Lawrence Livermore National Laboratory

Water's Impacts on Hydrogen

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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

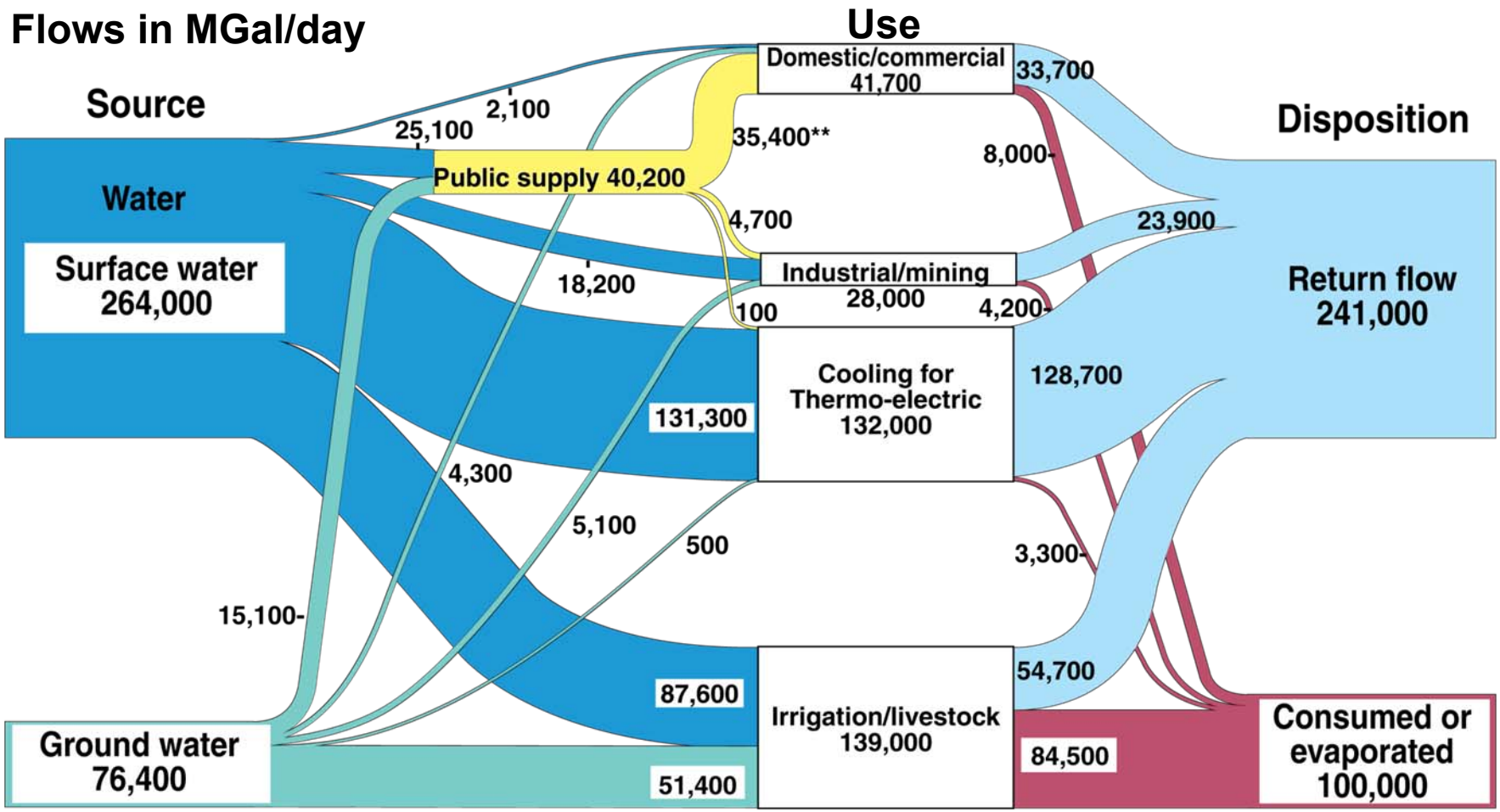
- **NREL**
  - HyDRA, MSM Coordination
- **Sandia**
  - MSM Interface, Water Model

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 H_2-Water stresses

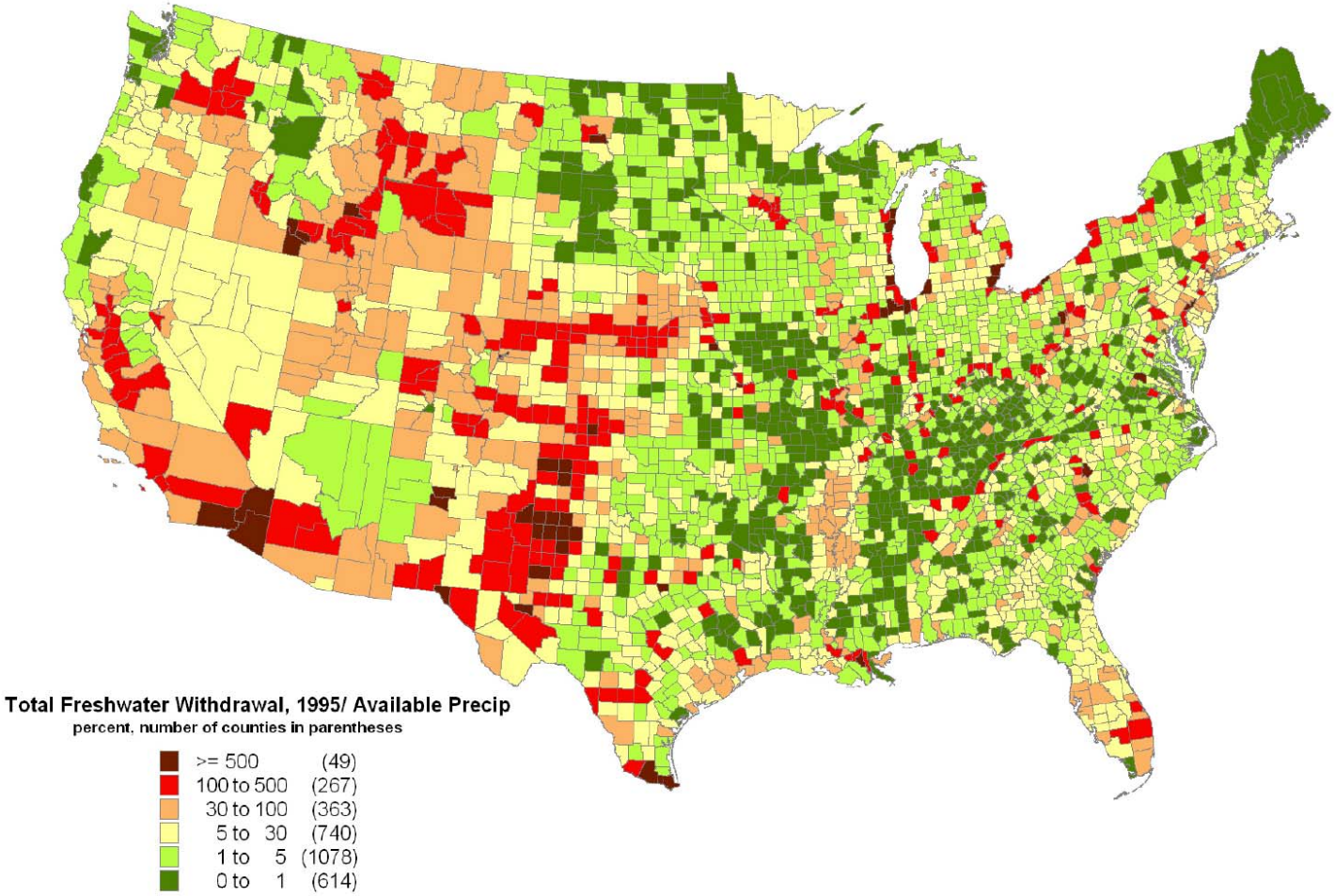
Relevance: feedstock - the energy-water nexus



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*In addition, 60,800 Mgal/day of saline water was withdrawn, primarily for thermo-electric use.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

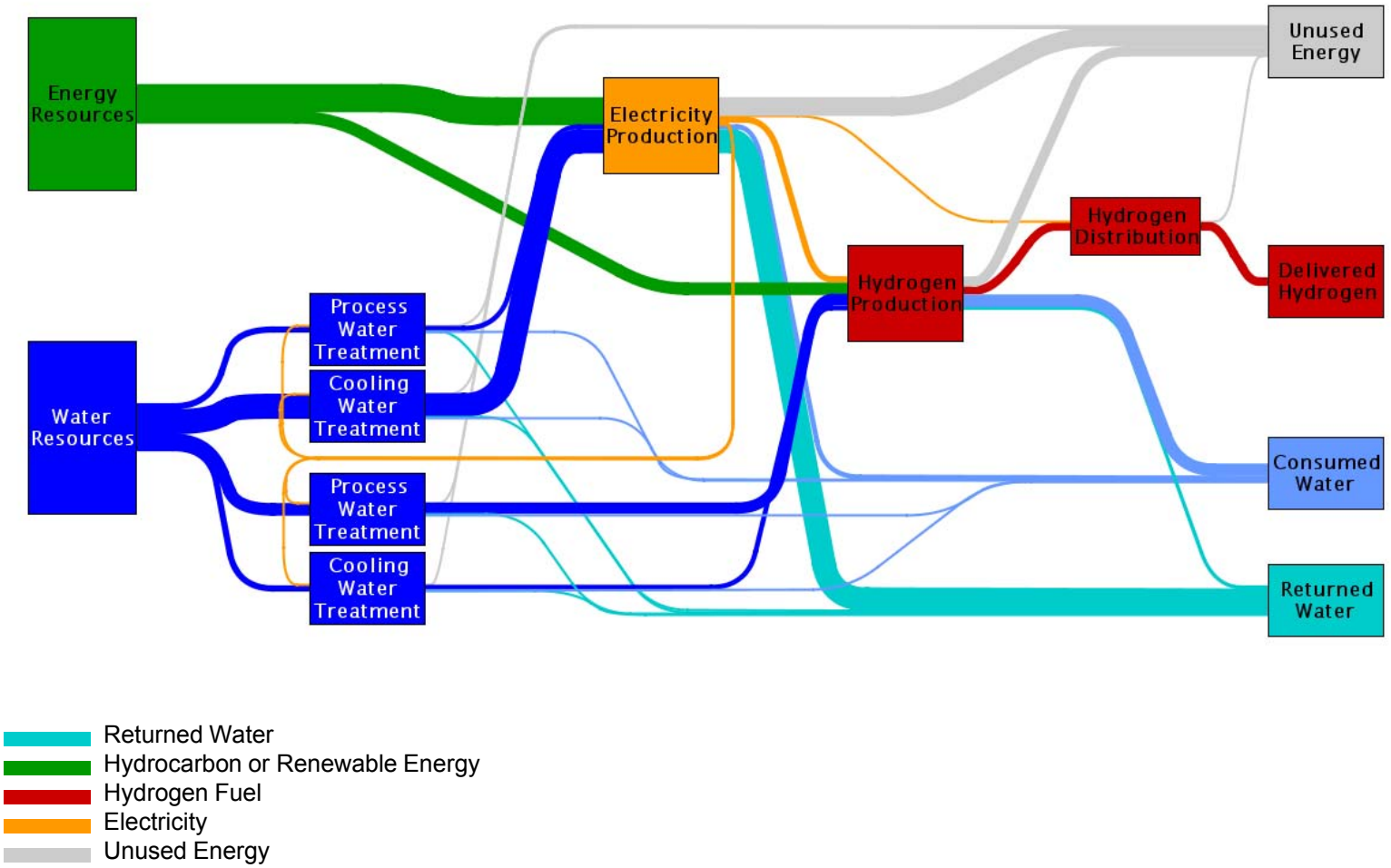
Lawrence Livermore National Laboratory, April 2003

Relevance: markets – timing and magnitude of water stress



EPRI, 2003

Approach: Water and energy material balances



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

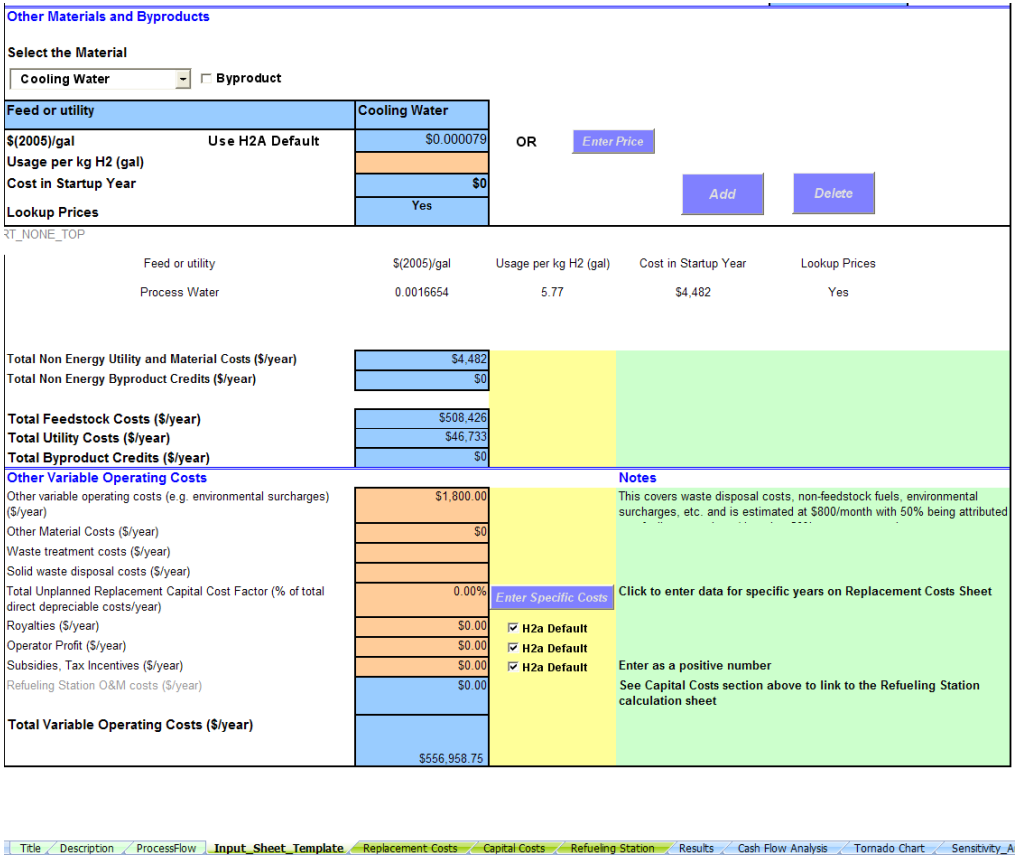
Process model

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

Regional analysis

Approach: H2A/MSM Integration

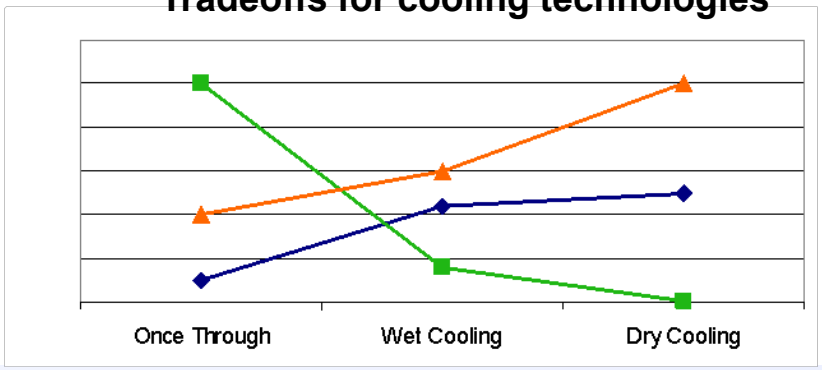
- Process water
  - Vendor information
- Cooling load
  - Calculate from energy balance
- Electricity demand
  - Direct from H2A spreadsheet
- Feedstock/fuel
  - Direct from H2A spreadsheet



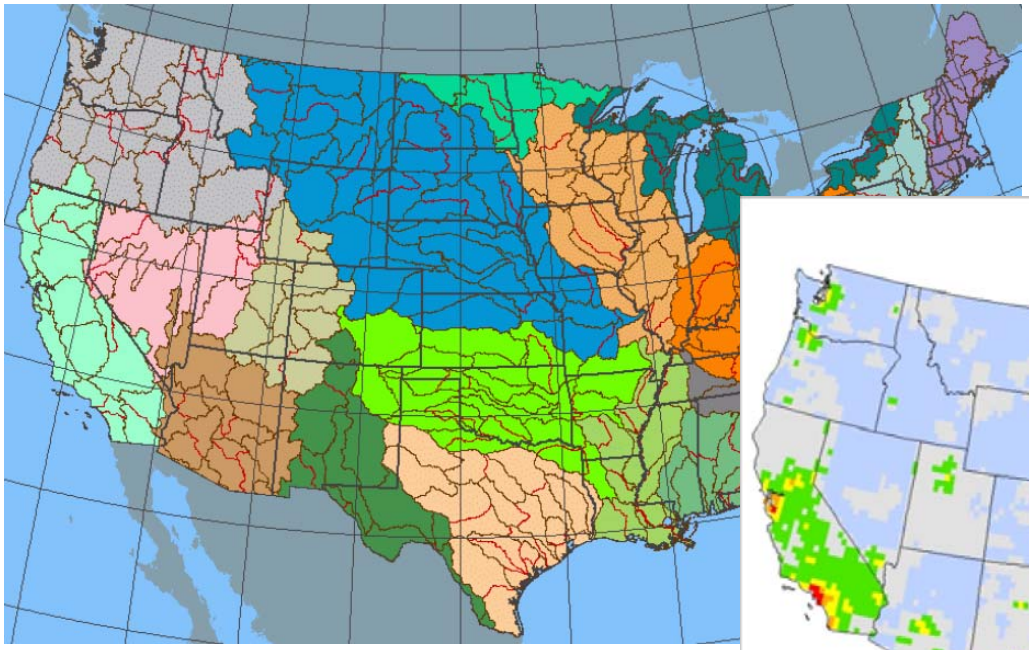
DOE Hydrogen Program, 2008

Approach: Economic optimization

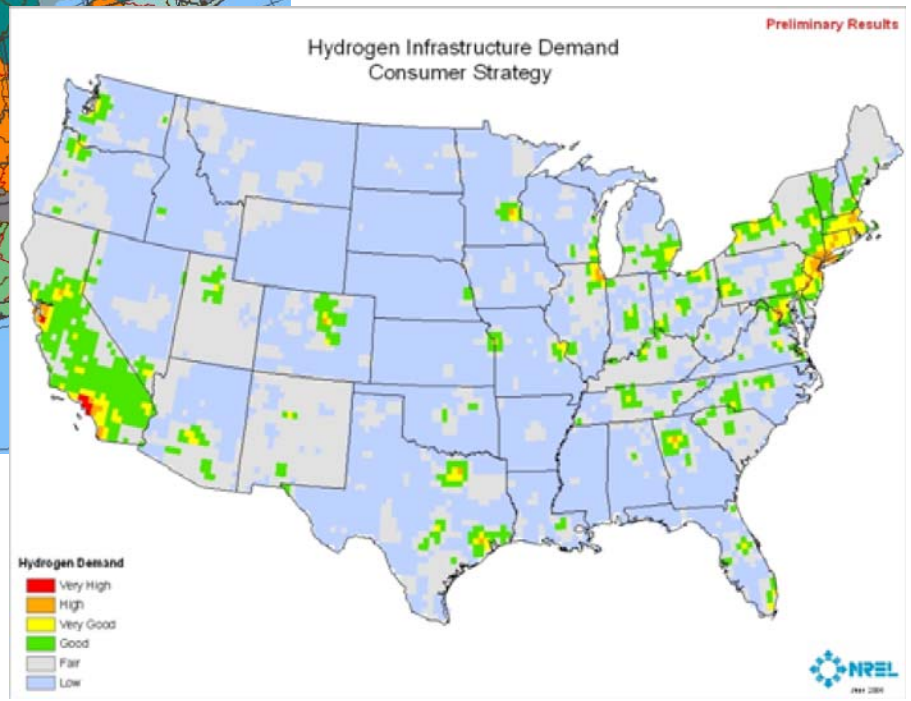
- Different water treatment and cooling technologies have different capital vs. O+M (water and electricity purchase) tradeoffs.
- Find the plant-gate water price cutoffs that mark the transition between increasingly water-conserving technologies.
- Perform sensitivity analysis to:
  - plant gate water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



Approach: regional watersheds and demand

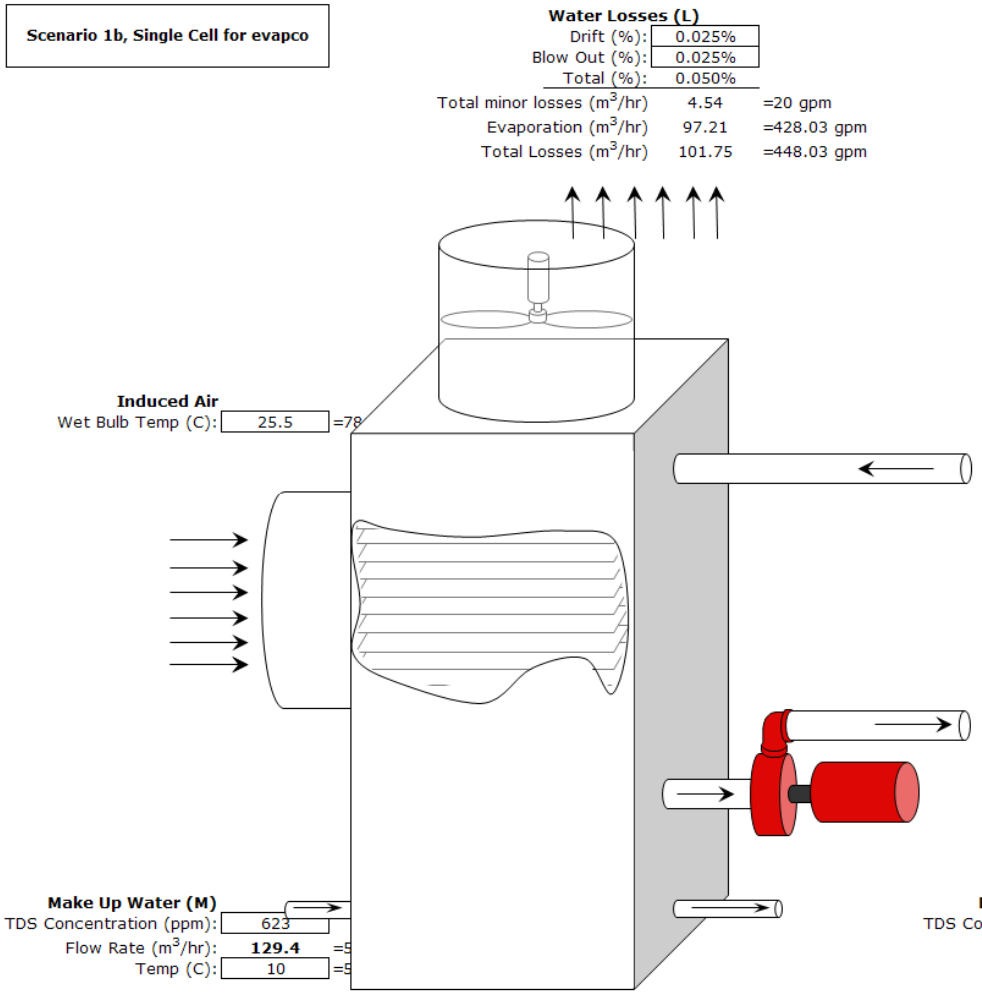


Dept. of Interior 2009



NREL, 2008

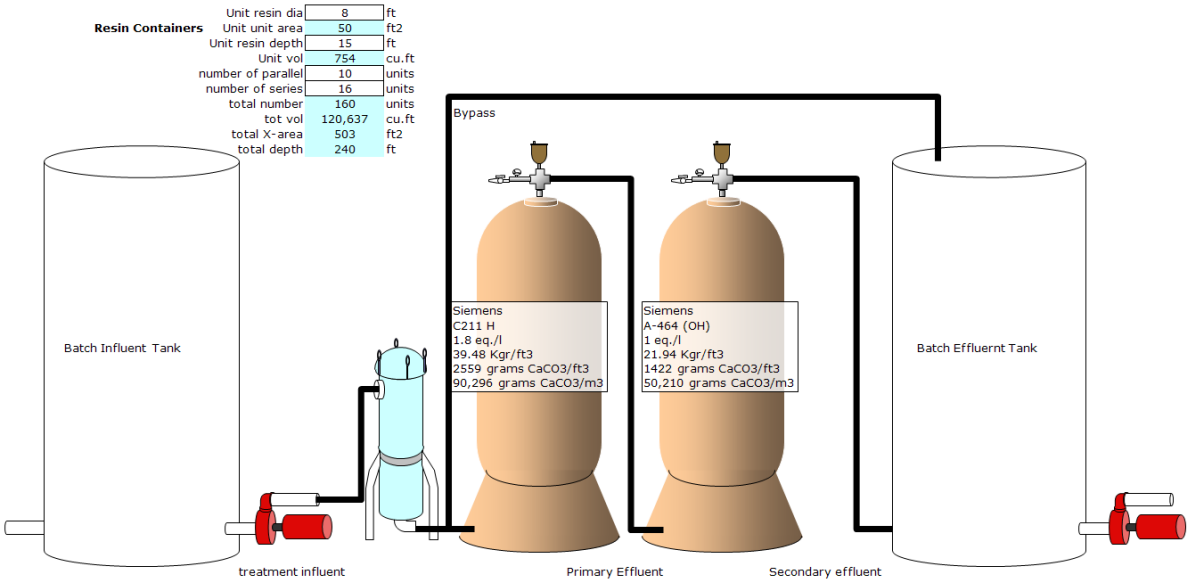
Accomplishments: cooling technology analysis



- 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