SAND2008-3008C

Seventh Annual Conference on Carbon Capture & Sequestration

Session: Geologic Storage - Saline

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

Malynda Aragon, Peter H. Kobos, Jim Krumhansl
David J. Borns, Michael M. Hightower, Andrea McNemar

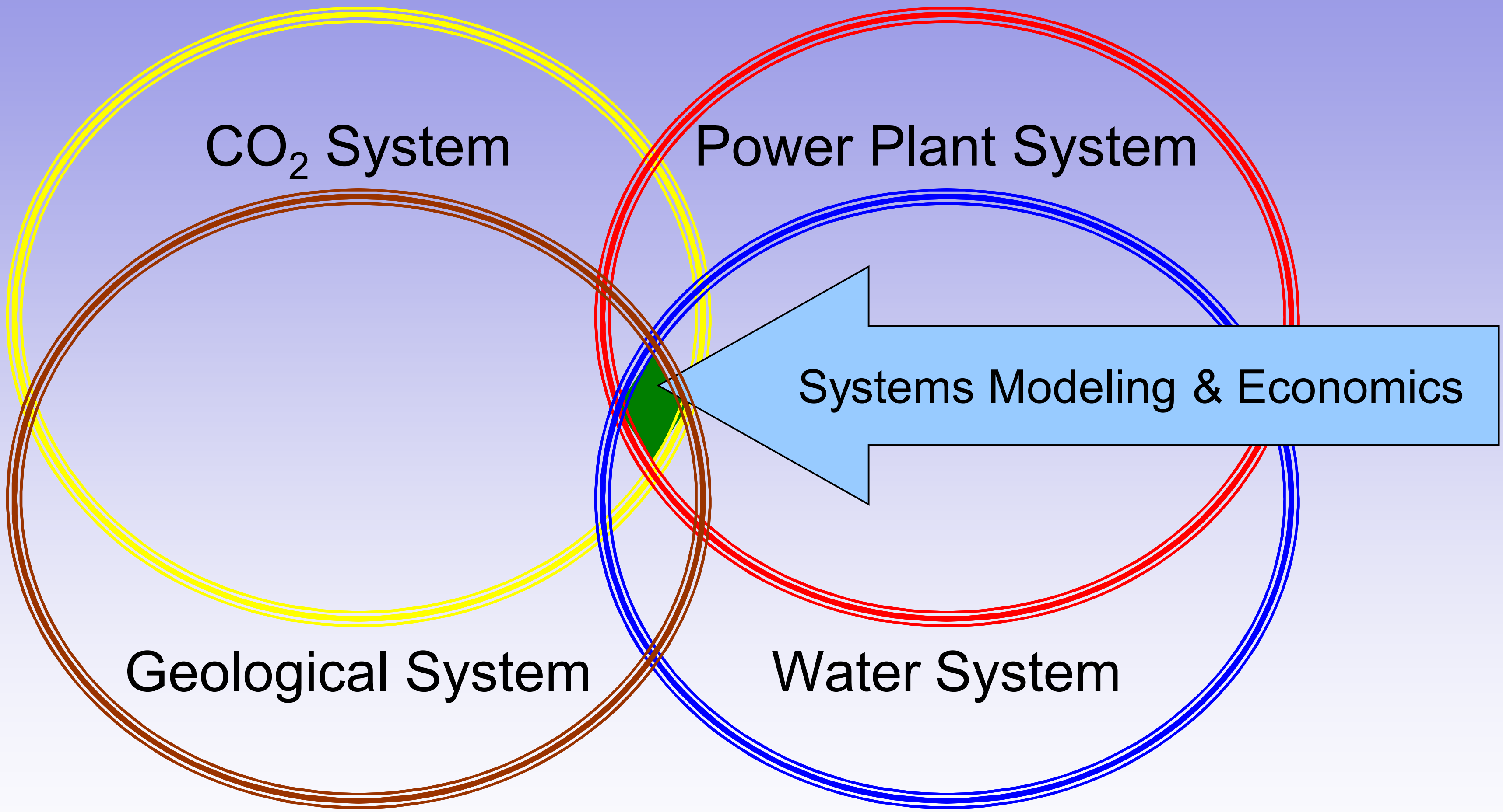
May 5 – 8, 2008 • Sheraton Station Square • Pittsburgh, Pennsylvania

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL85000

National Nuclear Security Administration

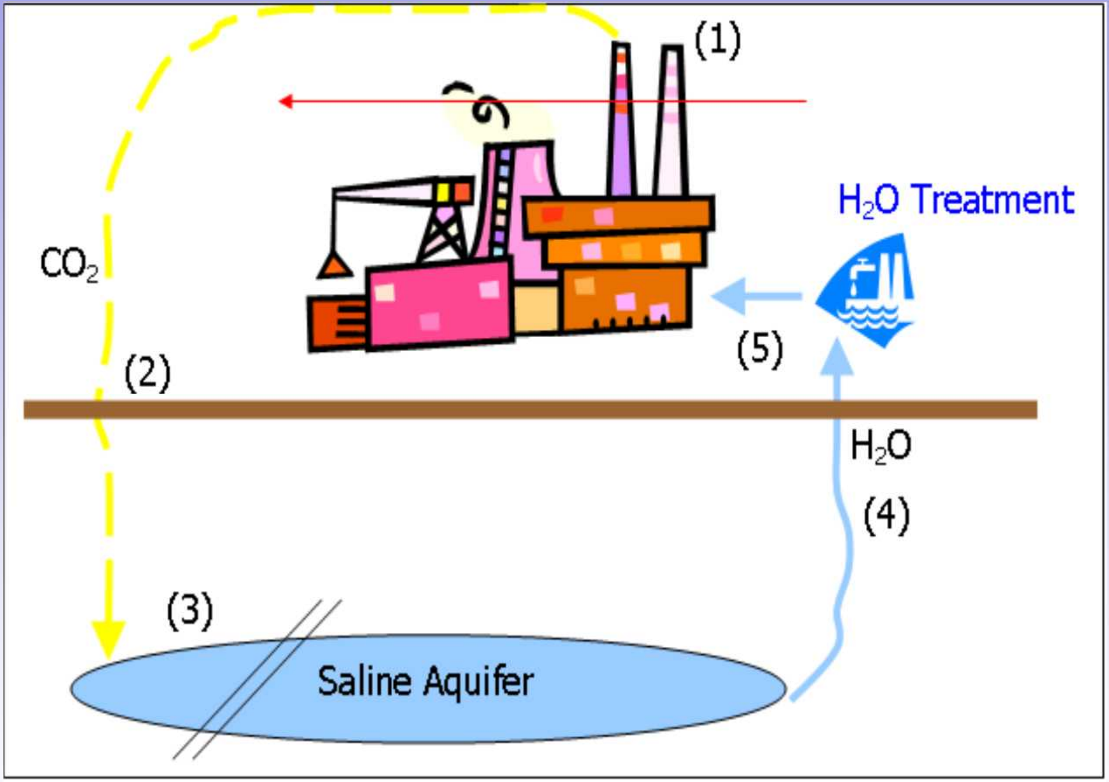
Sandia National Laboratories

Energy-Economic Modeling: Conceptual Layout of the Project



Can a power plant sequester Carbon Dioxide in a geological saline formation, while also utilizing produced water for cooling or other uses?

The Model
Building the Assessment Framework



Briefly describe steps.

(1) CO_2 power plant emissions

(2) CCS Potential

(3) Saline Aquifer CO_2 sequestration potential

(4) Pump Saline Aquifer for use at the power plant

(5) Desalinate water for use at the power plant

Notes: Carbon Capture and Sequestration (CCS)

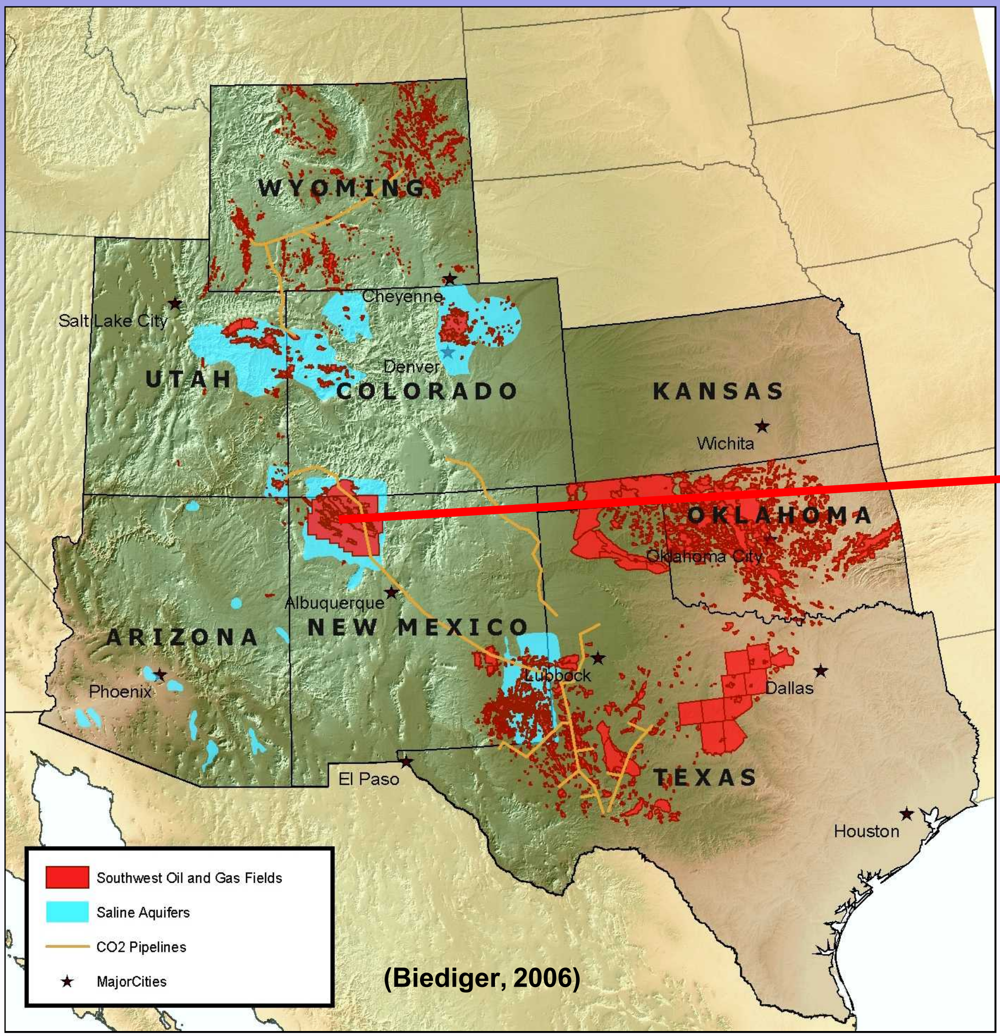
Key Metrics of Interest

- Costs
  - $/kWh
  - Carbon Capture and Sequestration
  - Produced Water Costs
- Water
  - Volumes associated with Formations, flow rates
  - Length of time water may last
- Carbon Dioxide
  - Volumes of CO_2 potentially sequestered, flow rates
  - Length of time geological sink may last
  - Financial ($/kWh), Energy (parasitic energy for systems) and Water (additional water for additional/parasitic systems) costs

Developing the Test Case Model Assessment Framework

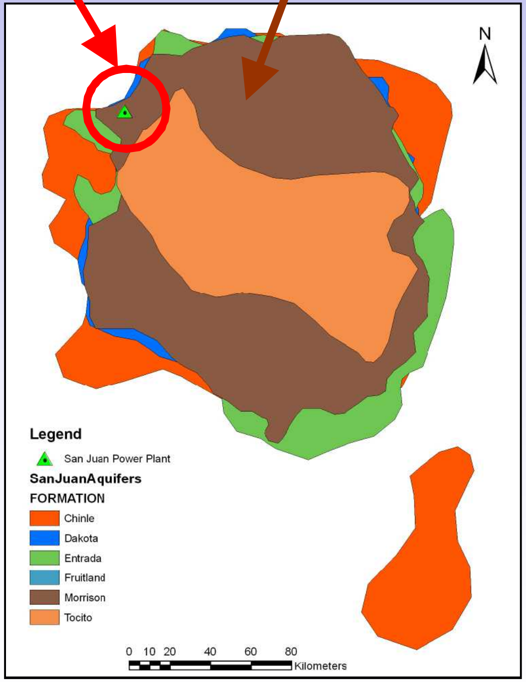
- Developing a Test Case to build the Framework
  - Looking to scale up the assessment to the Regional & National scale
- Power Plant: San Juan Generating Station
  - 1848MW Subcritical, Coal, Steam power plant
  - Annual Water Consumption: 22,400 acre-ft/year
    (7.3 billion gallons/yr) with the cooling towers representing 90% of consumption
  - Annual CO_2 Emissions: 14.5 million ton/yr
- Saline Formation: Morrison Formation
  - 5,000 million metric tonnes CO_2 sequestration capacity

The San Juan Power Plant and Morrison Formation



San Juan Power Plant

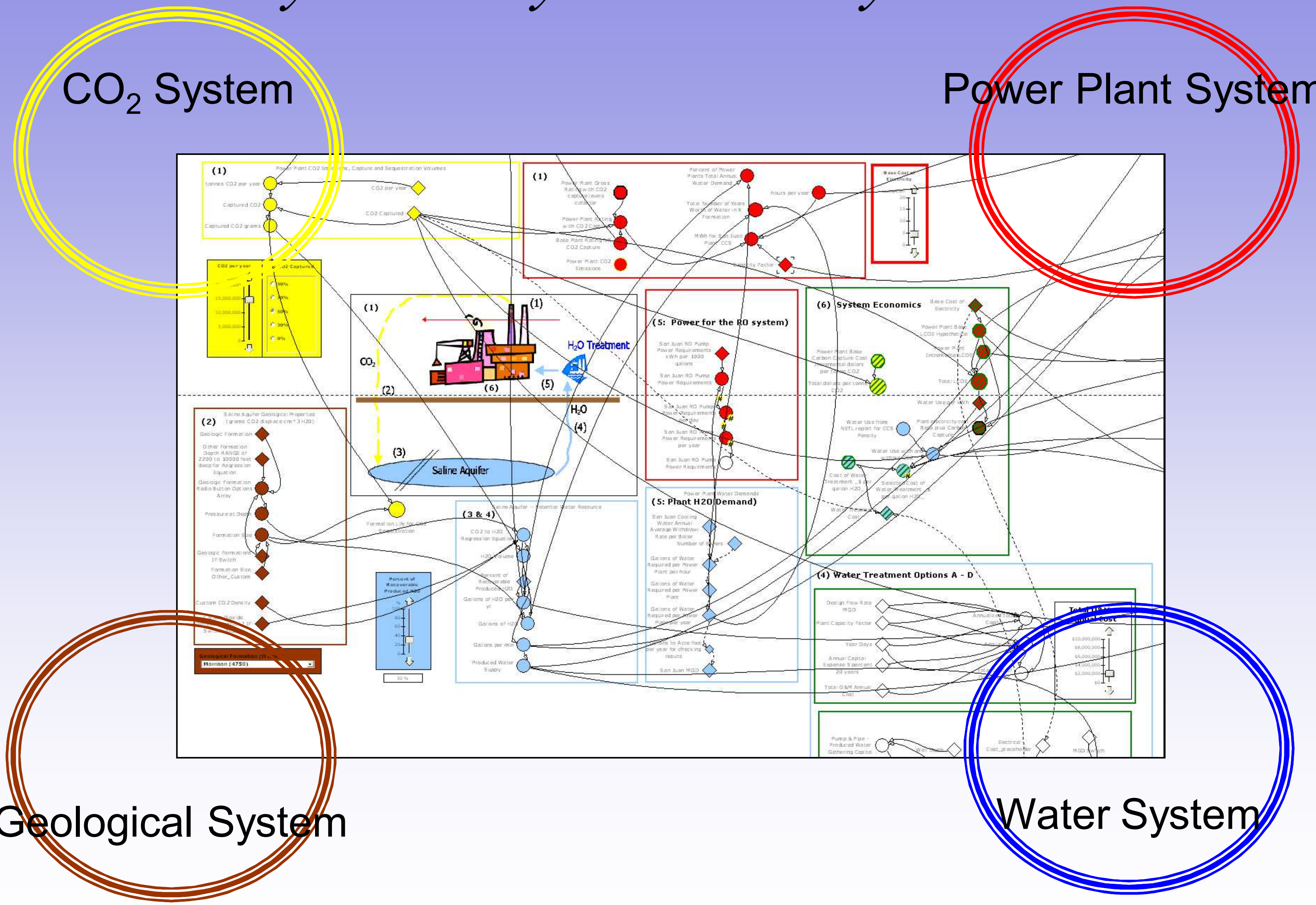
Morrison Formation



Formation CO_2 REACT 'box model' studies

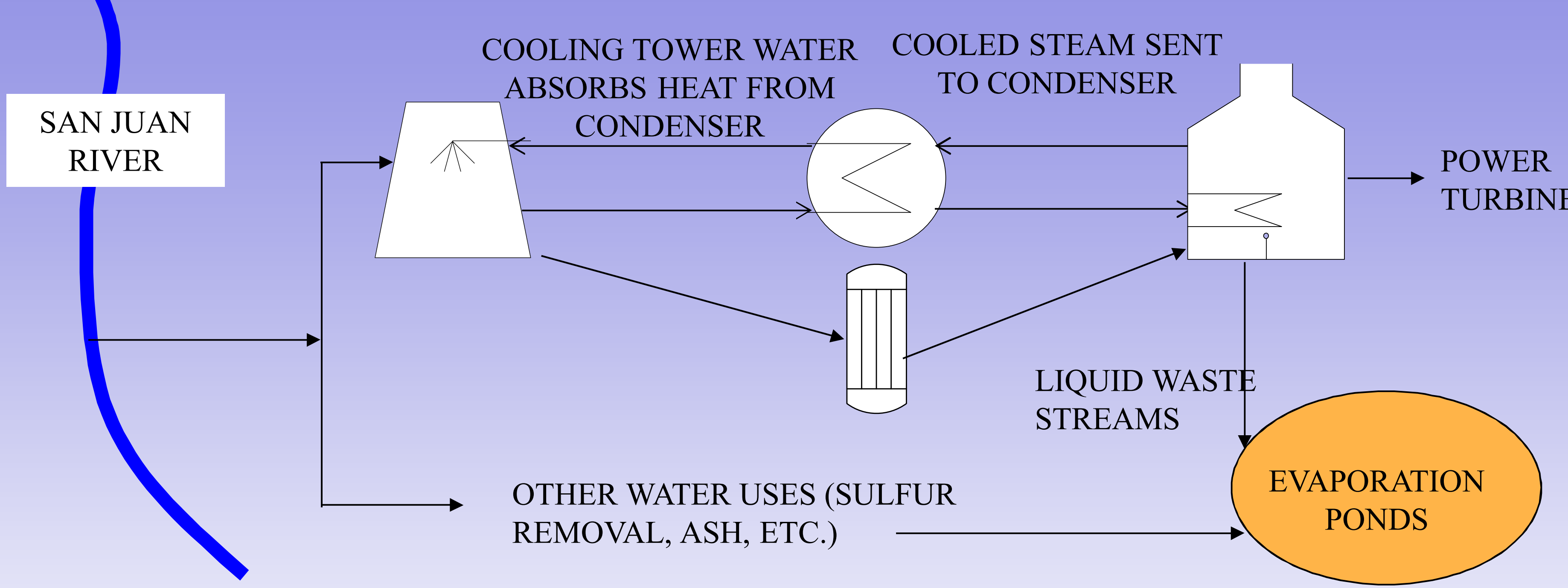
- Several Aquifers were studied in these formations:
  - Mesa Verde / Point Lookout
  - Dakota
  - Hermosa / Paradox
  - Morrison
- Insights:
  - Morrison may have the more favorable geochemical/geospatial conditions for CCS & water production
  - Morrison has a broad regional occurrence
  - Assess Formation's long term ability to retain sequestered CO_2

The Integrating Model:
A Dynamic Systems Analysis Tool



Note: Prototype Model Framework, Abbreviated Screenshot, Spring 2008

Water & Energy Flows - SJGS



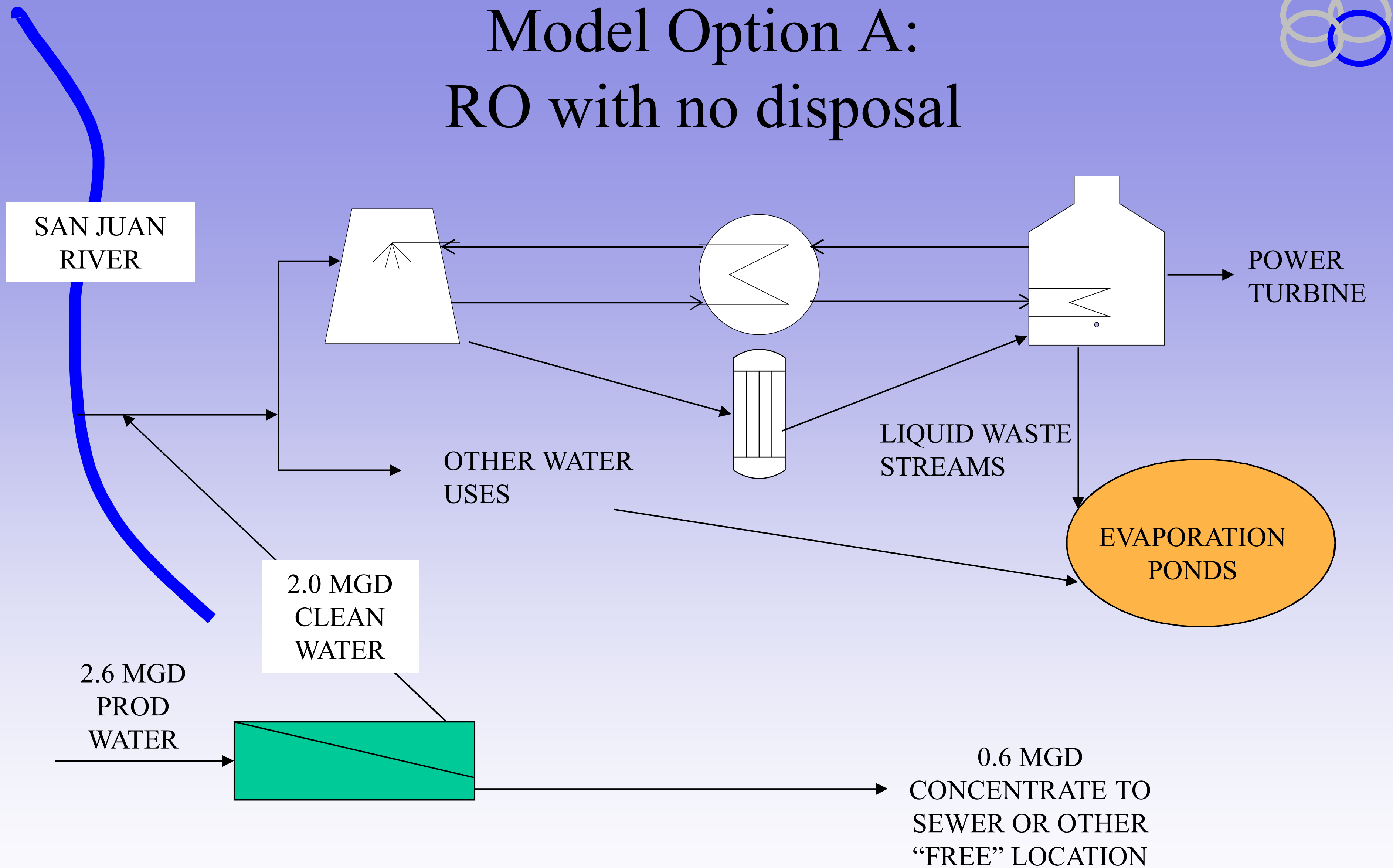
POTENTIAL FOCUS AREAS:

1. Cooling Tower Make-up water: Utilize Saline Aquifer as a resource (minimize fresh water consumption)
2. Cooling Tower Design: Dry vs. Wet Cooling Options (minimize/eliminate fresh water consumption)
3. Utilization of Waste Heat: Minimize Need for Cooling Tower

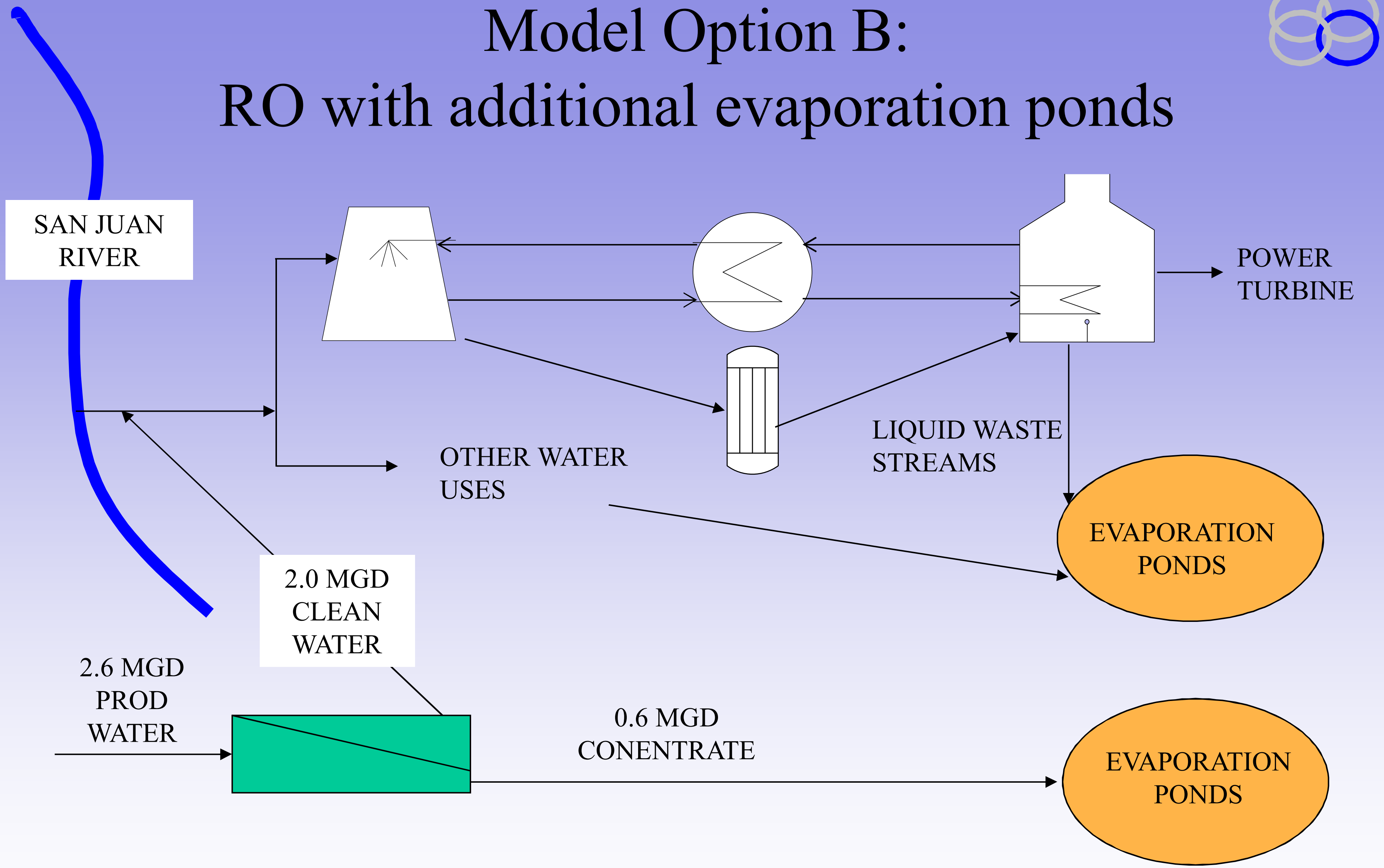
National Nuclear Security Administration

Sandia National Laboratories

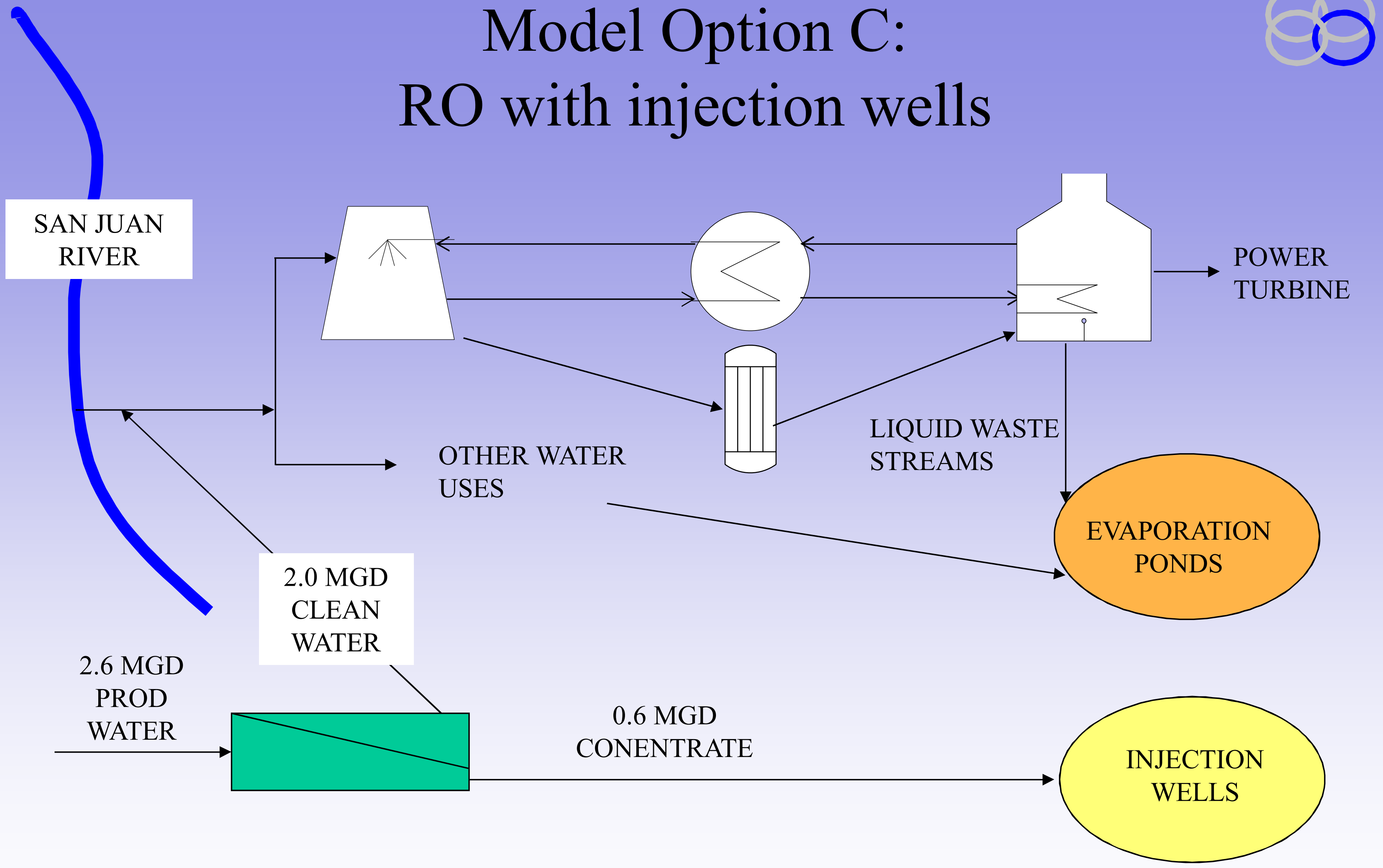
Model Option A:
RO with no disposal



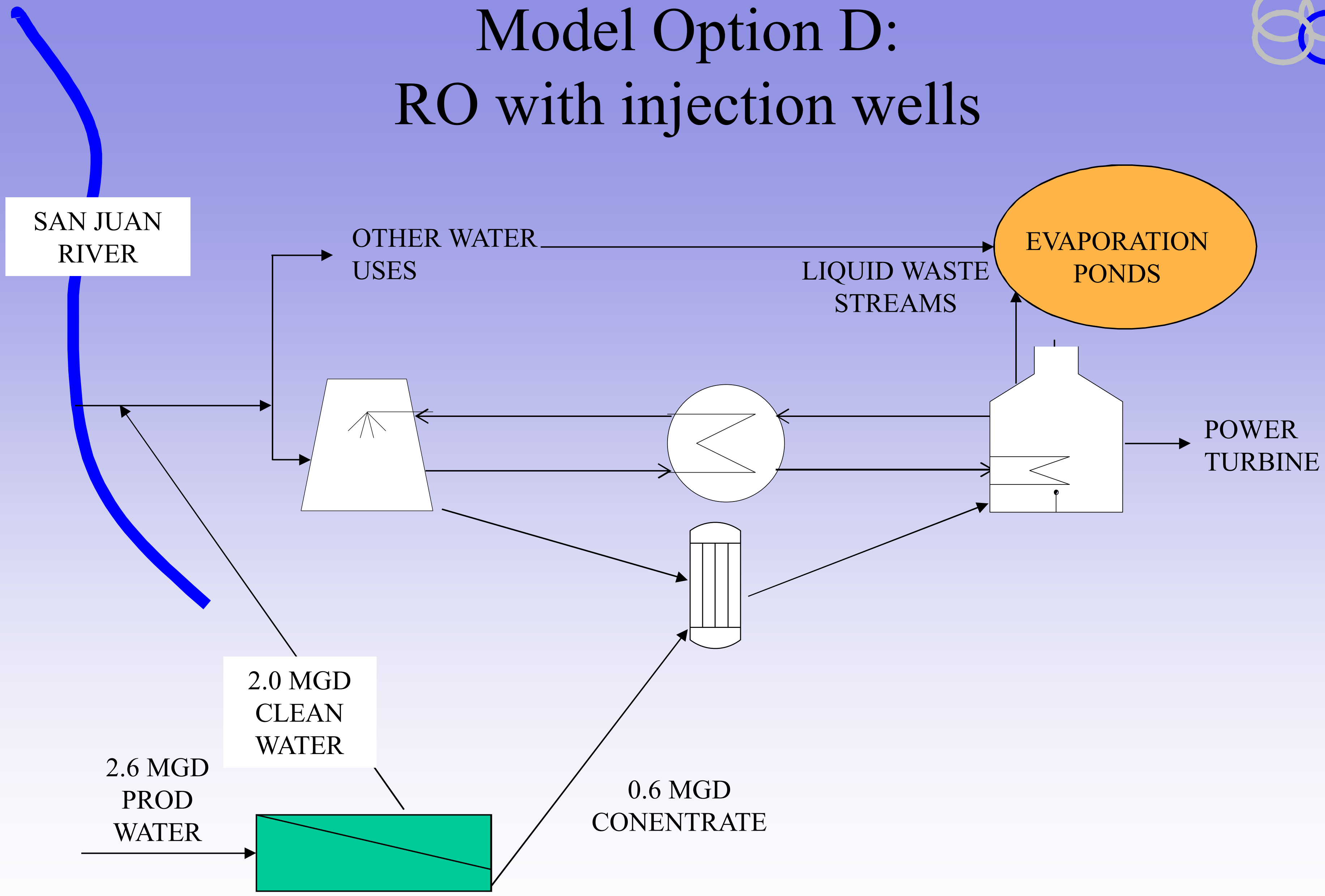
Model Option B: RO with additional evaporation ponds



Model Option C:
RO with injection wells



Model Option D: RO with injection wells



Water Treatment Options

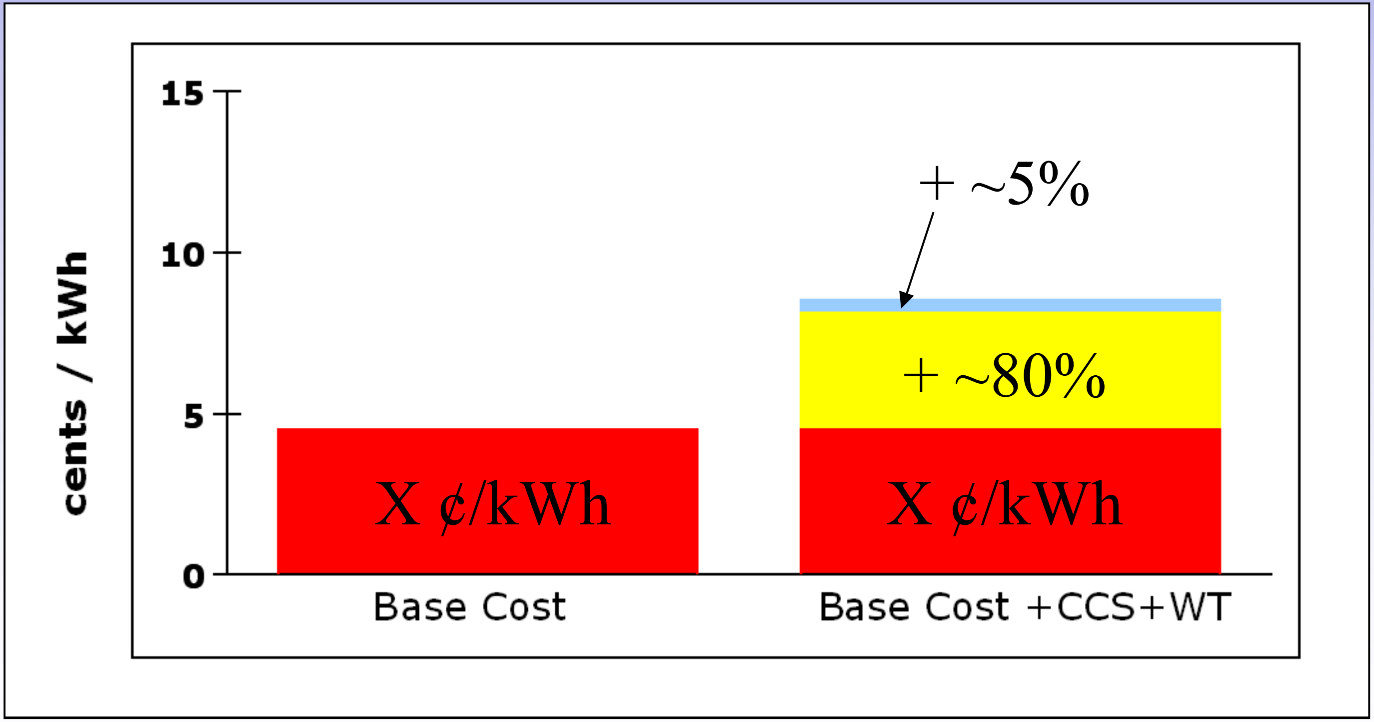
Order of Magnitude Technology Cost Options

Total Cost - includes equipment & O&M for desalination and concentrate disposal (e.g. ponds)	Option A BWRO-**no conc disposal** $/1000 gal		Option B BWRO-**evap ponds** $/1000 gal		Option C BWRO-**injection well** $/1000 gal		Option D HERO + **BC retrofit** $/1000 gal	
Annualized Total Capital	$	2.90	$	5.04	$	3.24	$	2.59
Annual O&M	$	2.31	$	2.35	$	2.32	$	2.73
Electrical	$	0.42	$	0.42	$	0.42		
Membrane Replacement	$	0.00	$	0.00	$	0.00		
Other	$	0.54	$	0.54	$	0.54		
Total Cost (O&M+cap)	**$**	**5.21**	**$**	**7.39**	**$**	**5.56**	**$**	**5.31**
Cost of Desalination only - includes only equipment & O&M for desalination (i.e. no ponds, no GW pumping)	Option A BWRO-no conc disposal $/1000 gal		Option B BWRO-evap ponds $/1000 gal		Option C BWRO-injection well $/1000 gal		Option D HERO+BC retrofit $/1000 gal	
Annualized Total Capital	$	1.59	$	1.59	$	1.59	$	1.28
Annual O&M	$	1.34	$	1.34	$	1.34	$	1.43
Electrical	$	0.42	$	0.42	$	0.42	$	0.86
Membrane Replacement	$	0.08	$	0.08	$	0.08	$	-
Other	$	0.59	$	0.62	$	0.59	$	0.64
Total Cost (O&M+cap)	**$**	**2.93**	**$**	**2.93**	**$**	**2.93**	**$**	**2.72**

Note: Brine Water Reverse Osmosis (BWRO); High Efficiency Reverse Osmosis + Brine Concentrator (HERO+BC); Ground Water (GW); Operations and Maintenance (O&M). Source: Bureau of Rec. Handbook.

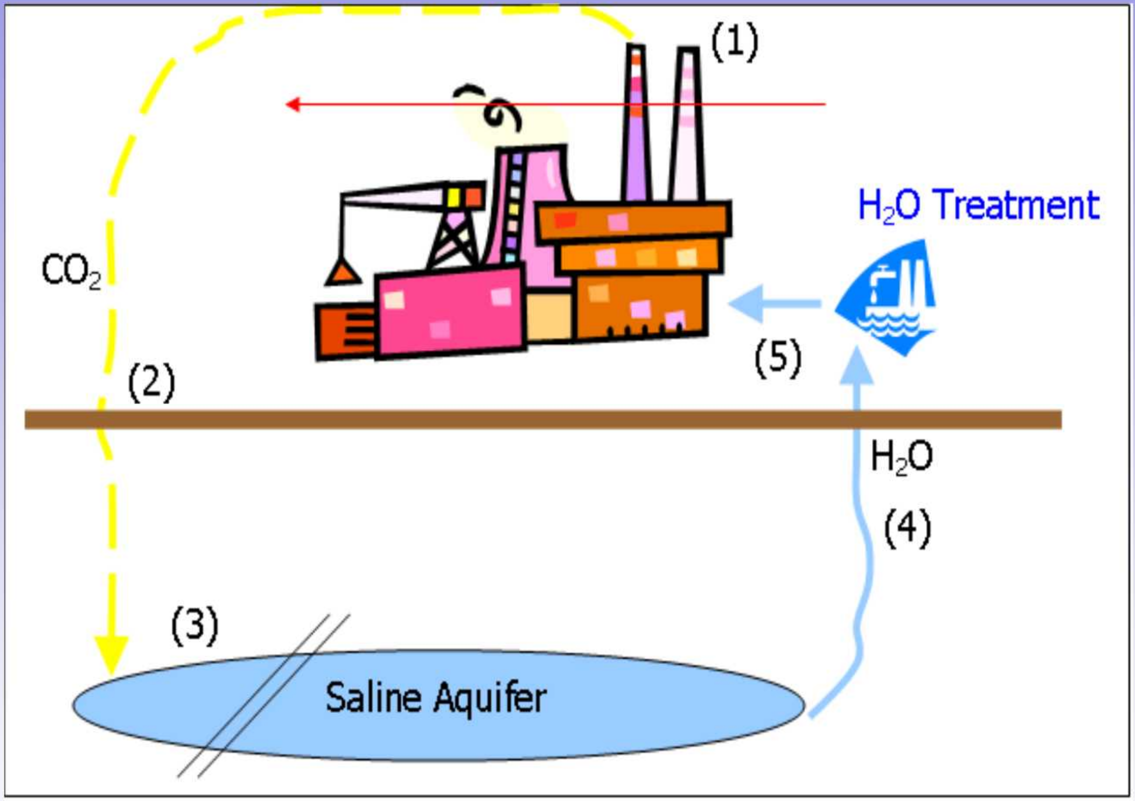
Prototype Model's Illustrative Cost Framework:

Hypothetical Base Cost of Electricity +
Carbon Capture and Sequestration (↑ 80%) +
Water Treatment (↑ 5%)



(1) Carbon Capture and Sequestration (CCS), 20%+ Energy Penalty, ↑ costs ~80%, ↑H_2O demands

(2) CCS, 50% capture and sequestration, ~7 mmt/yr



(5) Produced Water Treatment, ↑ costs 5%, meet potentially a portion of Power Plant's annual H_2O demand

(3) Morrison Formation, 5,000 mmt, 100s yrs. of CO_2 sequestration capacity

(4) <1 - 6 Million Gallons per Day for 100s yrs., Assuming 30% recoverable produced water potential

National Nuclear Security Administration

Sandia National Laboratories

Assumptions with the Framework: *Caveats*

- Can we sequester CO_2 at these flow rates?
- Can we produce water at these flow rates for what period of time?
- Will there be sufficient communication between the CO_2 and the H_2O in the formation without complications?
- Others

Progress of the Modeling Efforts

Timeline

2008

Summer

2009 +

- Completed:
  - Developed a Test Case Model
    - Formation Assessment, CO_2 and Water
    - San Juan Power Plant
    - Desalination (Reverse Osmosis)
  - Initial results indicate there may be several hundred years worth of CO_2 storage capacity in saline formations
  - Potential to displace and produce these waters, with treatment, could supplement the additional water requirements due to the parasitic water for energy loads due to CCS and producing and treating the water
- Ongoing:
  - Additional Desalination Technology Options
  - Thermal Assessment (potential to utilize waste heat)
- Where we are going:
  - Hydrology and Geology Assessment
  - Additional Scale up issues: Regional and National Level Analysis
  - Studying the expansion to additional aquifers
  - Looking to develop a portfolio of power plant systems (e.g., supercritical coal) models for comparison

NNSA National Nuclear Security Administration

Sandia National Laboratories

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

Thank You

Malynda Aragon, Peter H. Kobos, Jim Krumhansl
David J. Borns, Michael M. Hightower, Andrea McNemar

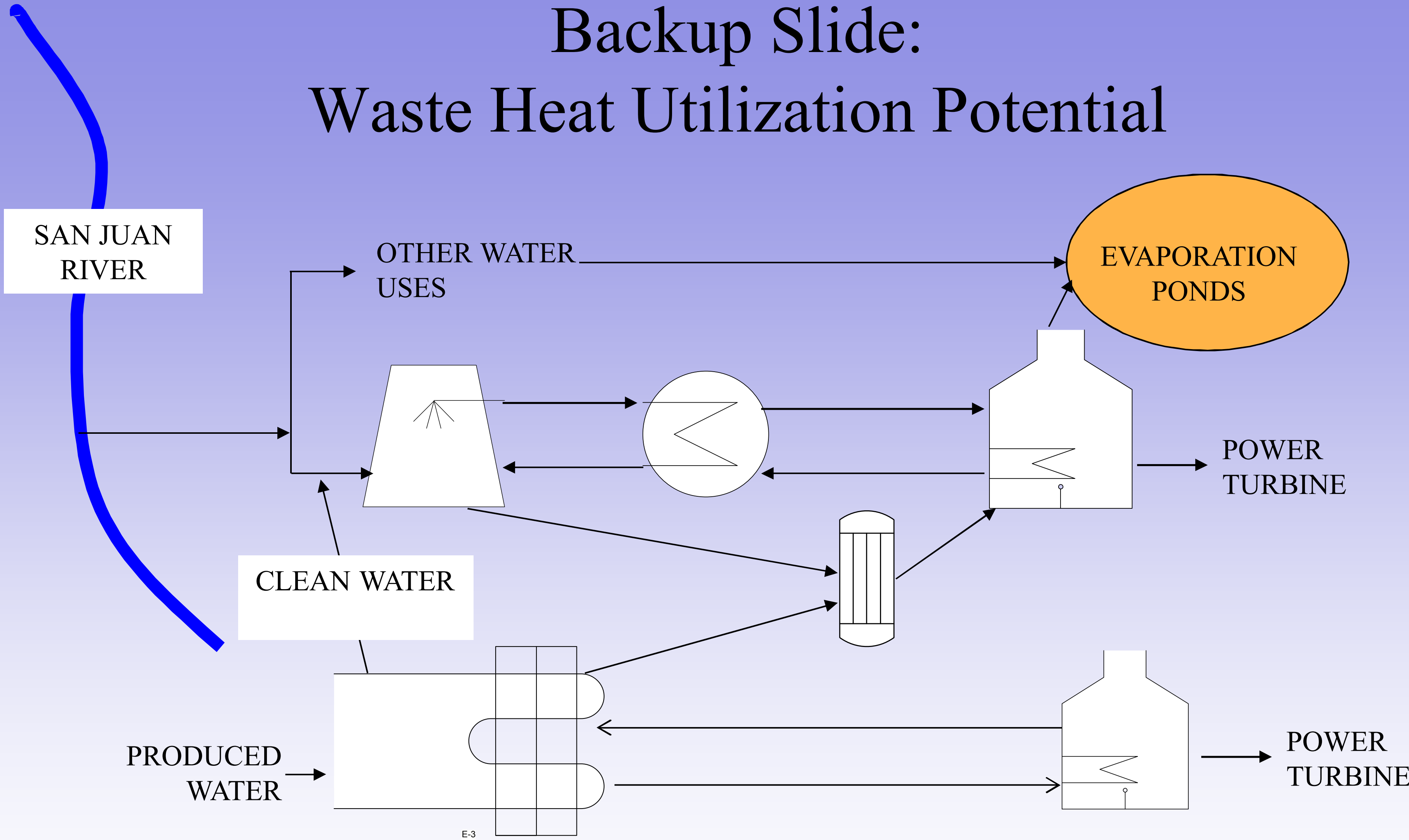
Backup Slide:
Desalination – Comparison of Aquifers

Formation/Water Source	TDS (ppm)	pH	Na (ppm)	Ca (ppm)	Mg (ppm)	Cl (ppm)	SO_4 (ppm)	HCO_3 (ppm)
MORRISON	**5947**	**7.9**	**1491**	**313**	**49**	**58**	**3764**	**272**
FRUITLAND	13602	8.4	4050	44	27	1460	5.6	8015
MESAVERDE/POINT LOOKOUT	4447	7.9	1572	87	28	2500	4.2	256
GALLUP - SS/ in Mancos	9145	8.4	3378	8	7	4060	7.7	1684
DAKOTA	2083	8.6	741	16	10	356	1.4	959
HERMOSA/PARADOX	4213	8	2654	368	49	425	9.0	708
San Juan River	348	8	29	54	11	22	107.0	125

Backup Slide:
A few more facts

- Drought: New Mexico has experienced drought conditions for several years
- Water Supplies are Limited: Most water in New Mexico is spoken for
  - Competition for water between agriculture/industry and population expected to increase (80% of water consumption in NM is for agriculture)
- Nationwide, Power Generation is expected to increase by 50% by 2030
  - Water consumption will double if current designs are utilized (wet recirculating cooling towers)

Backup Slide:
Waste Heat Utilization Potential



- Utilize existing "waste" heat from condensers for thermal desalination technique to provide clean water source for cooling towers
- Eliminate at least 1 cooling tower's worth of water consumption

Backup Slide: Dry Cooling vs. Wet Cooling

- Additional dry cooling towers could be installed
  - Decrease overall amount of water consumption
  - Potential significant decrease in electrical efficiency (increase in electrical consumption of cooling towers)
  - Could utilize for CCS technology (minimize additional water consumption)