

Lawrence Livermore National Laboratory

Water's Impacts on Hydrogen

This presentation does not contain any proprietary, confidential, or otherwise restricted information



Project ID #
an_02_simon

A.J. Simon
May 19, 2009

Overview

- **Project Start:** **October, 2007**
- **Project End:** **October, 2009**
- **Percent Complete:** **70%**

Timeline

- **Systems Analysis Barrier A:**
 - Future Market Behavior
- **Production Barrier D:**
 - Feedstock Issues

Barriers

- **Total Funding:** **\$640k**
- **FY07 Funding:** \$200k
- **FY08 Funding:** \$240k
- **FY09 Funding:** \$86k (received)
- **FY09 Funding:** \$114k (expected)
- **FY10 Funding:** none

Budget

- **NREL**
 - HyDRA, MSM Coordination
- **Sandia**
 - MSM Interface, Water Model

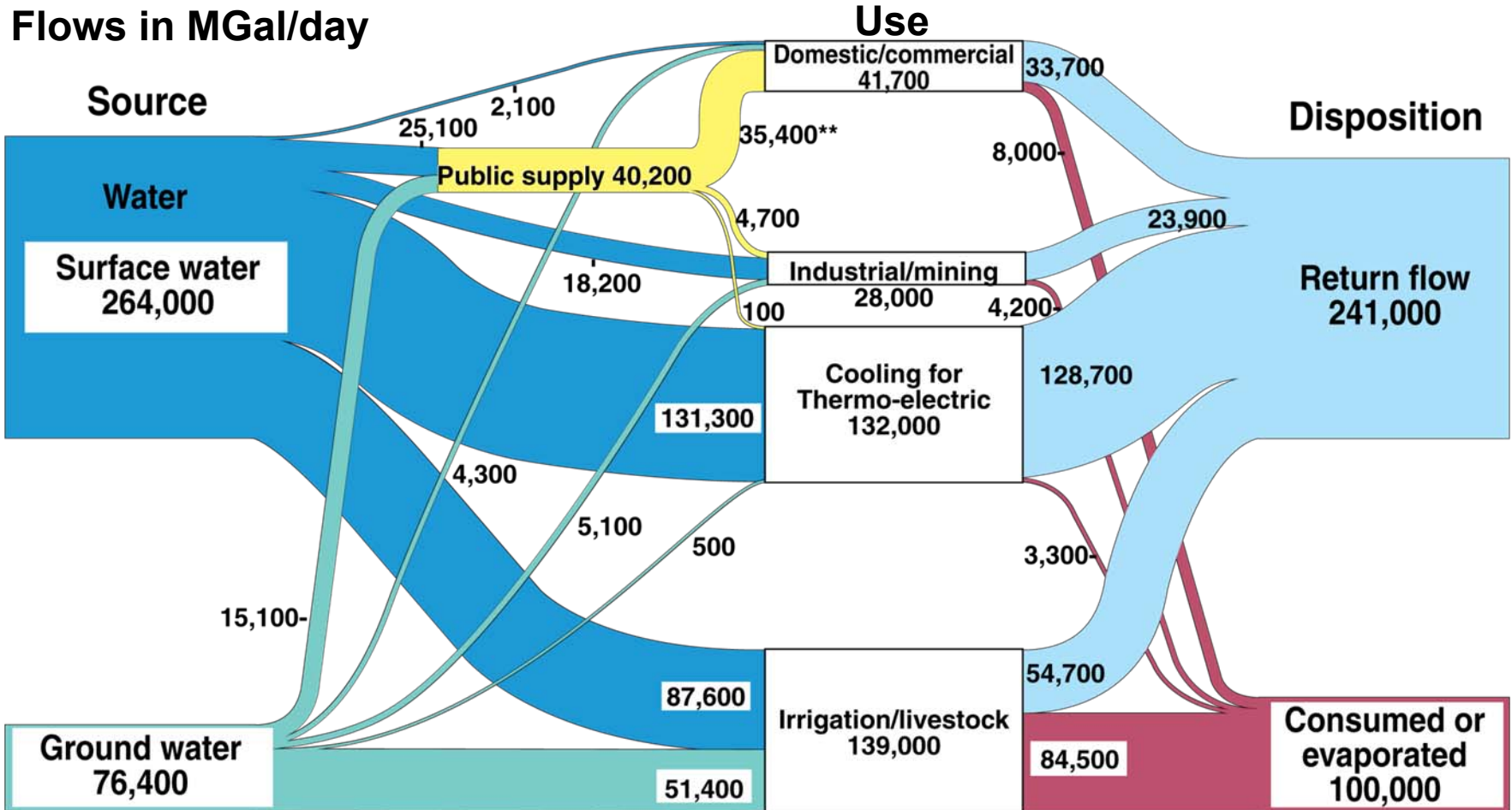
Partners



Objectives

- Quantify the *impact of water* on a future hydrogen economy
 - Economic impact of water prices on hydrogen production
 - Regional impact of hydrogen production on regional water resources
- Production Barrier D: Feedstock Issues
 - Energy-Water Nexus
- Systems Analysis Barrier A: Future Market Behavior
 - Timing and magnitude of H₂-Water stresses

Relevance: feedstock - the energy-water nexus



Source: U.S. Geological Survey, Publication 1998-064214.

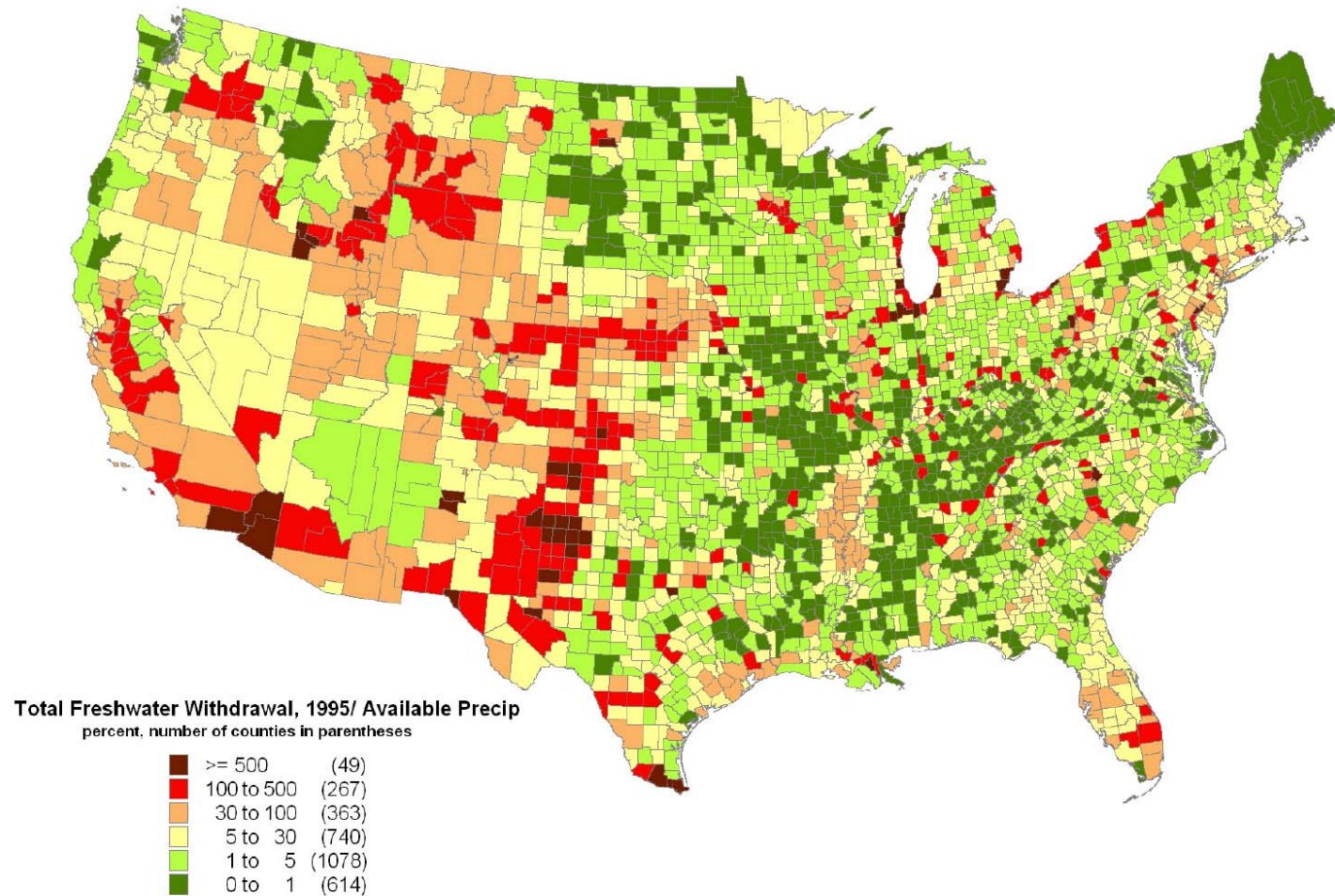
*In addition, 60,800 Mgal/day of saline water was withdrawn, primarily for thermo-electric use.

**Includes public use and losses of 5,980 Mgal/day.

Note: Numbers shown may not add to totals because of independent rounding.

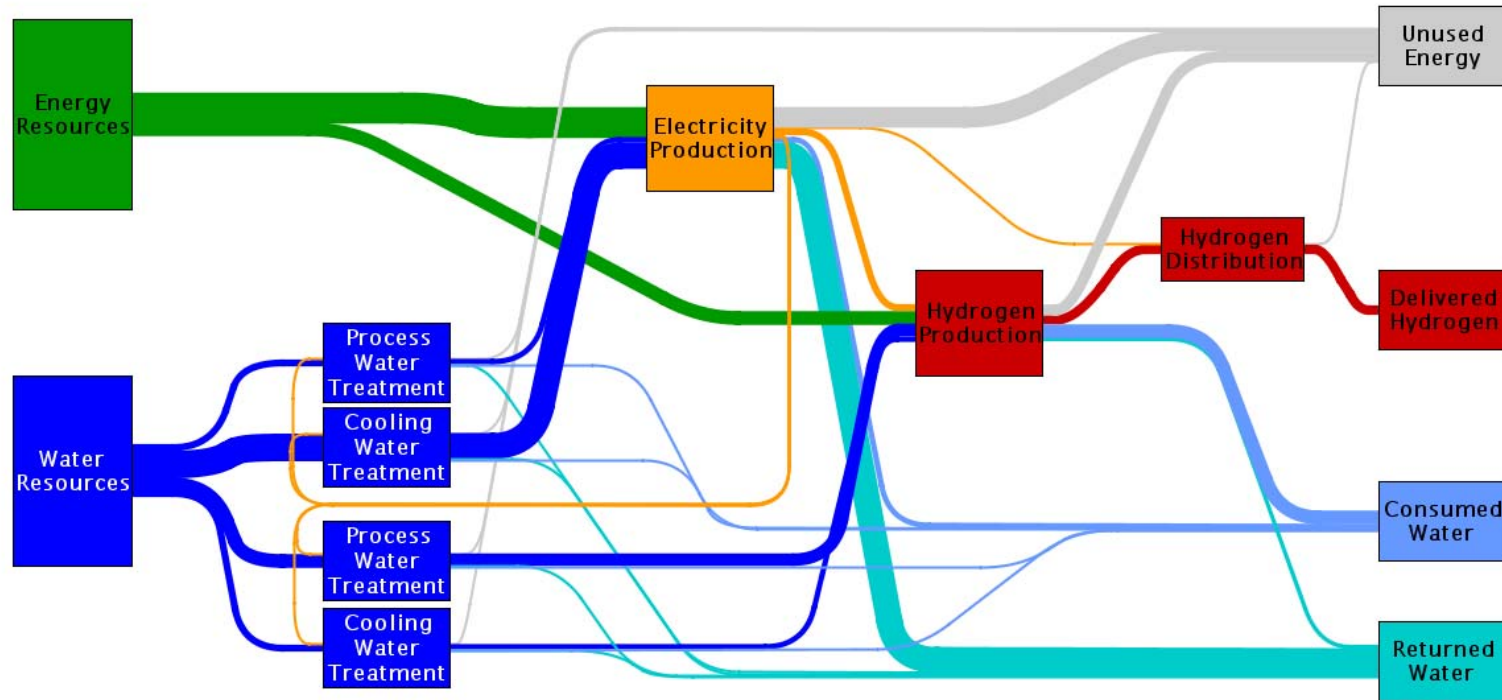
Lawrence Livermore National Laboratory, April 2003

Relevance: markets – timing and magnitude of water stress



EPRI, 2003

Approach: Water and energy material balances



- Returned Water
- Hydrocarbon or Renewable Energy
- Hydrogen Fuel
- Electricity
- Unused Energy

Approach: lifecycle analysis

- Level 1: hydrogen production process inputs
 - Process water
 - Cooling load
 - Electricity
 - Feedstock/fuel
- Level 2: cooling system
 - Water withdrawal
 - Water disposal
 - Electricity
- Level 3: water treatment
 - Water disposal
 - Electricity

Process model

- Level 4: electricity and feedstock
 - Water withdrawal
 - Water consumption
- Level 5: hydrogen dispensing process inputs
 - Electricity
 - Fuel

Regional analysis

Approach: H2A/MSM Integration

- Process water
 - Vendor information
- Cooling load
 - Calculate from energy balance
- Electricity demand
 - Direct from H2A spreadsheet
- Feedstock/fuel
 - Direct from H2A spreadsheet

Other Materials and Byproducts

Select the Material
 Byproduct

Feed or utility	Cooling Water	
\$(2005)/gal	Use H2A Default	\$0.000079
Usage per kg H2 (gal)		
Cost in Startup Year		\$0
Lookup Prices	Yes	

OR

Feed or utility	\$(2005)/gal	Usage per kg H2 (gal)	Cost in Startup Year	Lookup Prices
Process Water	0.0016654	5.77	\$4,482	Yes

Total Non Energy Utility and Material Costs (\$/year)	\$4,482
Total Non Energy Byproduct Credits (\$/year)	\$0
Total Feedstock Costs (\$/year)	\$508,426
Total Utility Costs (\$/year)	\$46,733
Total Byproduct Credits (\$/year)	\$0

Other Variable Operating Costs

Other variable operating costs (e.g. environmental surcharges) (\$/year)	\$1,800.00	Notes This covers waste disposal costs, non-feedstock fuels, environmental surcharges, etc. and is estimated at \$800/month with 50% being attributed to H2A.
Other Material Costs (\$/year)	\$0	
Waste treatment costs (\$/year)		
Solid waste disposal costs (\$/year)		
Total Unplanned Replacement Capital Cost Factor (% of total direct depreciable costs/year)	0.00%	
Royalties (\$/year)	\$0.00	
Operator Profit (\$/year)	\$0.00	
Subsidies, Tax Incentives (\$/year)	\$0.00	
Refueling Station O&M costs (\$/year)	\$0.00	
Total Variable Operating Costs (\$/year)	\$556,958.75	

H2a Default H2a Default H2a Default

Click to enter data for specific years on Replacement Costs Sheet

Enter as a positive number
See Capital Costs section above to link to the Refueling Station calculation sheet

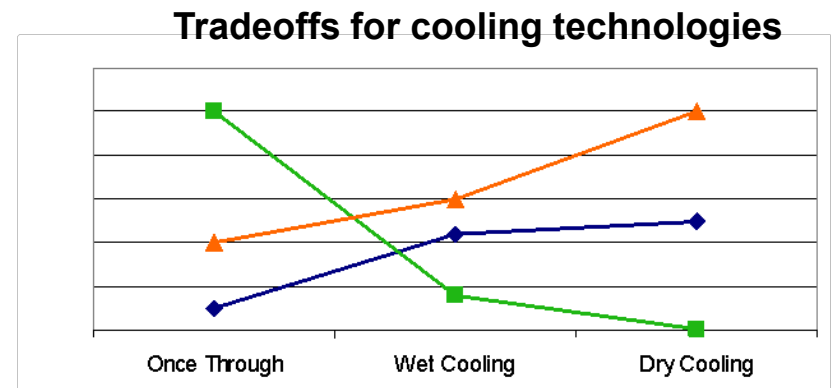
Title Description ProcessFlow Input_Sheet_Template Replacement_Costs Capital_Costs Refueling_Station Results Cash_Flow_Analysis Tornado_Chart Sensitivity_A

DOE Hydrogen Program, 2008

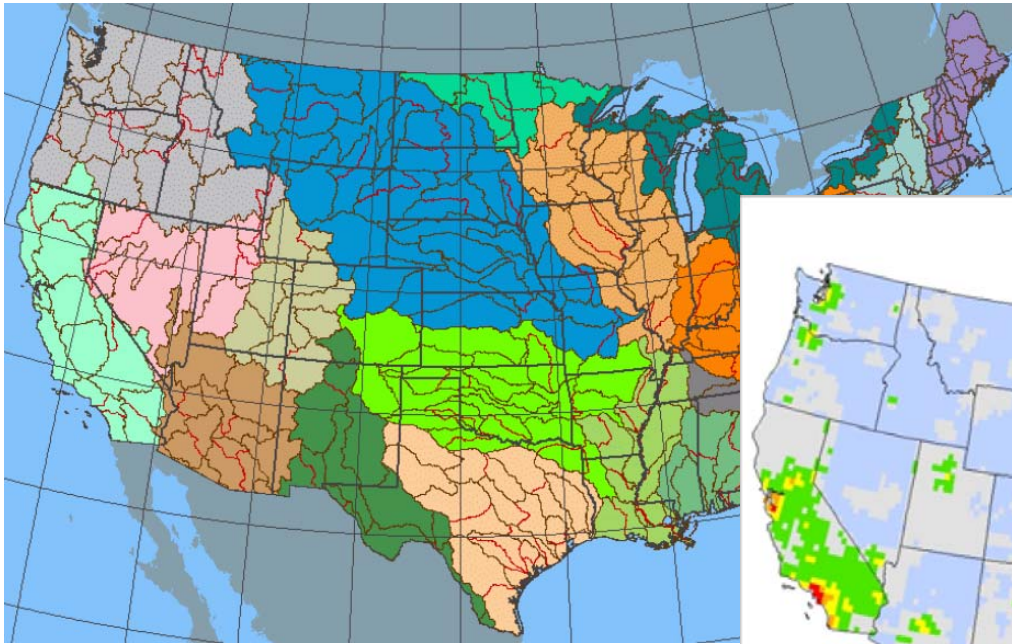


Approach: Economic optimization

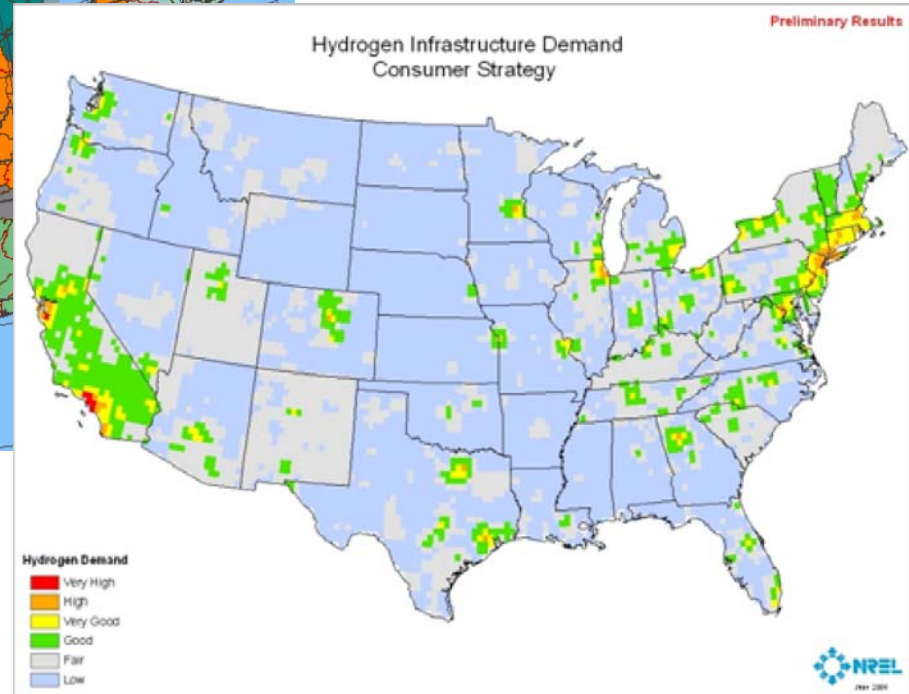
- Different water treatment and cooling technologies have different capital vs. O+M (water and electricity purchase) tradeoffs.
- Find the plant-gate water price cutoffs that mark the transition between increasingly water-conserving technologies.
- Perform sensitivity analysis to:
 - plant gate water quality
 - electricity price



Approach: regional watersheds and demand



Dept. of Interior 2009



NREL, 2008

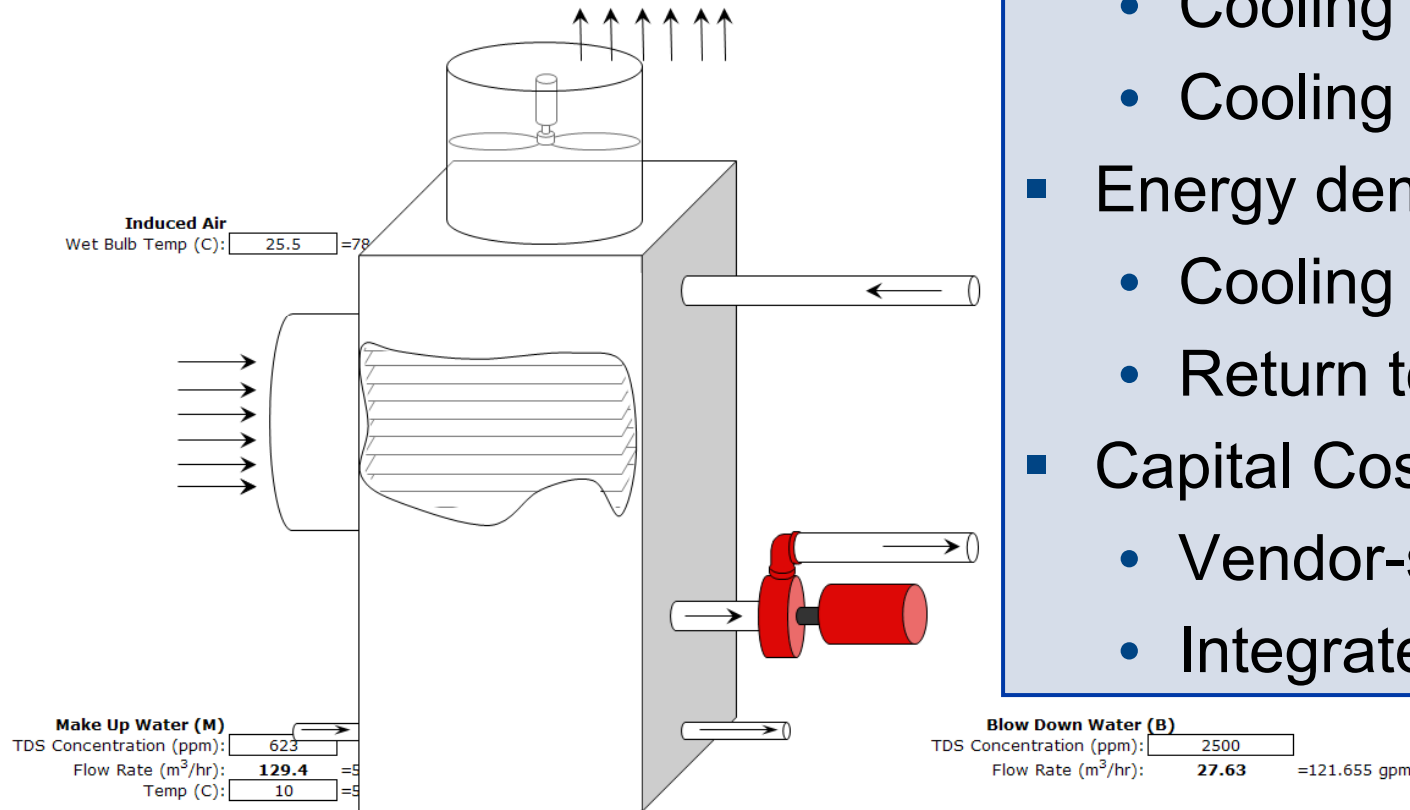
Accomplishments: cooling technology analysis

Scenario 1b, Single Cell for evapco

Water Losses (L)

Drift (%)	0.025%
Blow Out (%)	0.025%
Total (%)	0.050%

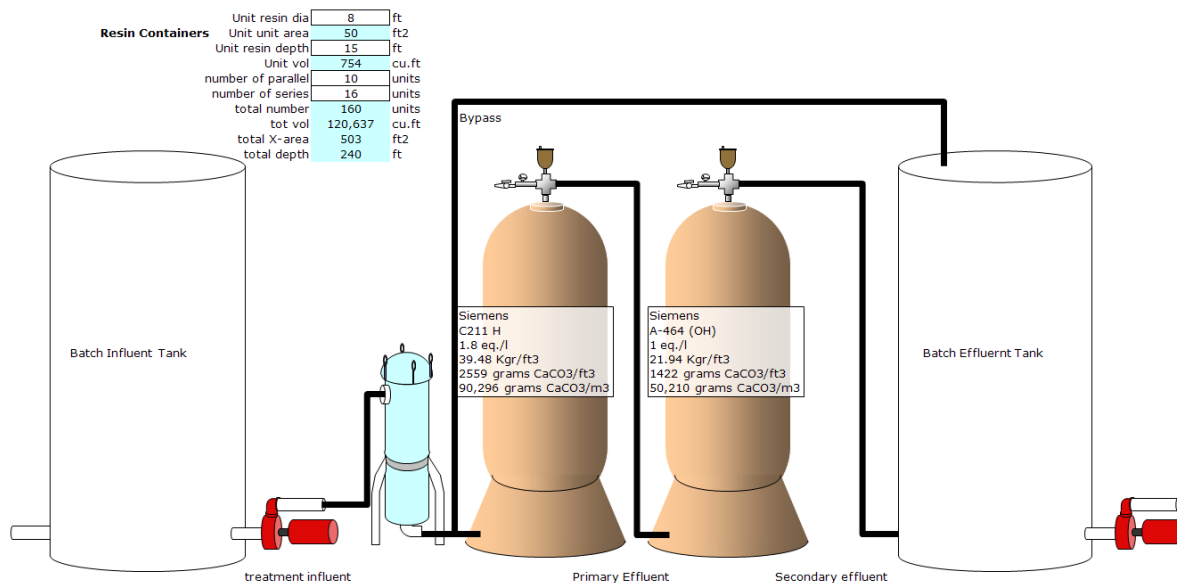
Total minor losses (m ³ /hr)	4.54	=20 gpm
Evaporation (m ³ /hr)	97.21	=428.03 gpm
Total Losses (m ³ /hr)	101.75	=448.03 gpm



- Circulation/makeup
 - Cooling tower model
 - Cooling load
- Energy demand
 - Cooling tower model
 - Return to H2A
- Capital Cost
 - Vendor-specific
 - Integrate into H2A

Accomplishments: treatment technology analysis

- Withdrawal/consumption
 - Treatment model
 - Return to H2A “other”
- Energy demand
 - Integrate into H2A “electricity”
- Operating Expense
 - Treatment model
 - Return to H2A “other”
- Capital Cost
 - Integrate into H2A



Collaborations

- Energy-Water nexus group
 - NETL
 - Sandia
 - UND EERC
- NREL
 - MSM team
 - RPM/HyDRA



Future Work

- Develop understanding of water economics
- Assess key regional scenarios
- Assess climate change related concerns
- Perform rigorous engineering analysis
- Integrate with MSM
- National scenario analysis



Summary

- Energy-water nexus affects all future fuels
 - Hydrogen, Biofuels, EV/PHEV, GTL, CTL...
- Plant level analysis feeds cost/price curve directly
 - Water saving technologies limit cost impact at high water prices
- Water impact analysis is fundamentally regional
- H2A framework provides “plug-in” to MSM
- Water permitting is likely to be a bigger impediment to hydrogen adoption than water price