential*

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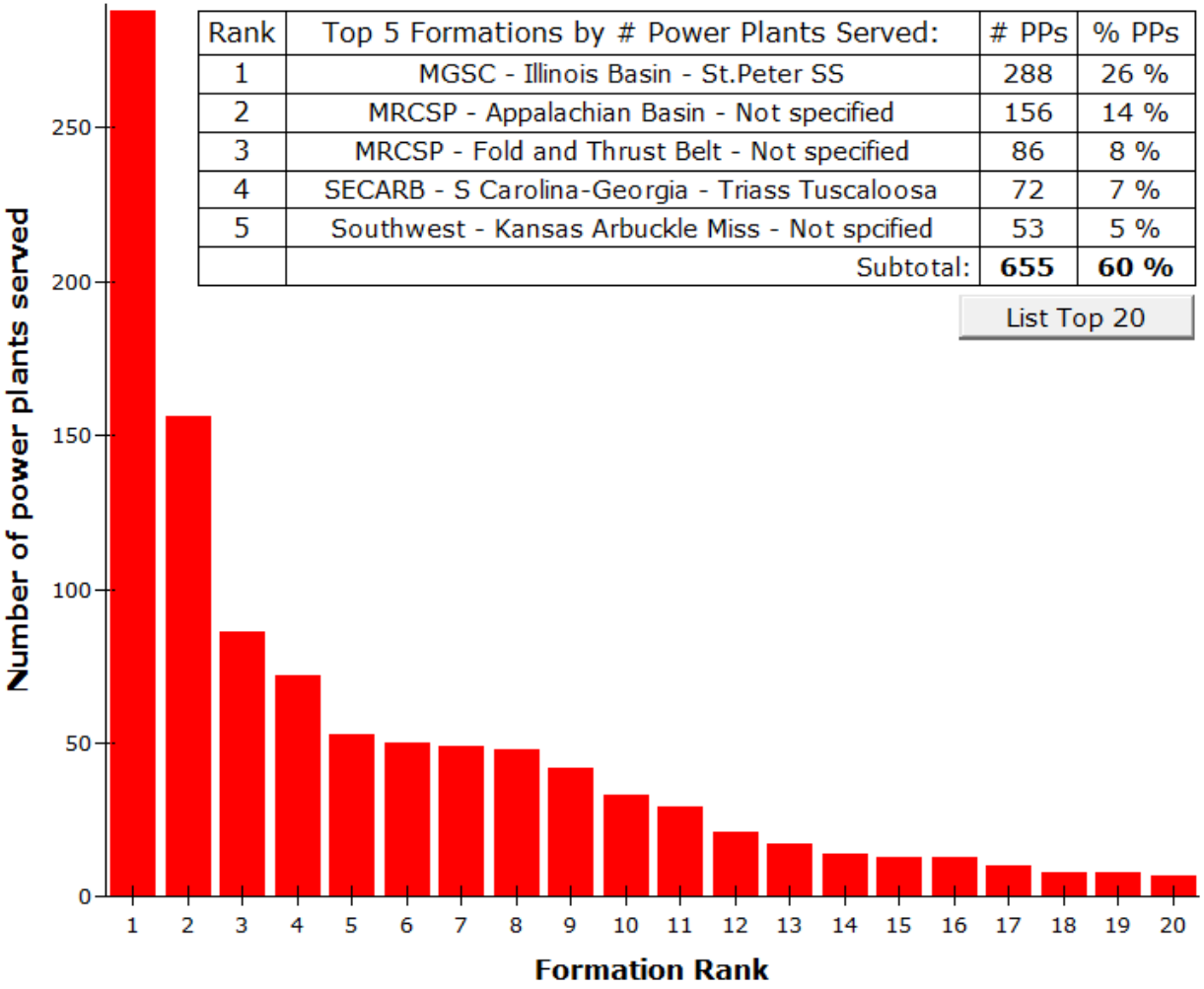
- Top 5 formations may hold 60% of CO_2 emissions
- Over 25% storage in St. Peter Sandstone or Mt. Simon (w/o SWETT)*
- Large(r) and more favorable storage formations may face competition for the best 'supply' of storage space

Rank	Top 5 Formations by # Power Plants Served:	# PPs	% PPs
1	MGSC - Illinois Basin - St.Peter SS	288	26 %
2	MRCSP - Appalachian Basin - Not specified	156	14 %
3	MRCSP - Fold and Thrust Belt - Not specified	86	8 %
4	SECARB - S Carolina-Georgia - Triass Tuscaloosa	72	7 %
5	Southwest - Kansas Arbuckle Miss - Not spcified	53	5 %
	Subtotal:	**655**	**60 %**

List Top 20



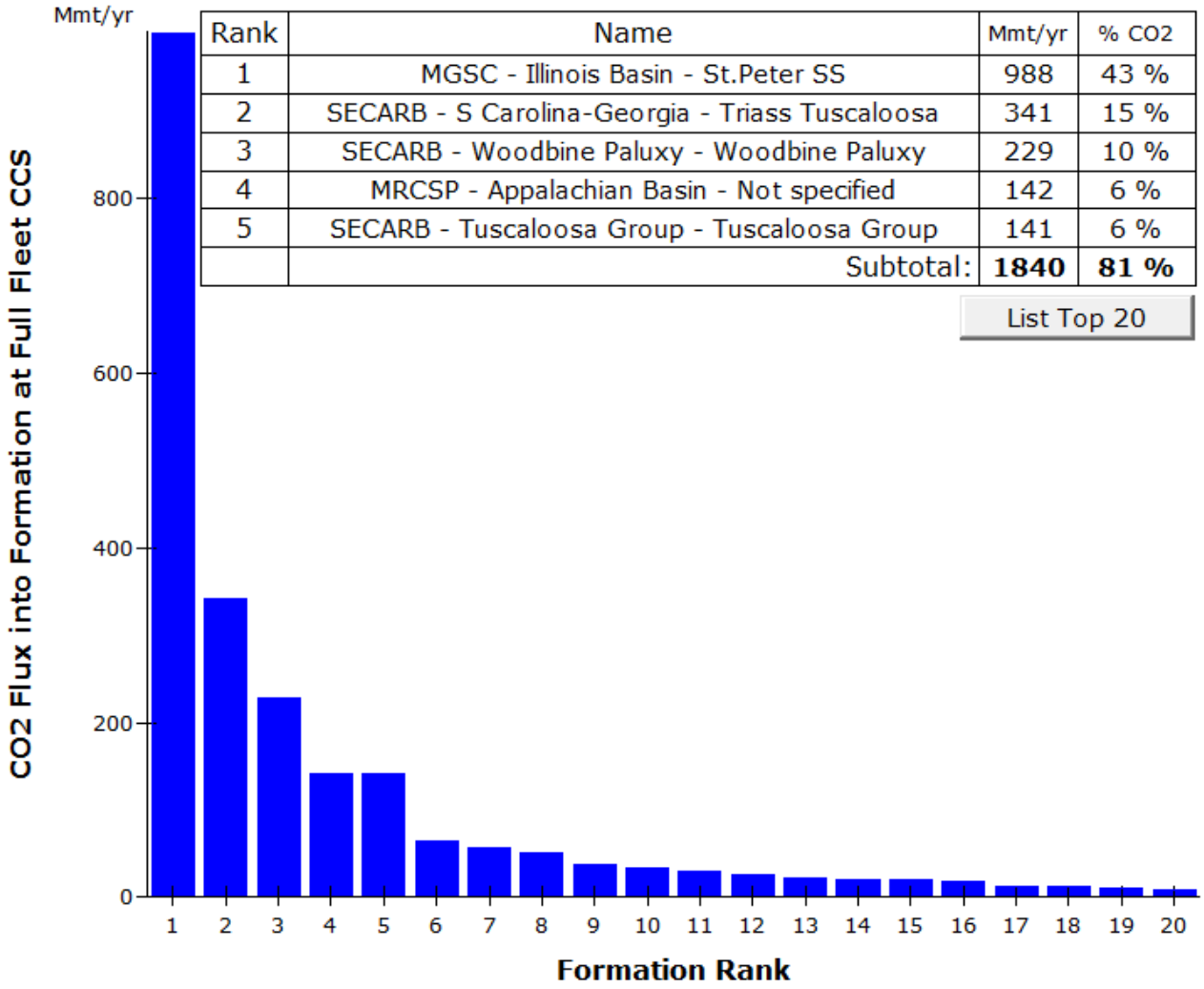
*Limited geologic saline formation water information available for the Mt. Simon.

The Top 5 Saline Formations in the Lower U.S.: *storage potential*

- Top 5 formations may hold 60% of CO_2 emissions
- Over 25% storage in St. Peter Sandstone (988 Mt/yr) or Mt. Simon (1,202 Mt/yr) w/o SWETT

Rank	Name	Mmt/yr	% CO2
1	MGSC - Illinois Basin - St.Peter SS	988	43 %
2	SECARB - S Carolina-Georgia - Triass Tuscaloosa	341	15 %
3	SECARB - Woodbine Paluxy - Woodbine Paluxy	229	10 %
4	MRCSP - Appalachian Basin - Not specified	142	6 %
5	SECARB - Tuscaloosa Group - Tuscaloosa Group	141	6 %
	Subtotal:	**1840**	**81 %**

List Top 20



WECSsim Analysis Can also Investigate a Specific Power Plant to a Specific Sink

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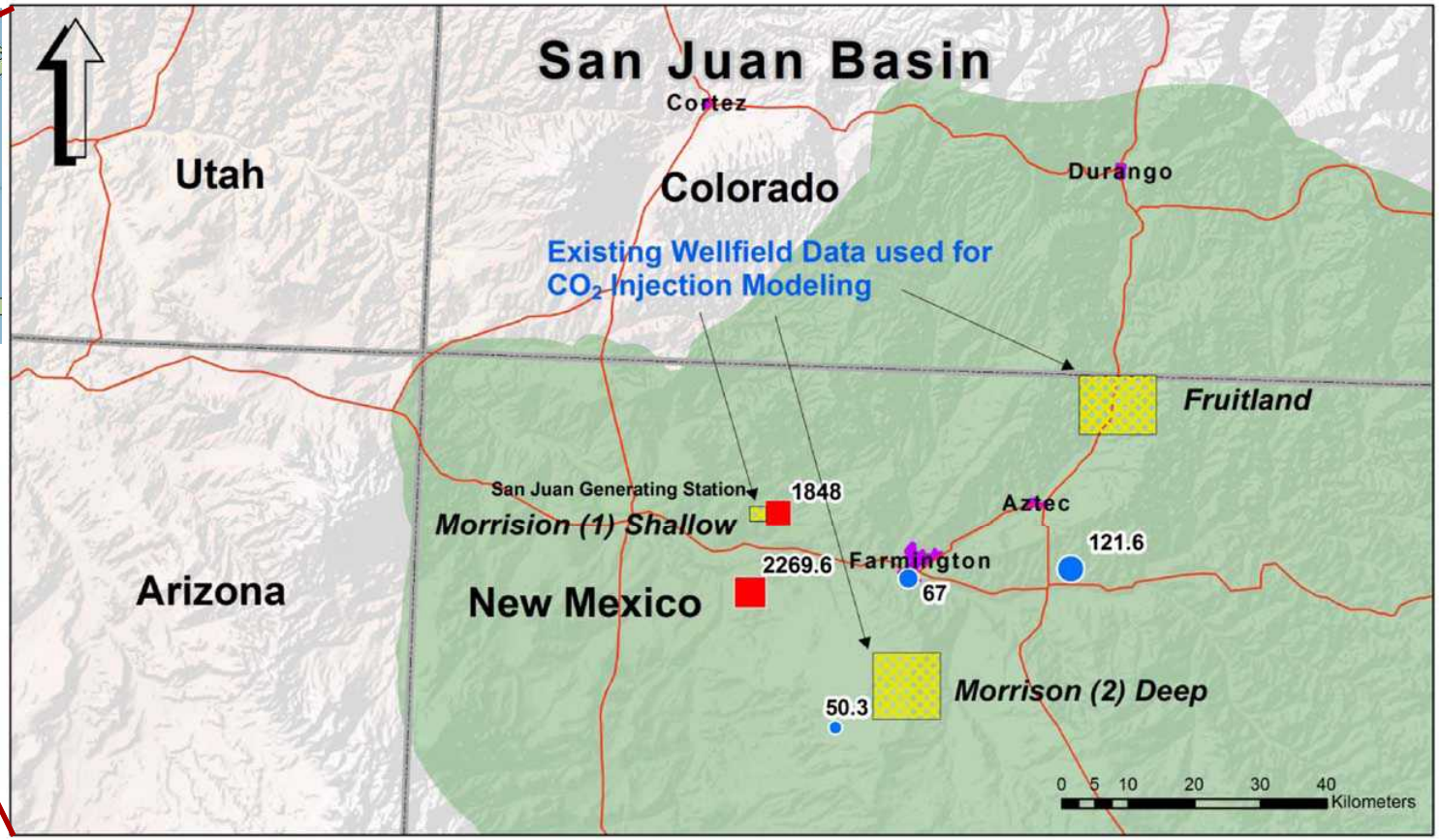


Natural Gas Power Plants
nameplate capacity (MW)
- 50.3
- 67
- 121.6

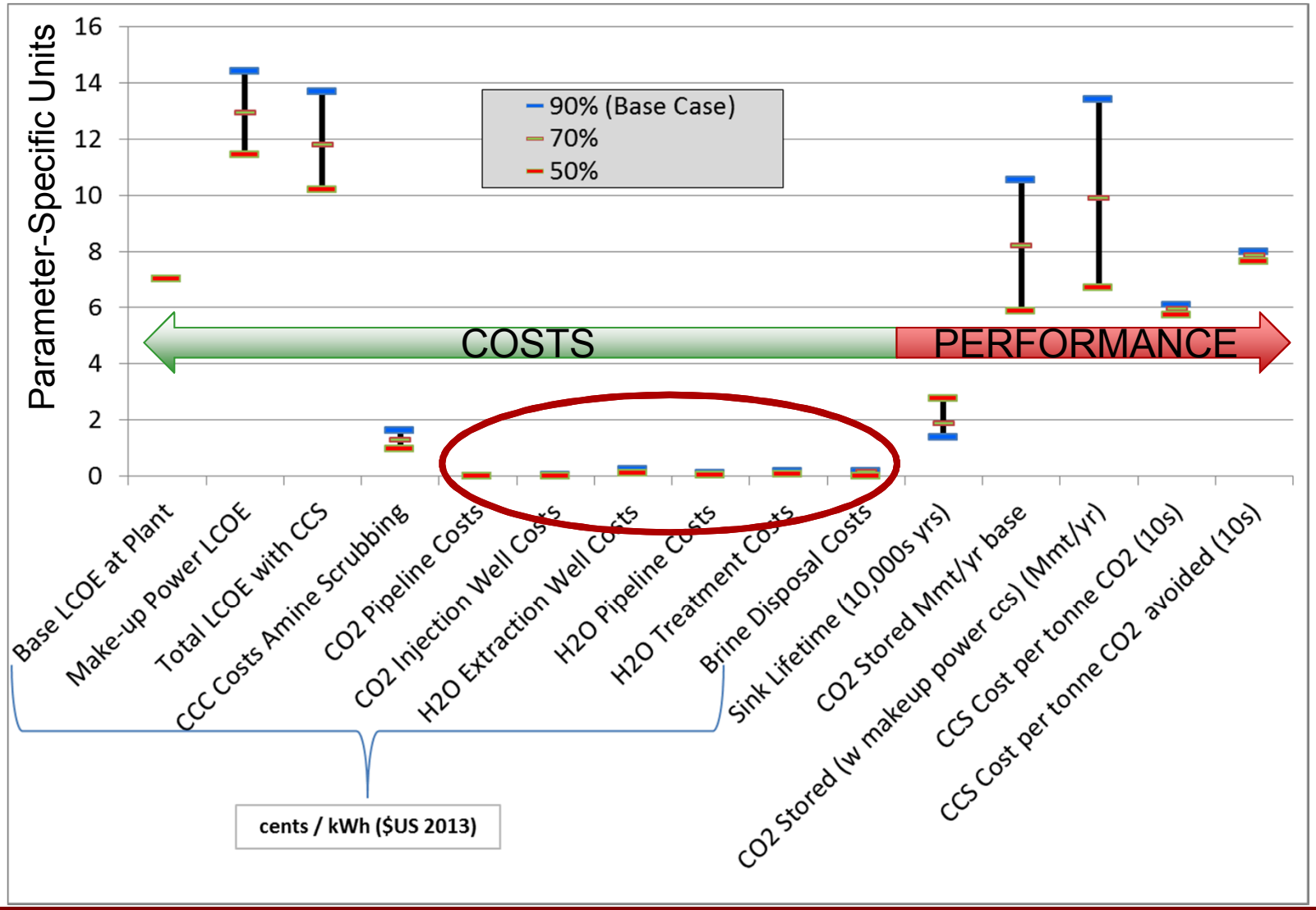
Coal Power Plants
nameplate capacity (MW)
- 1848
- 2269.6

- NATCARB identified saline formation
- Existing wellfield data area

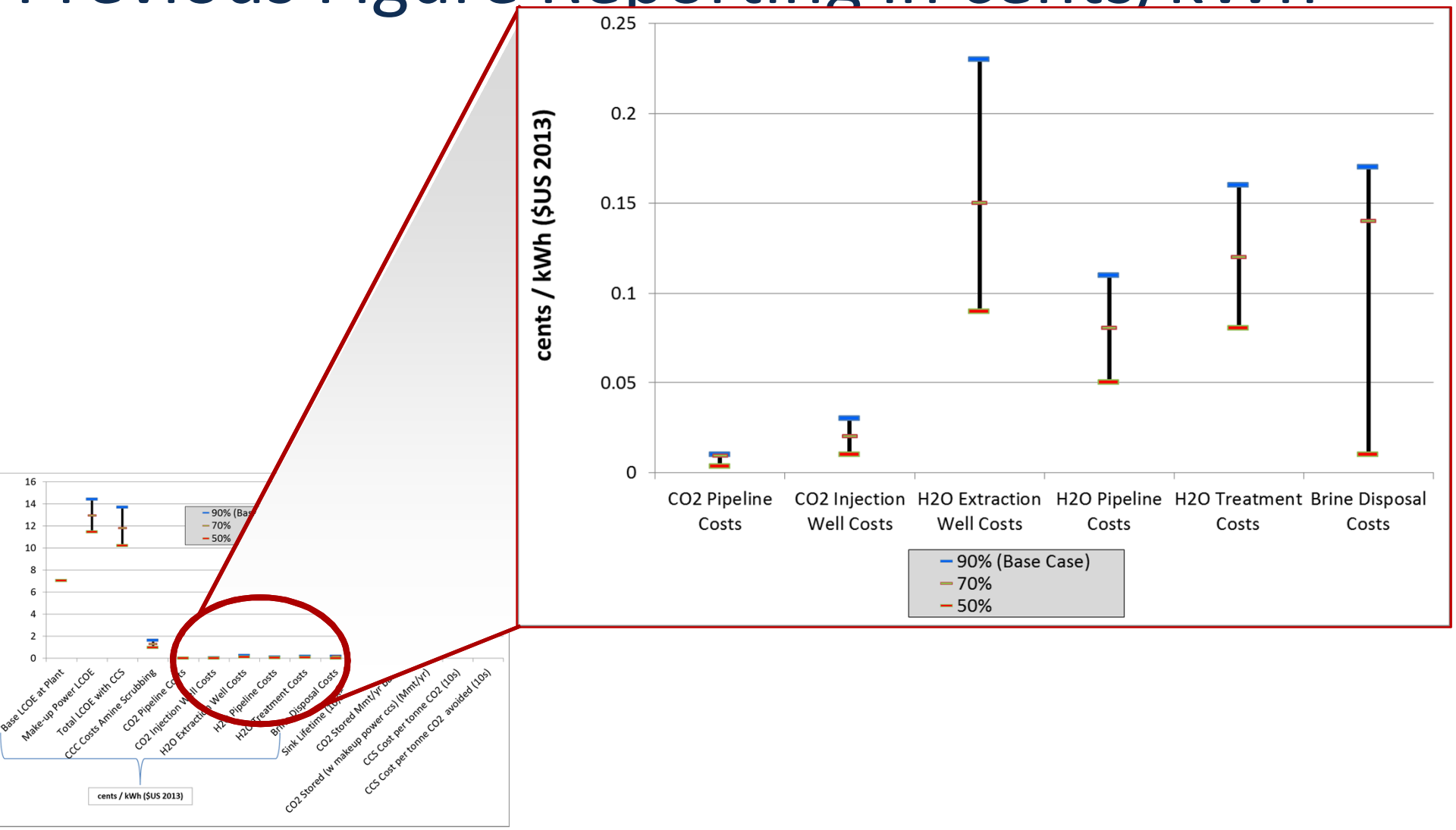
Source: Kobos, P.H., Cappelle, M.A., et al., Combining power plant water needs and carbon dioxide storage using saline formations: Implications for carbon dioxide and water management policies, *International Journal of Greenhouse Gas Control*, Volume 5, Issue 4, July 2011, pp. 899 − 910.

Percent CO_2 Captured:

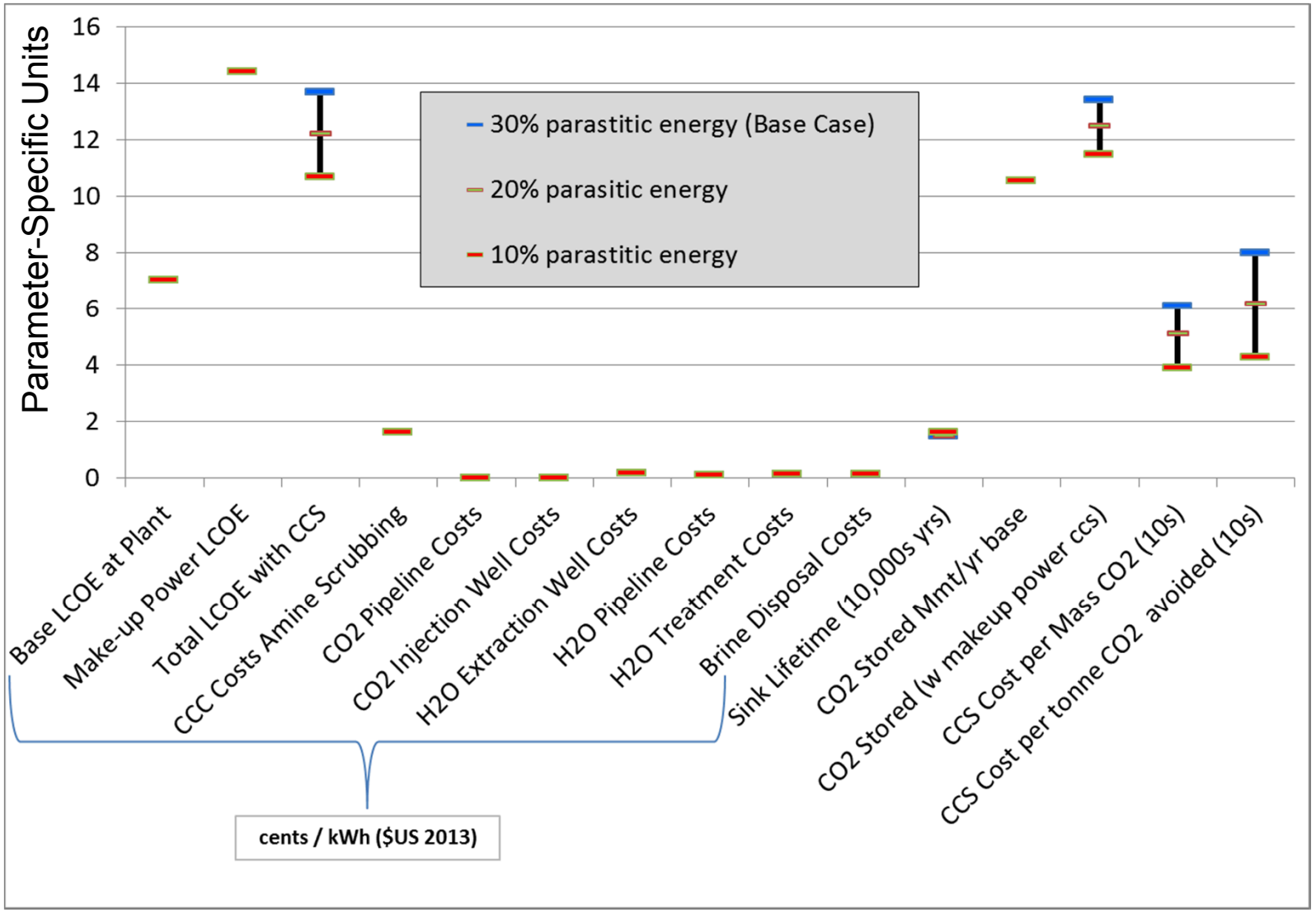
San Juan Generating Station: *90% (base case), 70%, 50%.*



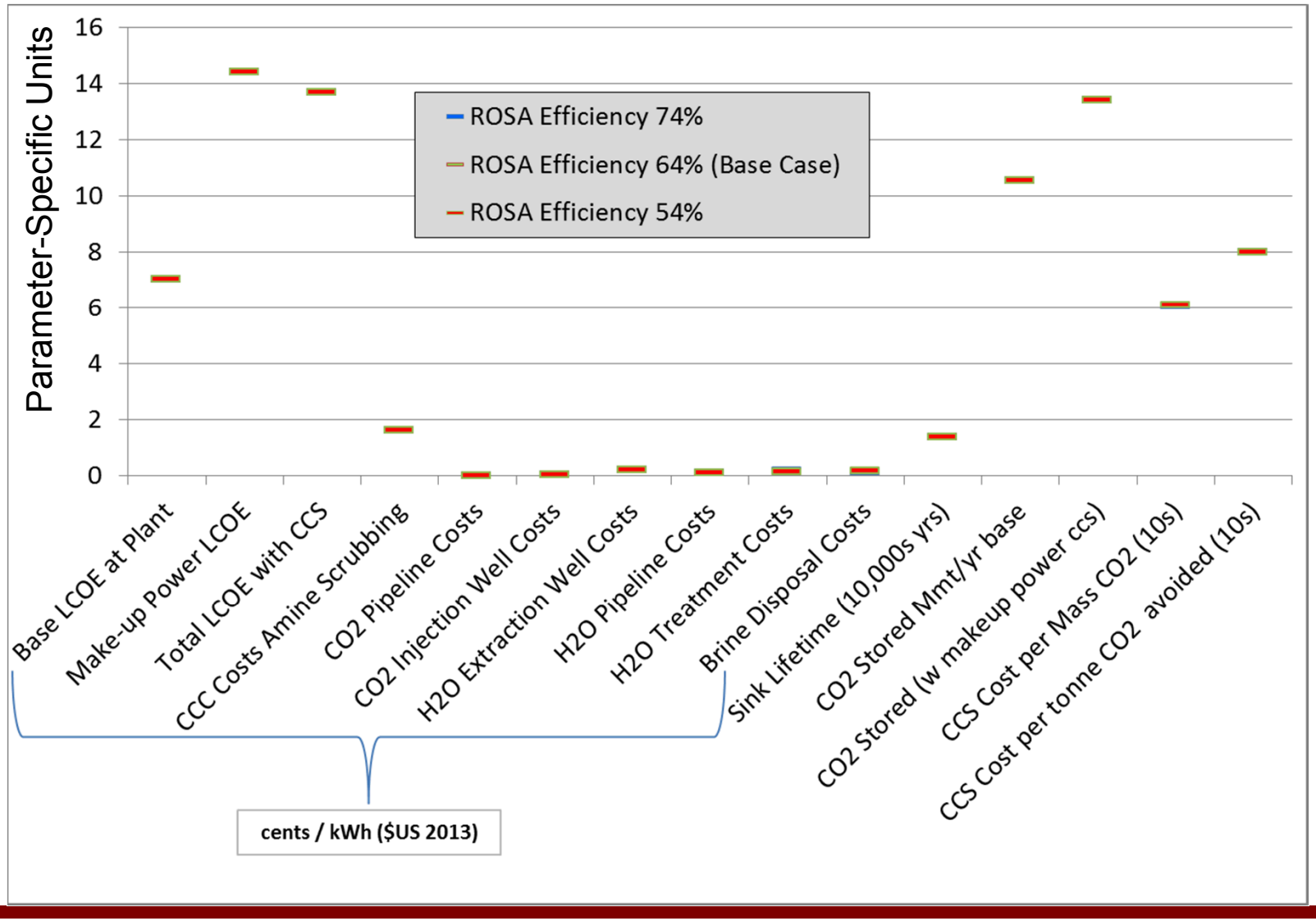
Expanding Select Results from Previous Figure Reporting in cents/kWh



Parasitic Energy for CCS: 30%, 20%, 10%



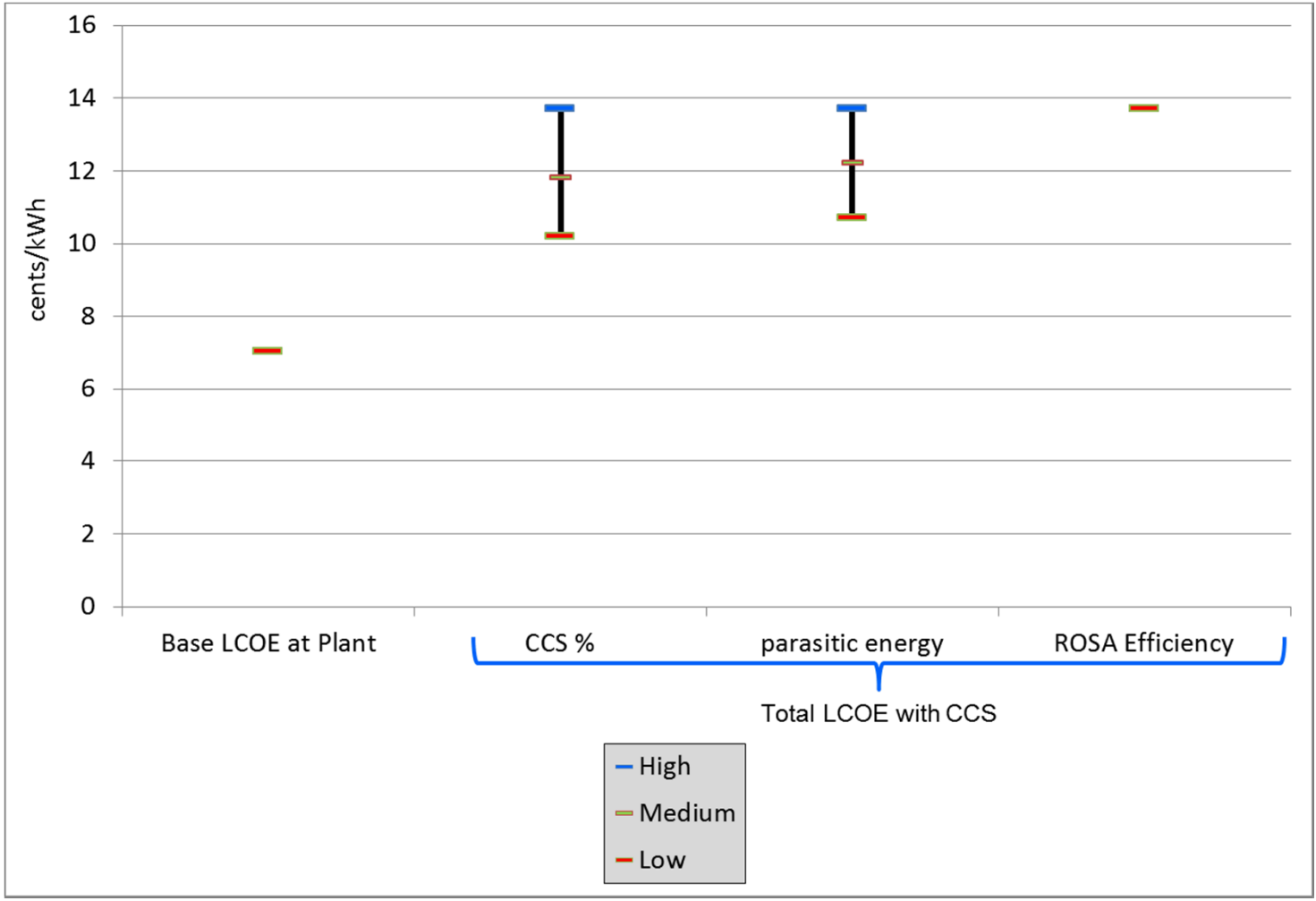
Efficiency of the Reverse Osmosis System Analysis (ROSA): 74, 64, 54%



Cost and Performance Drivers:

% CO_2 captured, Parasitic Energy, Water Treatment Efficiency

- Percent Capture & parasitic energy greatly affect the LCOE
- Water Treatment Efficiency changes to LCOE are small
- Highlights importance to:
  - Decide on % CO_2 capture
  - Reduce parasitic energy load & costs



Cost and Performance Drivers:

% CO_2 captured, Parasitic Energy, Water Treatment Efficiency

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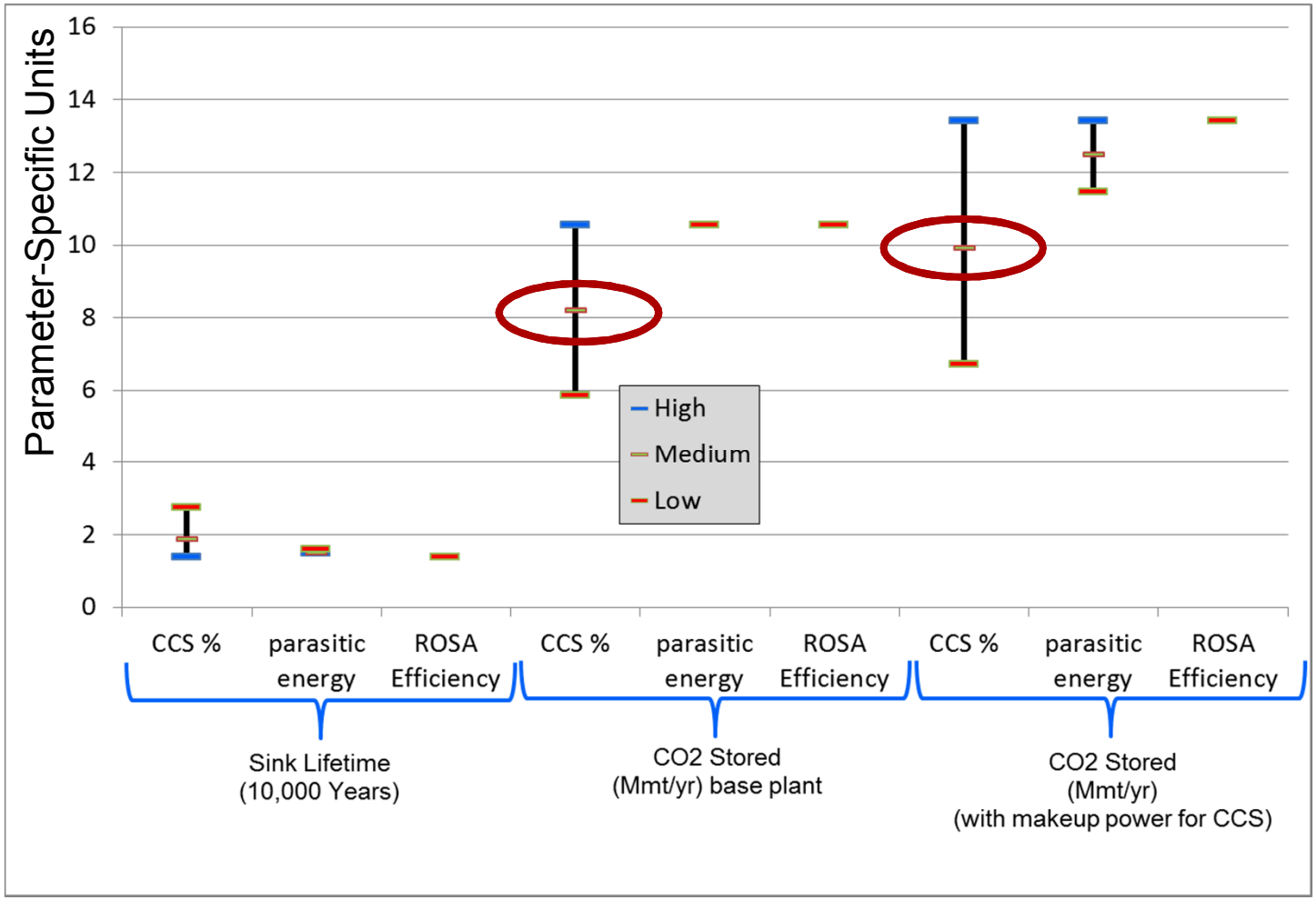
- Percent Capture greatly affects sink lifetime and CO_2 stored
- Parasitic energy requirements affect the amount of CO_2 stored
- Supports notion to focus on avoided CO_2 rather than absolute CO_2 stored



Future Analysis Considerations

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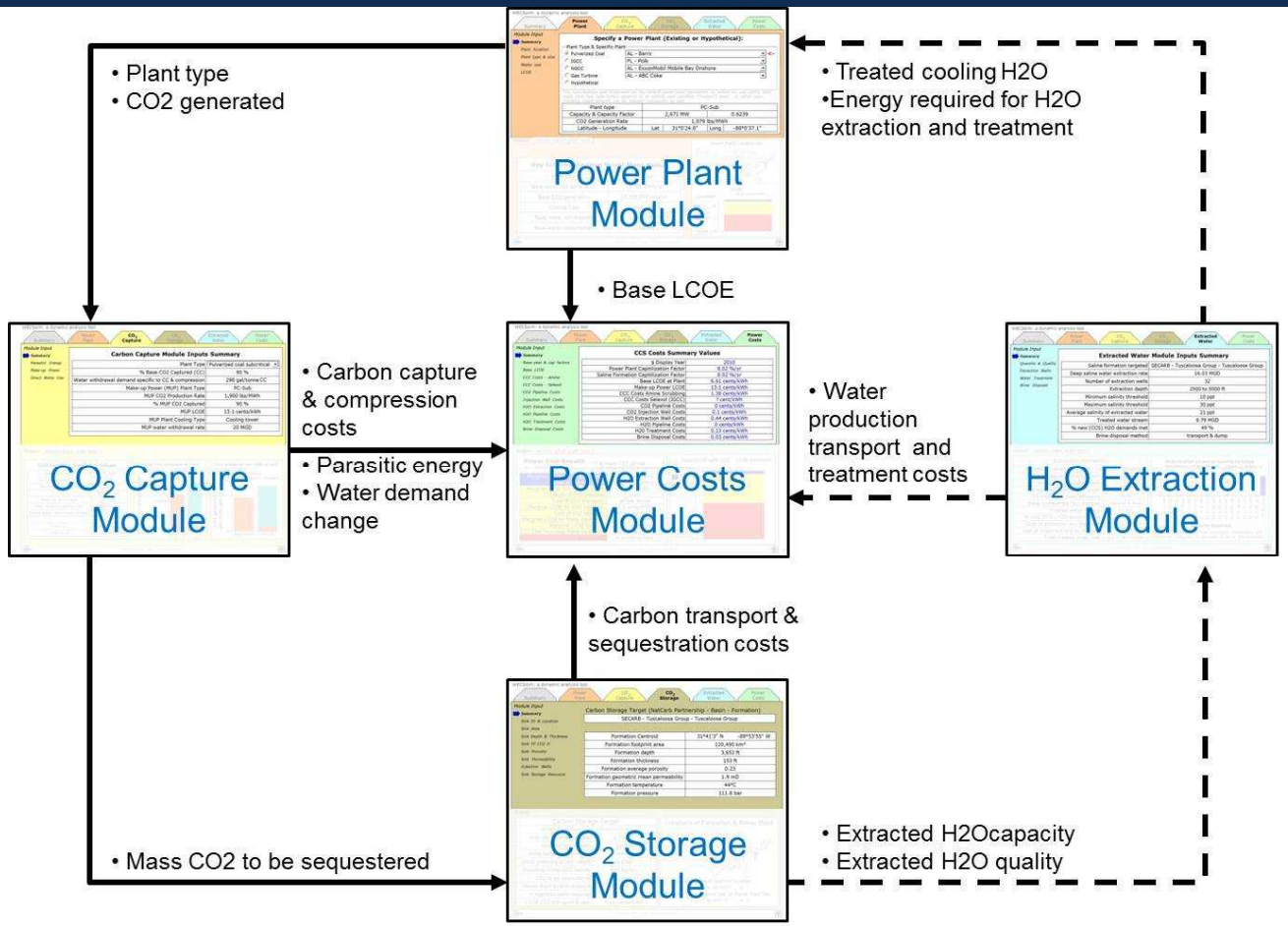
- Expand the framework of WECSsim and other Integrated Assessment Modeling efforts to new technologies and regions
- Focus on engineered systems' components that reduce total costs the most
- Focus on reducing parasitic energy loads
- Continue to utilize WECSsim© for fleet and plant-specific analysis
- Select model resources and publications available at: http://carbonmanagement.sandia.gov/

Thank You.

Questions?



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