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A River of Energy Solutions

Future Infrastructure, Desalination and Security

Phillip Isabio Pohl, PhD

Energy, Security and Defense Technologies
Sandia National Laboratories, Albuquerque, New Mexico

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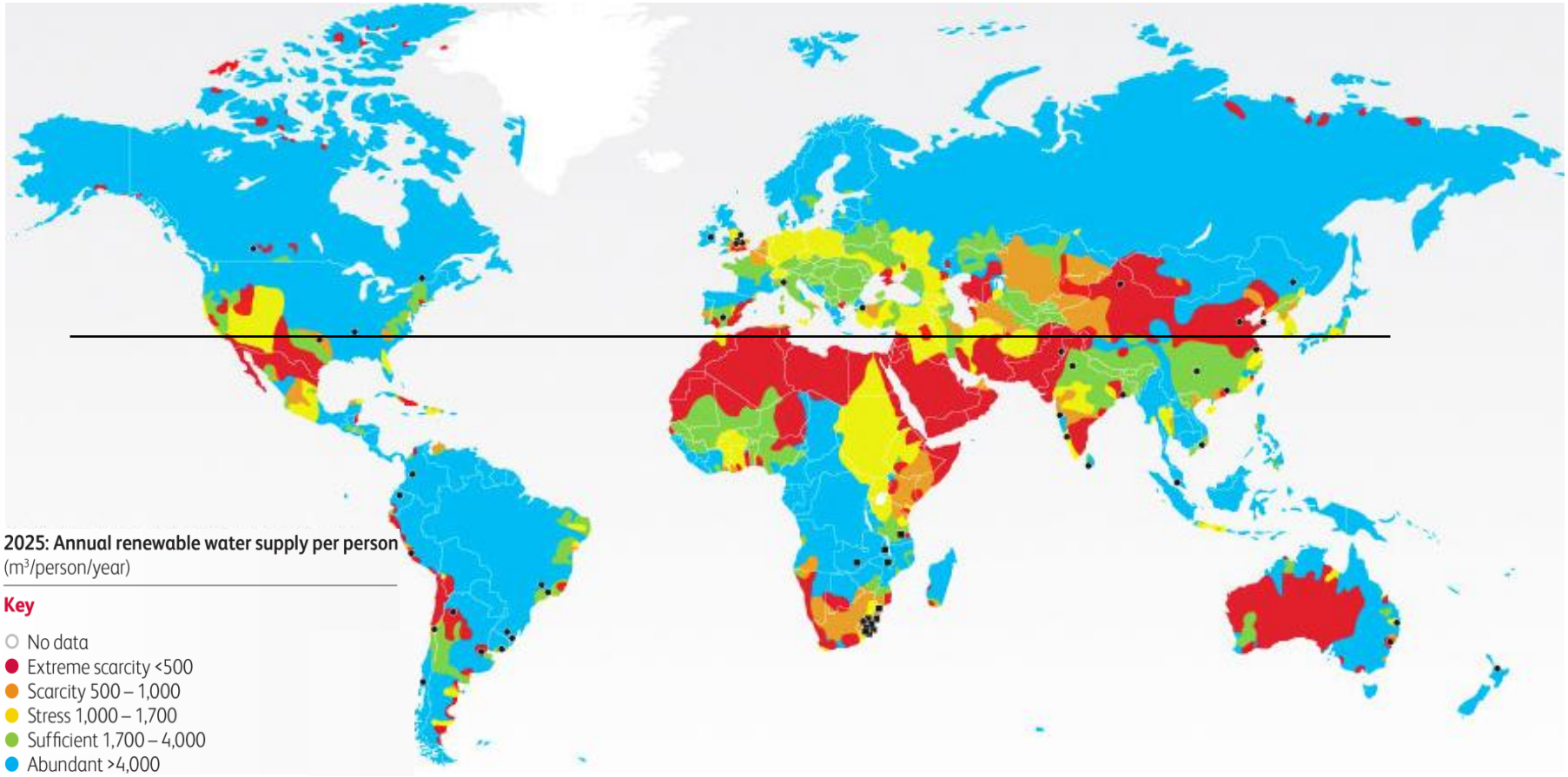
Outline

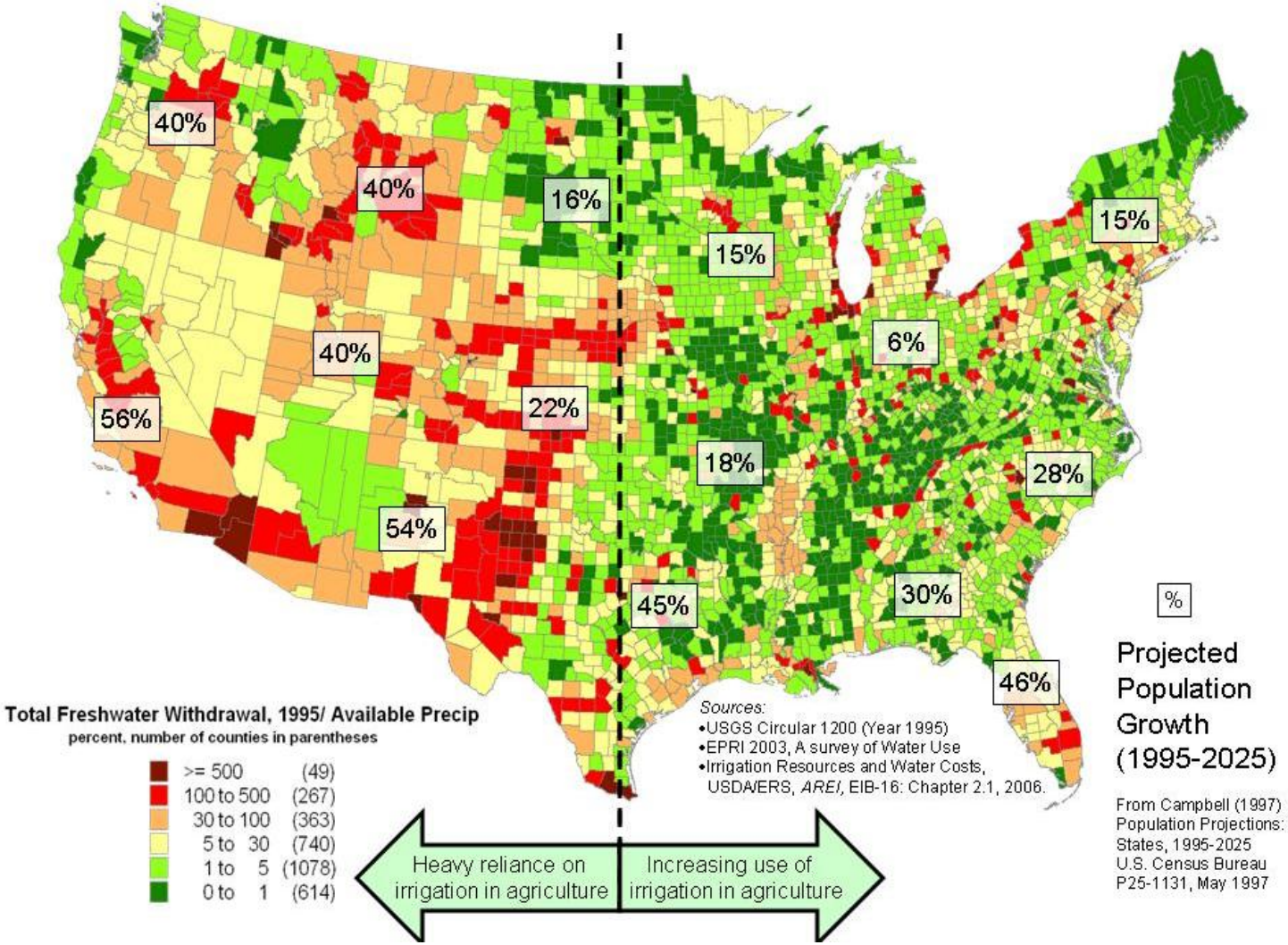
- Why water?
- Energy-Water and Biofuels
- Agriculture and Water Reuse
- Desalination and Water Treatment
- Decision Support Tool Development

Water Stress - 2025



(World Business Council for Sustainable Development's World Water Tool, 2010.)

Water challenges are nationwide



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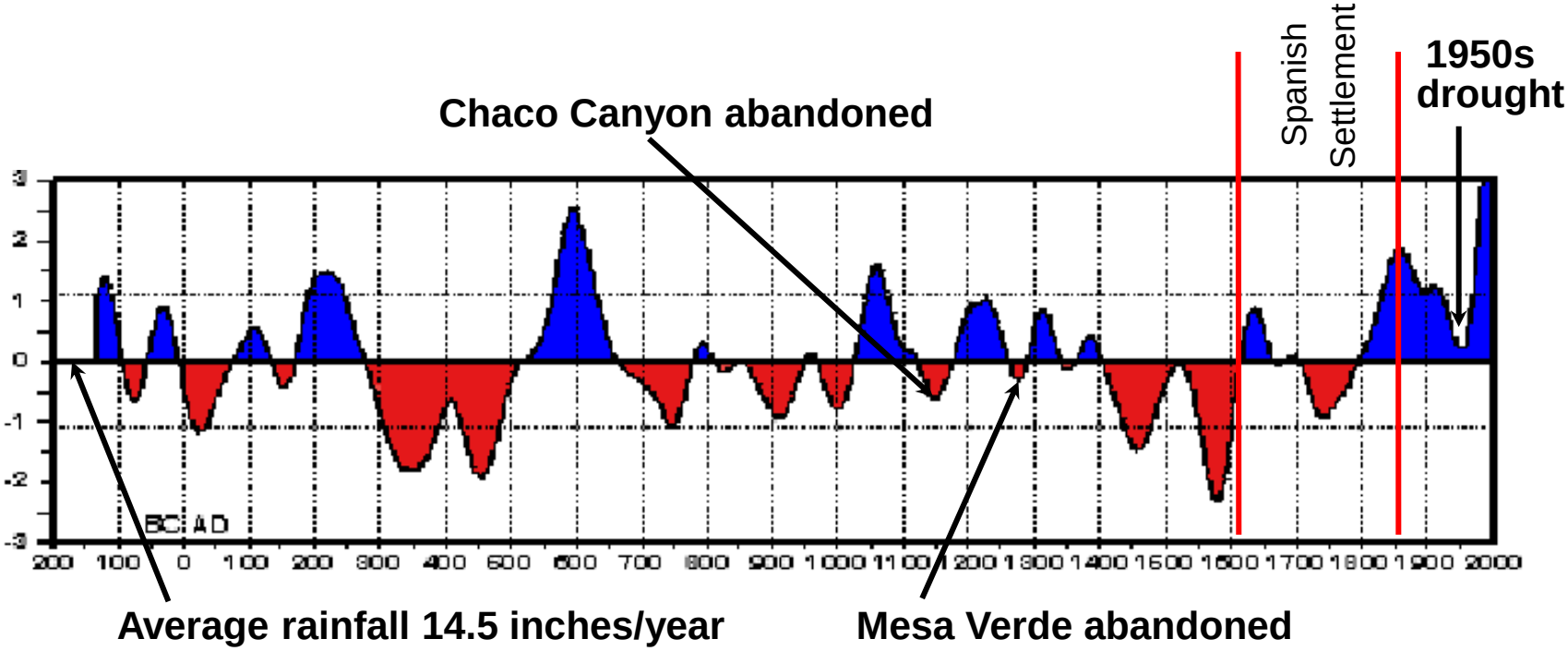
NM Rainfall & Culture Over 2000 Years

Tree ring data from El Malpais National Monument



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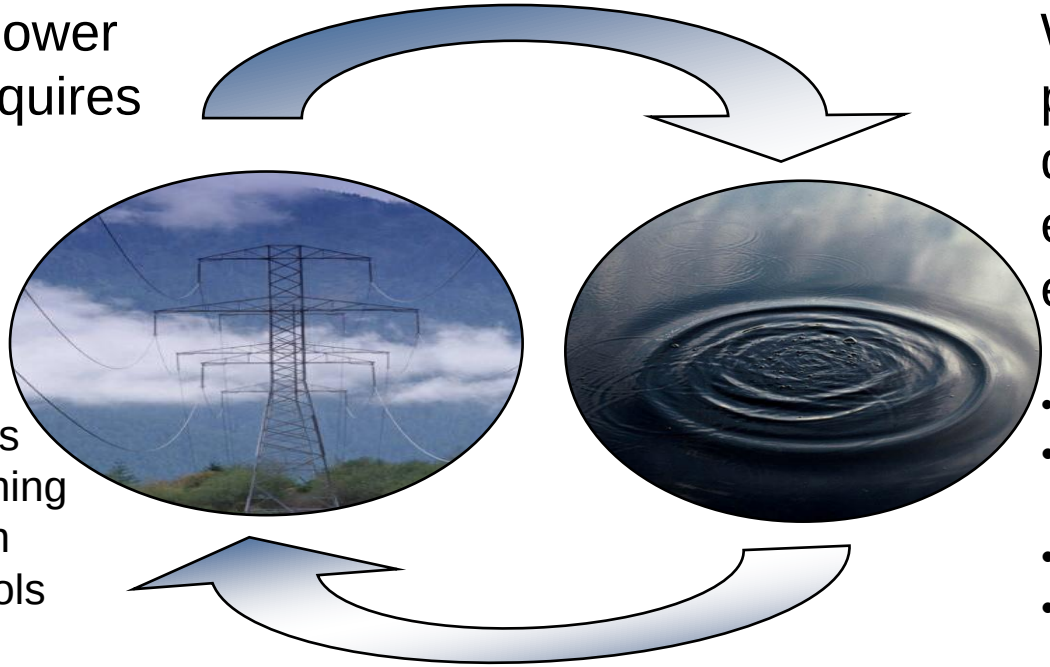
Energy and Water are… Inextricably linked

Water for Energy and ***Energy for Water***

Energy and power production requires water:

- Thermoelectric cooling
- Hydropower
- Energy minerals extraction / mining
- Fuel Production
- Emission controls

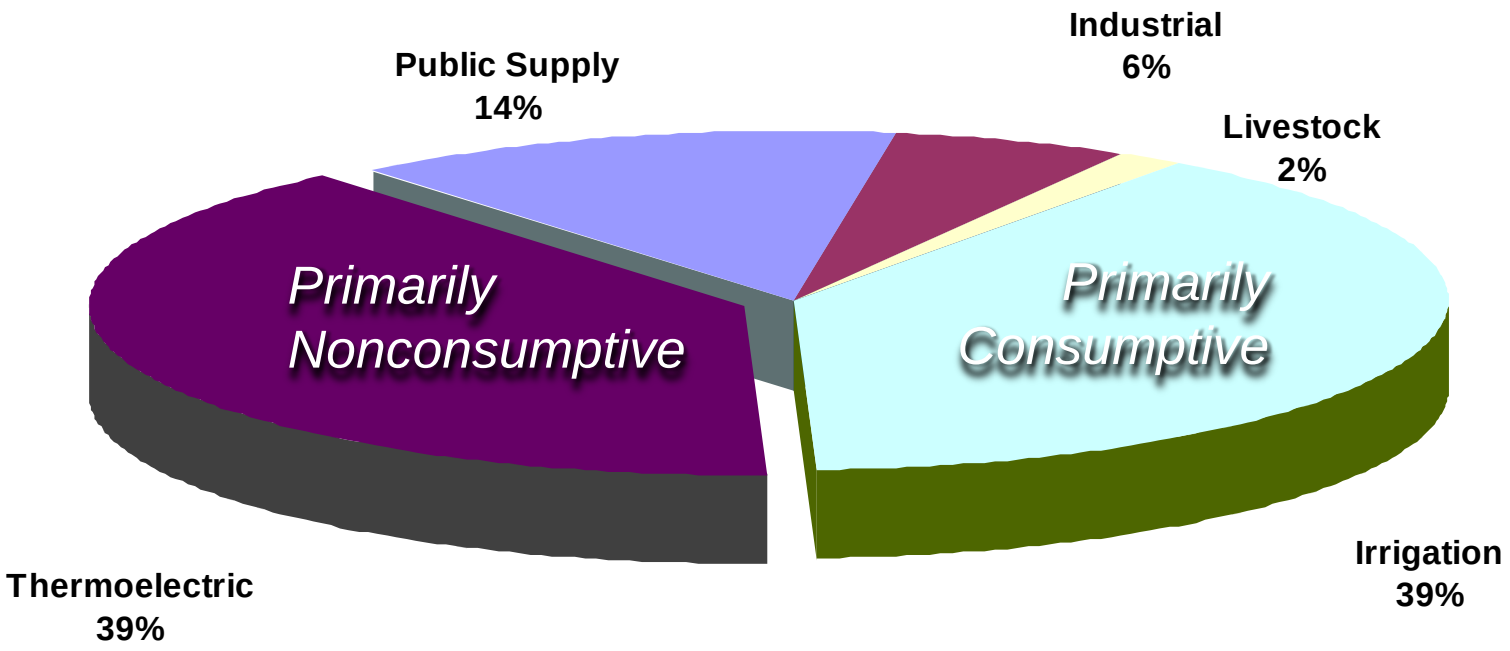


Water production, processing, distribution, and end-use requires energy:

- Pumping
- Conveyance and Transport
- Treatment
- Use conditioning

Agriculture/Energy withdraw the most water

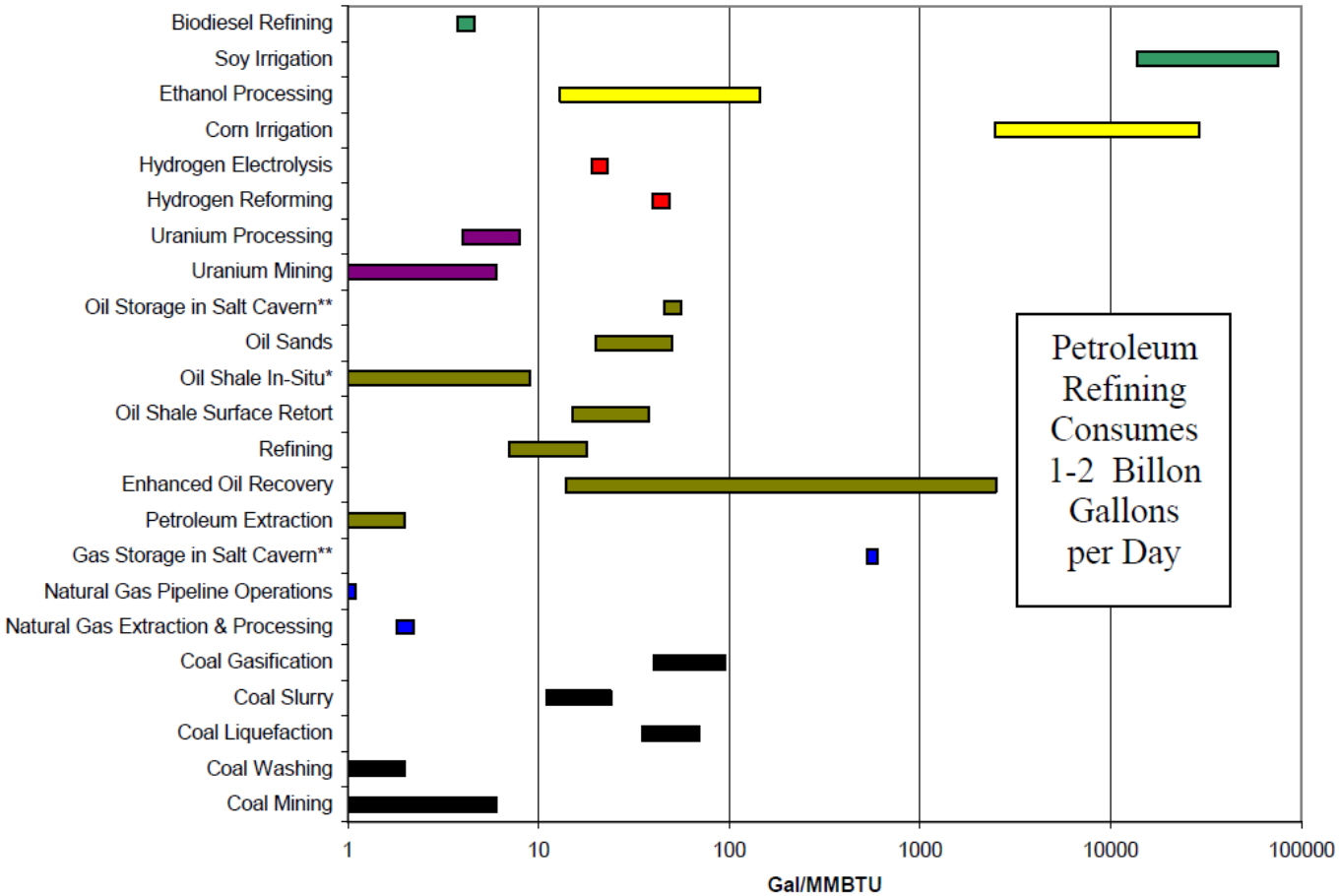
Estimated Freshwater Withdrawals by Sector, 2000



Source: USGS Circular 1268, March, 2004

Note:Hydropower uses are not included here!

Water Use for Fuel Extraction and Processing



From Energy Demands on Water Resources - Report to Congress, released in December, 2006, http://www.sandia.gov/energy-water/docs/121-RptToCongress-EWwEIAcomments-FINAL.pdf

Algae Biofuels and the Energy-Water Nexus

Among the major findings*:

- Water for Biofuels is an Emerging Issue
- Water Impacts of National Biofuels Scale-up Needs Attention
- Corroborated by 2007 National Academy Report
- **Need Biofuel Options that can Exploit Non-Fresh Water**

- We've been growing grass (e.g. corn) for food for thousands of years. Cellulosic bioenergy crops will be a straightforward development
- Algae present the greatest scale, sustainability, AND risk

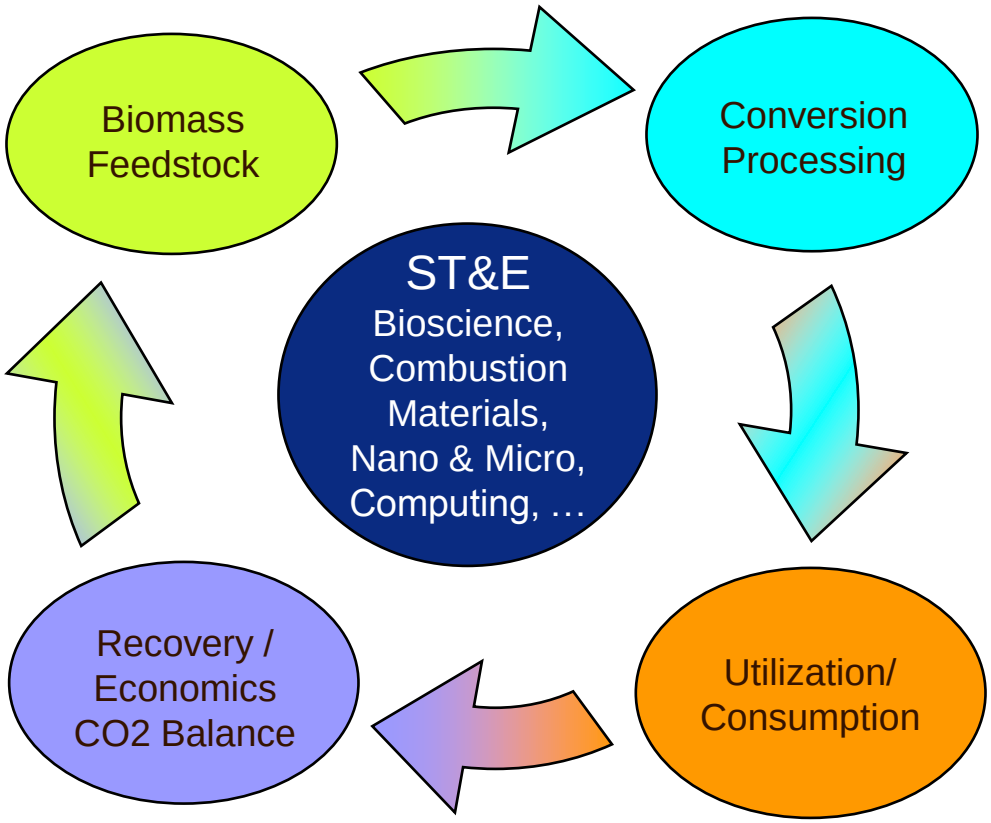
*(National Algal Biofuels Technology Roadmap, U.S. DOE, 2010)

Sandia's Biofuels Strategy:
A Systems Approach

Challenges
- Biomass
  - Production
  - Optimization
  - Pretreatment
  - Scale-up
- Sustainability
  - Water usage

Increase Yield

Challenges
- Biomass processing
  - Catalysis
  - Thermochemical
  - Biochemical
  - Scale-up
  - Microbial communities



Challenges
- Carbon Implications
  e.g. Co-siting with Coal-fired generators
- Biomass production
  e.g. Transportation costs & Water availability

Challenges
- Engine design
- Fuel Distribution
- Fuel Storage
- Materials Compatibility
- US Infrastructure Implications (Systems)

Our program is focused on two primary sources of biomass: cellulose & algae

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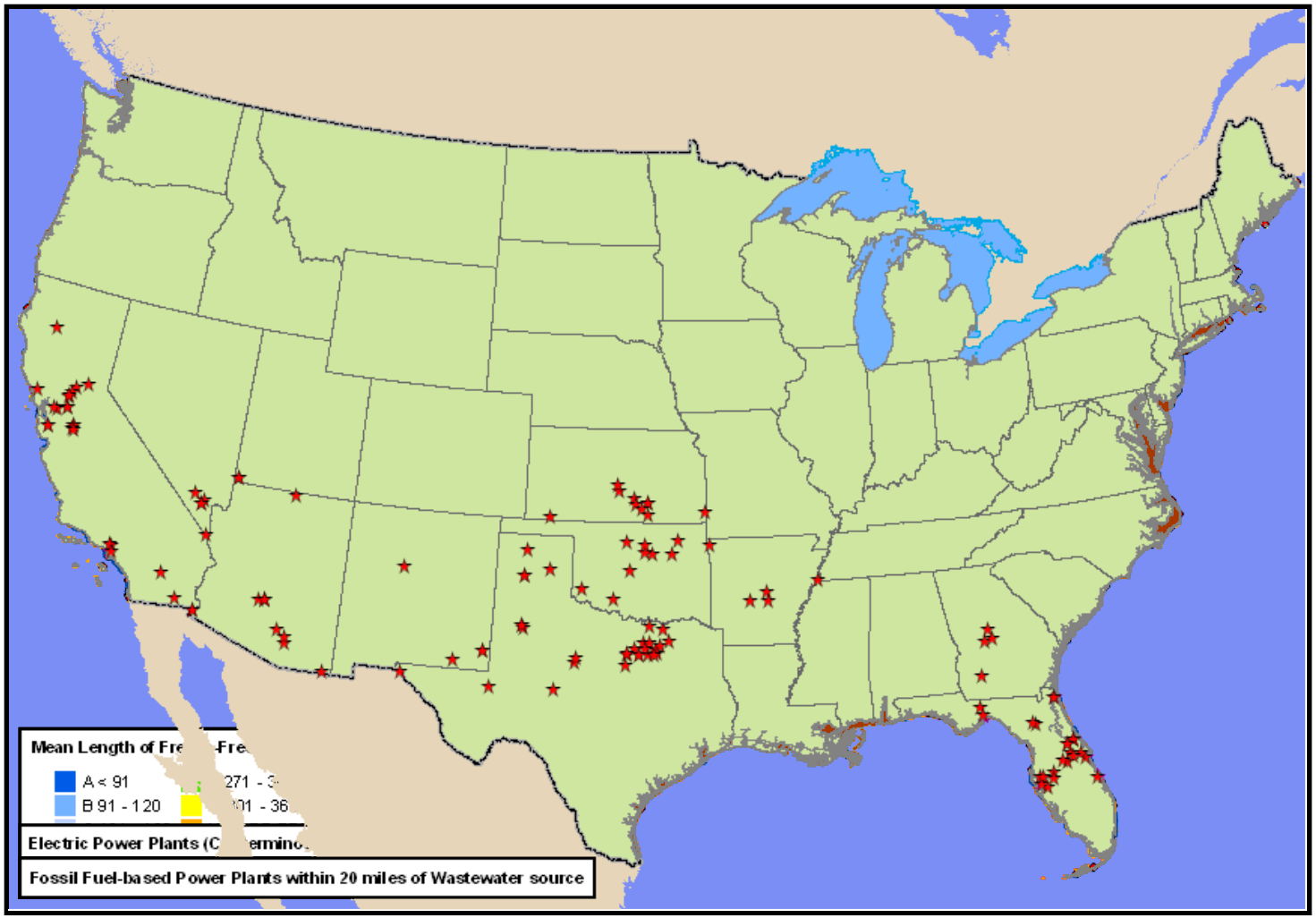
High Nutrient-Loaded Water Treatment

Generating biomass (chlorophyll) and removing ammonia from concentrated animal feeding operation (CAFO) wastewater.

(Photo courtesy Arizona State University)

Siting an Algae-Oil Production Facility



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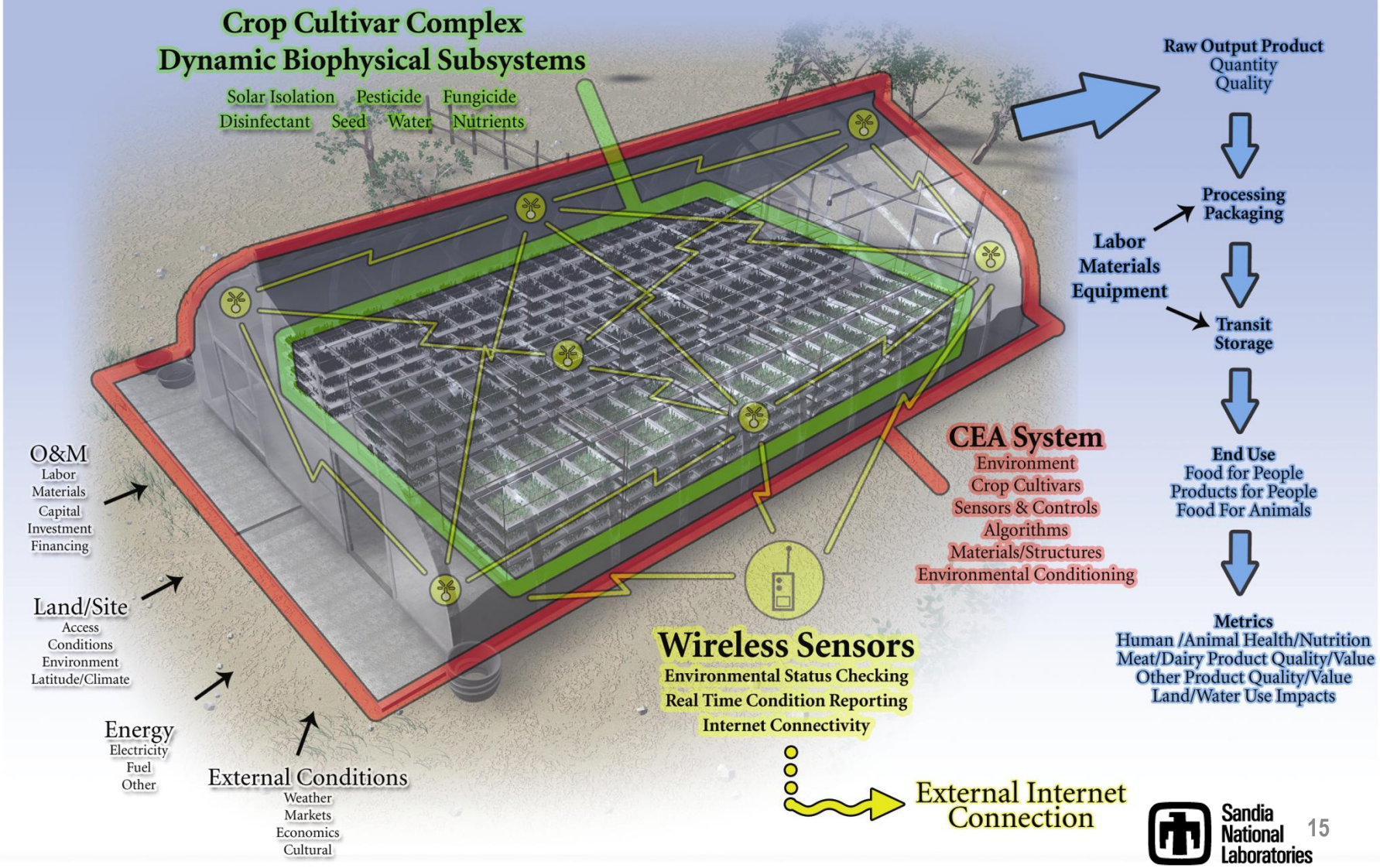
Controlled Environment Agriculture



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CEA's Efficiencies established for Tomatoes and Other High Value Crops

Hydroponic Citrus

(FW Environmental, Reedley, California)

- 1/15 water use
- Optimum product control
- Closed mineral cycle
- Produce fruit sooner
- Less Energy

What about Green Roofs?

Benefits: storm water management, improved public health from the absorption of nitrogen oxides, insulation

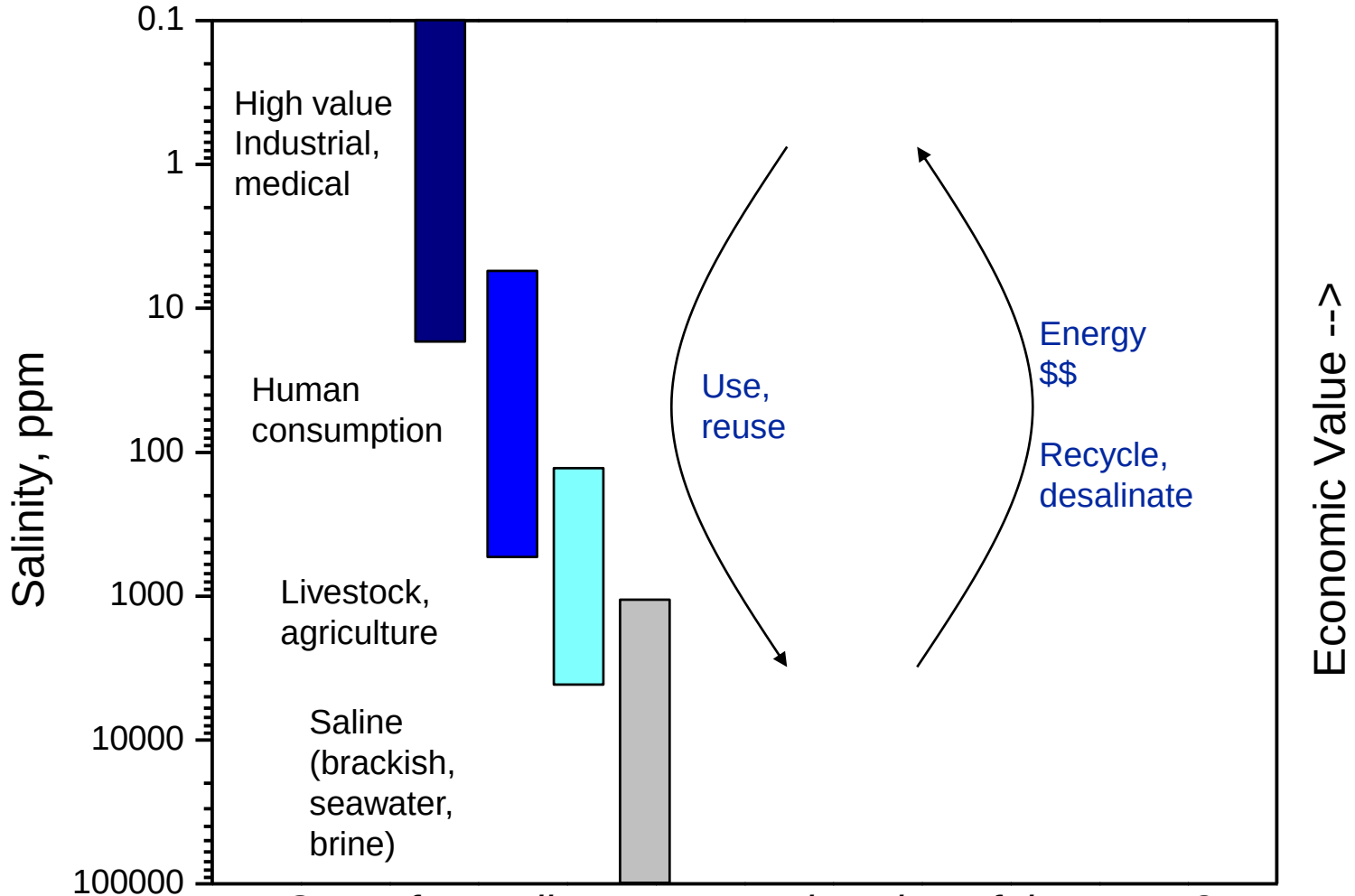
(Photo courtesy of Portland Bureau of Environmental Services)

Comparing costs of conventional roofs with the cost of 21,000 ft^2 (1,950 m^2) green roof*.

- green roof costs $464,000 installed vs. $335,000 for a conventional roof '06$
- over lifetime, the green roof save ~$200,000.
- ~2/3 of savings from reduced energy needs

*Clark, C., P. Adriaens, and F.B. Talbot. 2008. Green roof valuation: a probabilistic economic analysis of environmental benefits. *Environmental Science and Technology* 42(6):2155–2161.

Water is infinitely recyclable --- at a cost!



Cost of recycling < economic value of the water?

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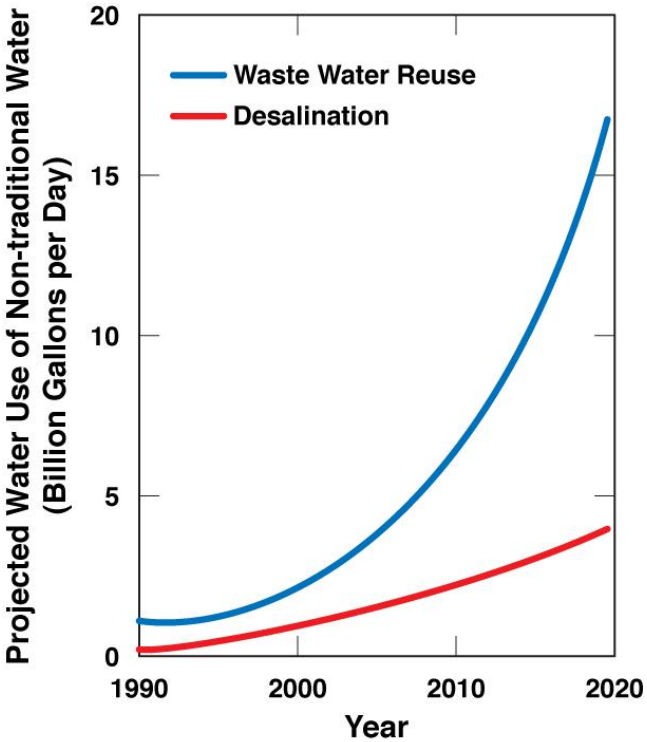
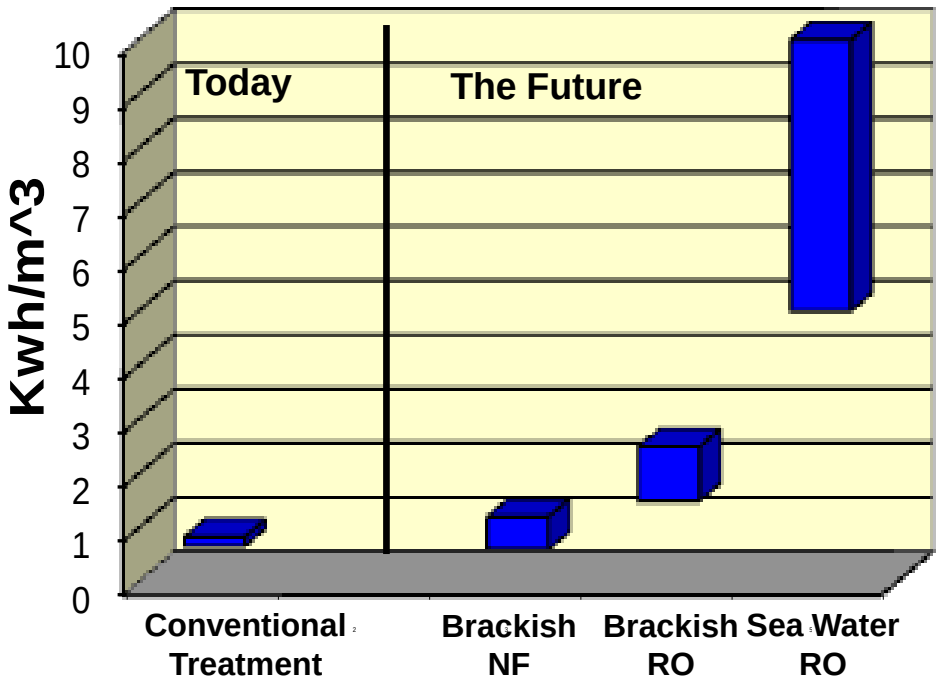
Water Demand Projection Model

Power Requirements For Treatment



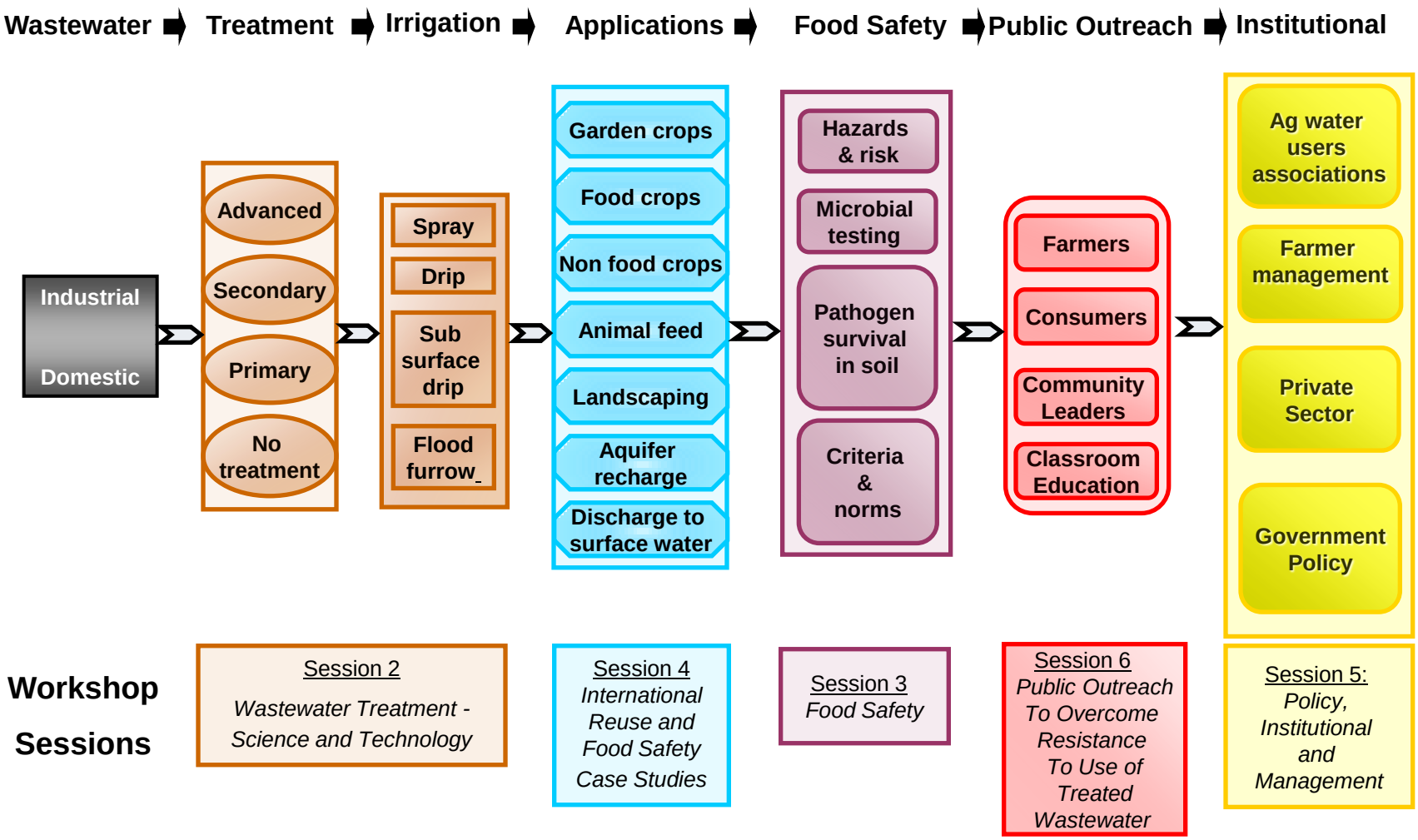
(Modified from EPA 2004, Water Reuse 2007, Mickley 2003)



(Einfeld 2007)

- Desal growing 10% per year, waste water reuse 15% per year
- Non-traditional water use is energy intensive

USDA Water Management & Food Safety



Middle East Partnership Initiative Water Reuse Workshops
(Tunis-'06, Rabat-'07, Muscat-'08)

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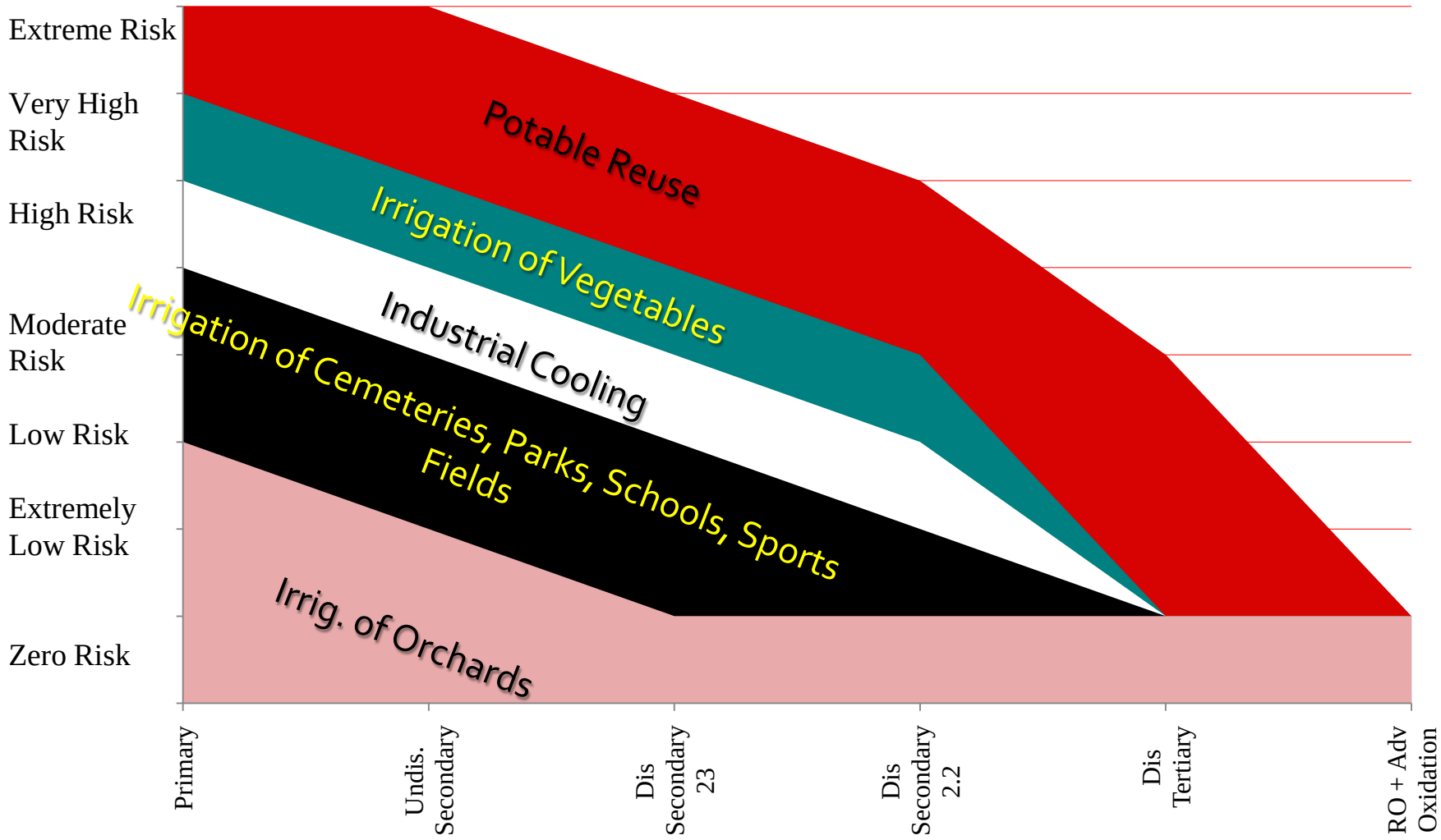
Risk Vs. Use Vs. Treatment



(from: Bahman Sheikh, PhD, PE, San Francisco)

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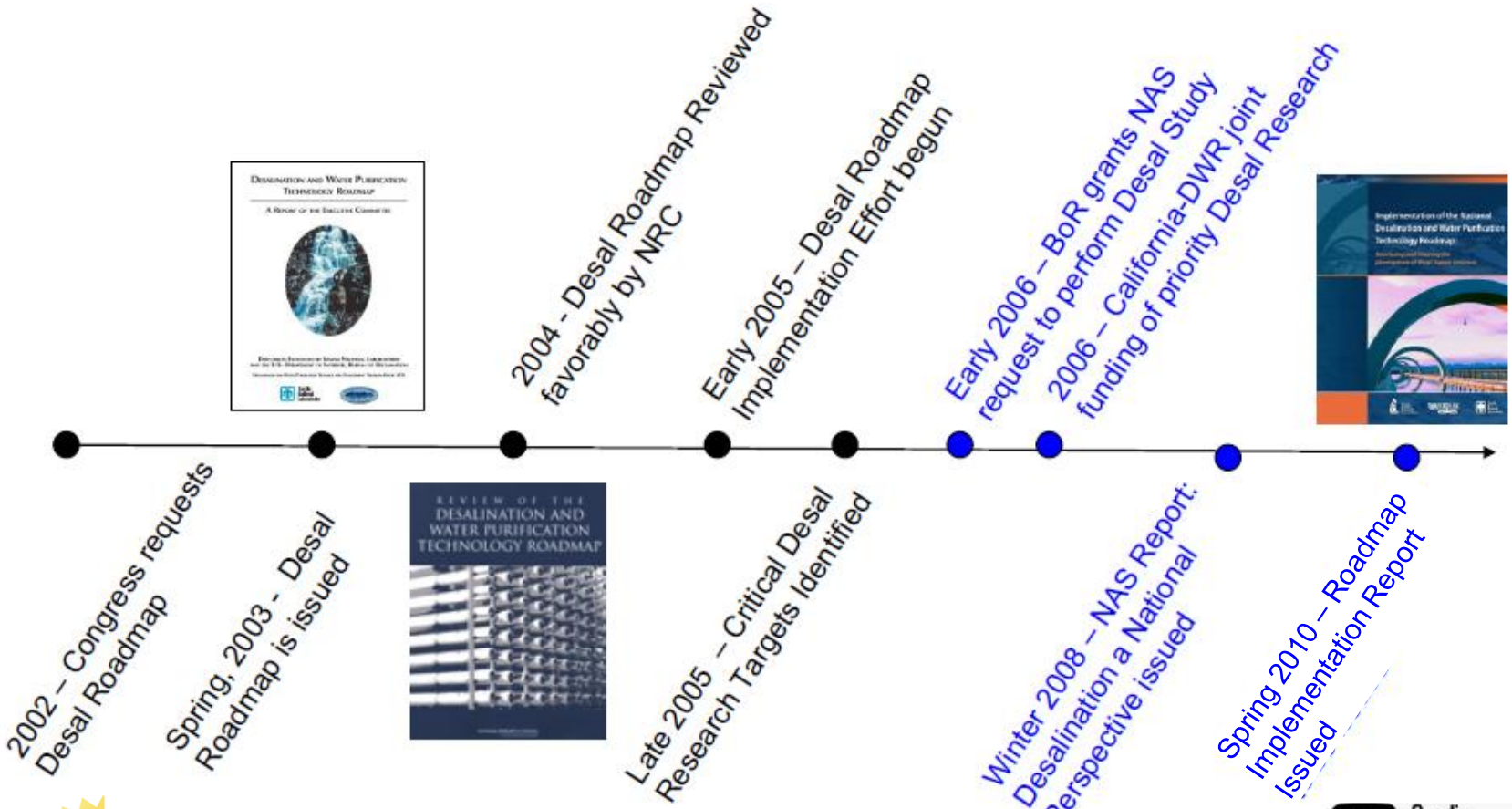
National Desalination Research Roadmapping Effort



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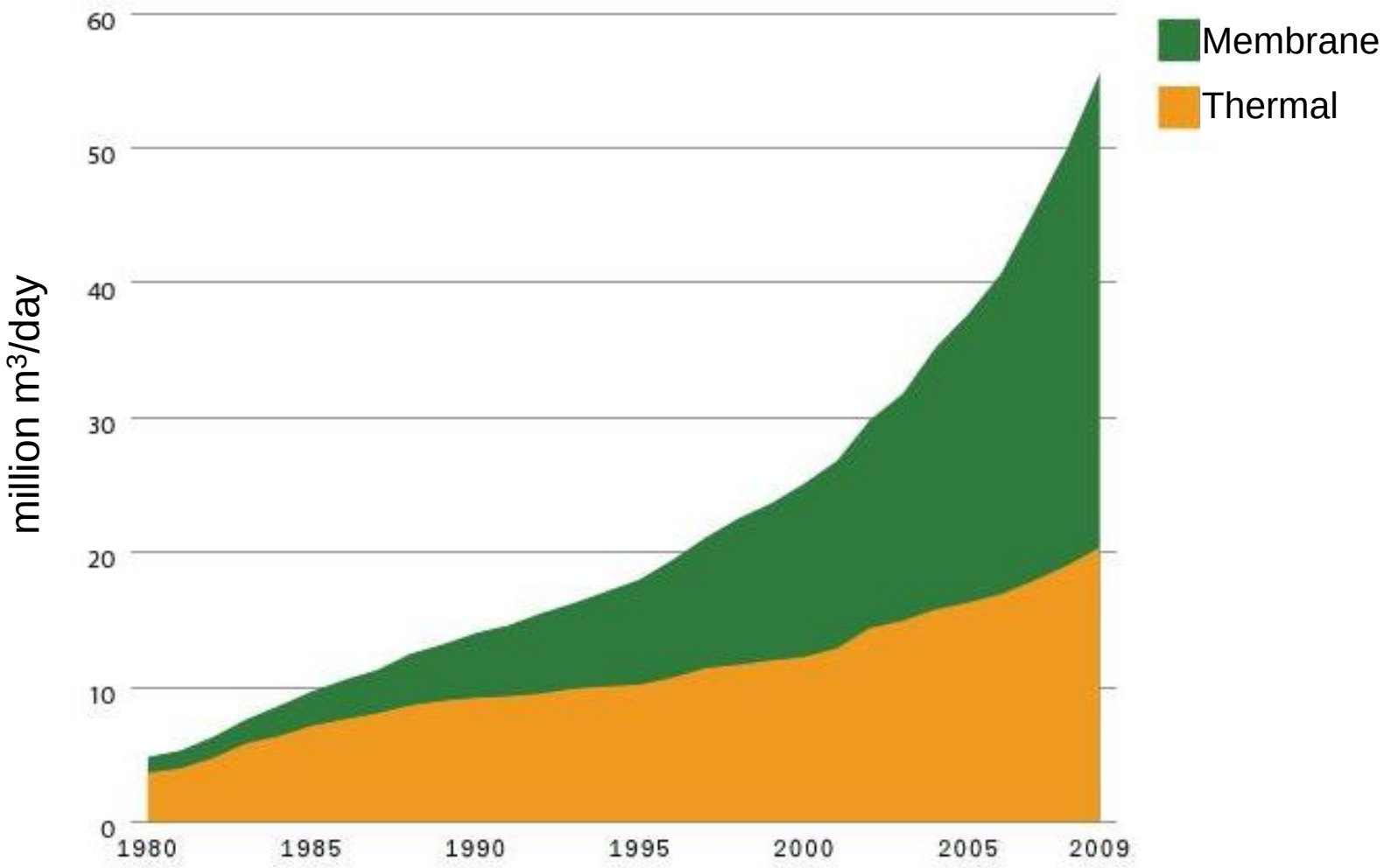
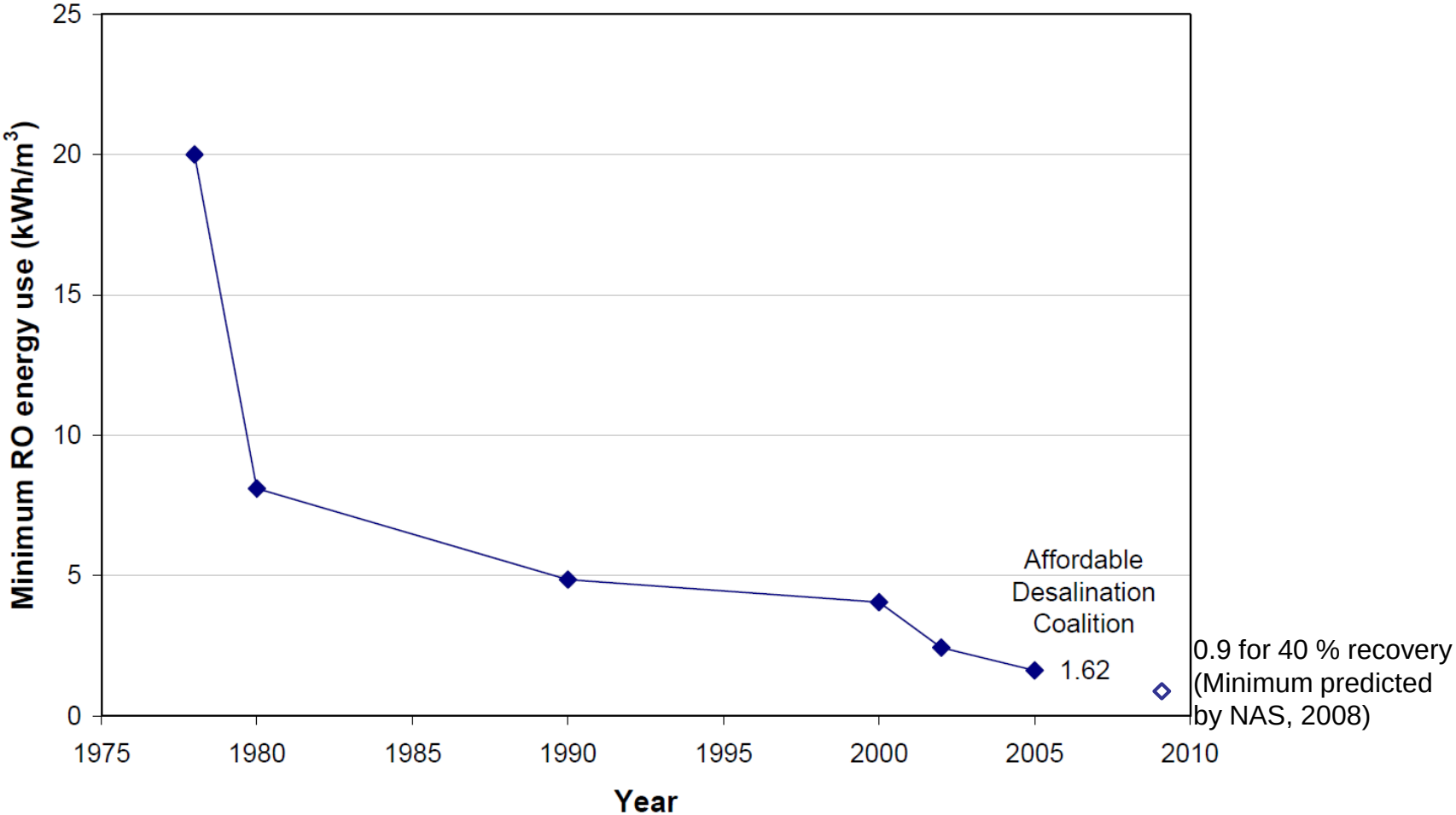
Cumulative Global Installed Capacity



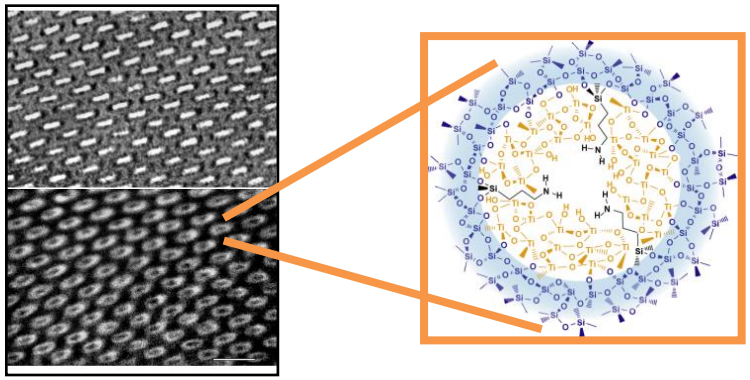
(From IDA Desalination Yearbook 2010-2011)

Seawater Reverse Osmosis Energy Use



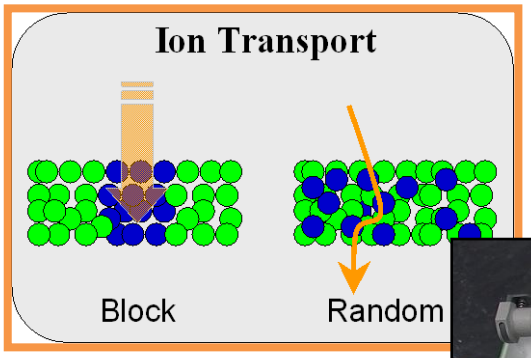
(From McHarg and Truby, 2004)

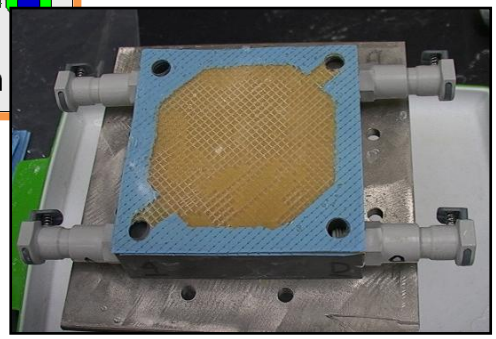
Treatment Technologies: Long Range Research



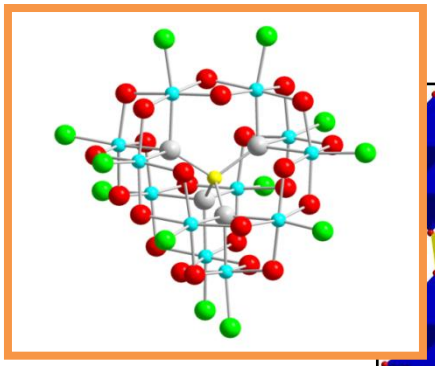
Novel Membrane Technologies

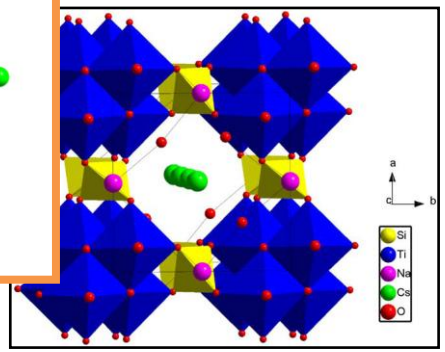
Physical and Chemical Solutions for Biofouling Control





Advanced Electrodialysis

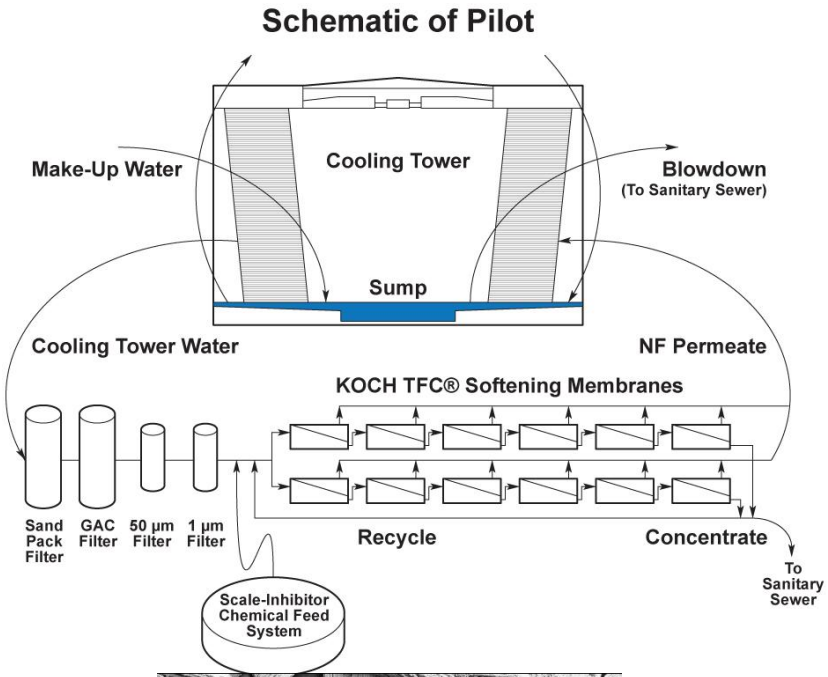


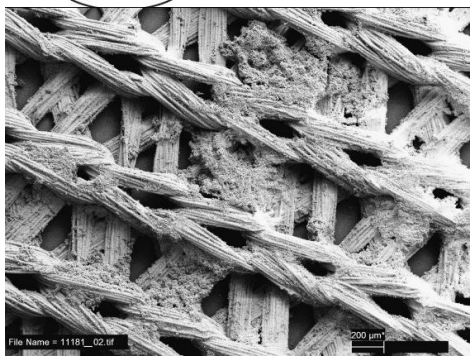


Novel Materials for Contaminant and Pathogen Removal

(Sandia only)

Nanofiltration Treatment of Side-Stream Cooling Tower Water for Reduction of Water Usage



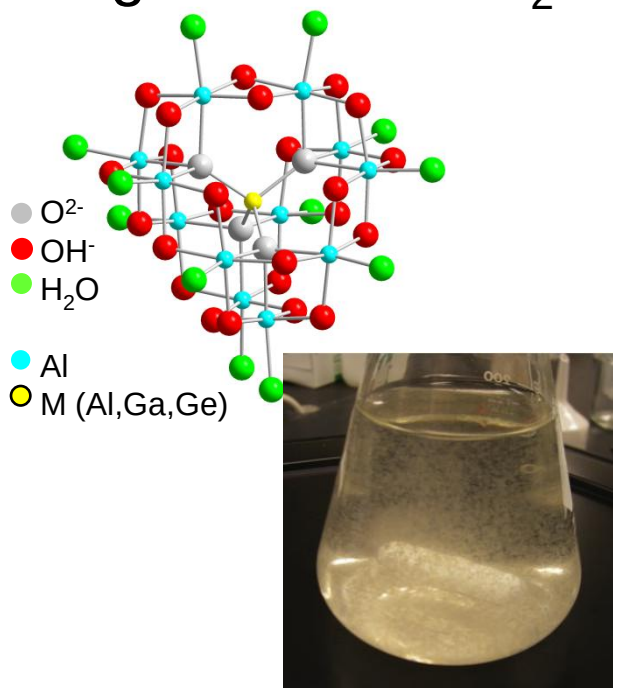


- Water savings observed
- Water savings can pay for electrical costs
- Scaling control is critical for economic operation

(Sandia only)

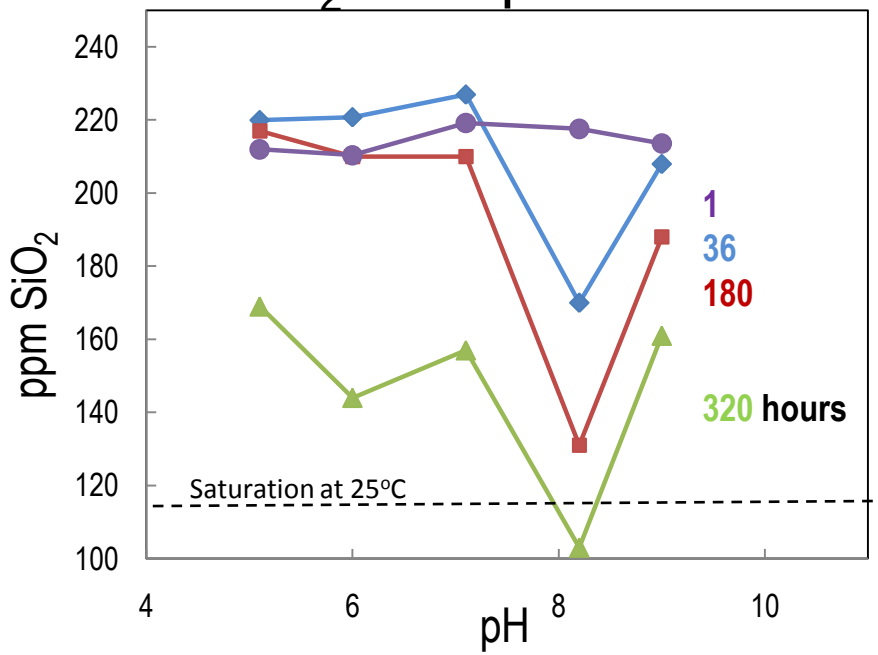
Strategies for Controlling SiO_2 Scaling

Coagulation of SiO_2



Simple aluminum-based agents are effective and compatible with other industrial processes.

pH Control to Delay SiO_2 Precipitation



Lowering solution pH decreases equilibrium calcite solubility and kinetic rates of silica polymerization.

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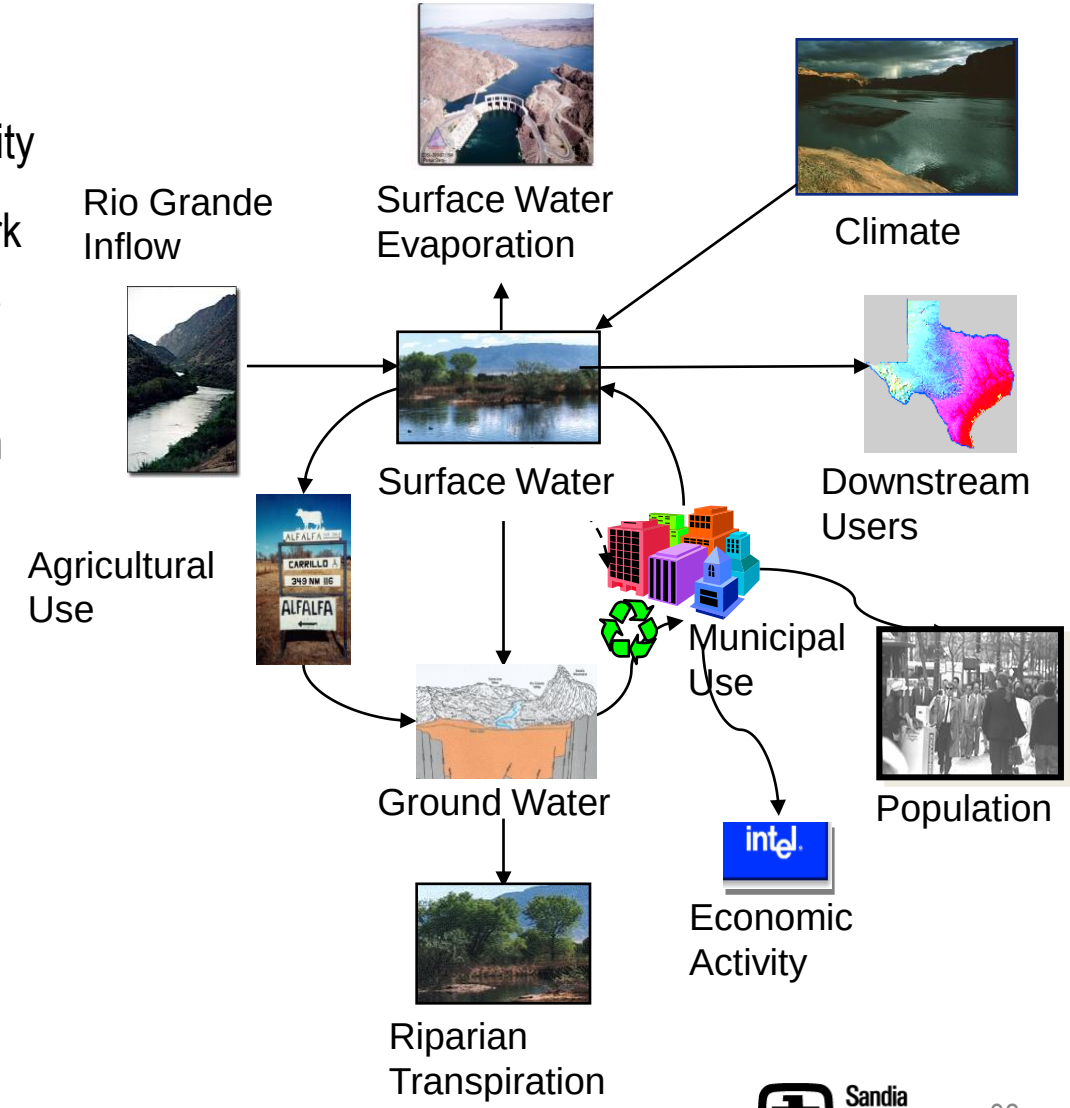
Model Objectives

- Develop a general framework for “what if” policy analysis,
- Adopt a national view while allowing regional analysis, and
- Provide interactive environment for stakeholder/decision maker engagement

Modeling and Management Details

- "Holistic" approach to quantitatively assessing water resource sustainability
- System Dynamics provides framework for modeling multiple, interdependent subsystems each = f(time, space)
- Focus is on intermediate to long-term interdependencies between resource supply and demand
- Major areas of interest include interdependencies of <u>energy, water, and agricultural</u> sectors



Model Overview

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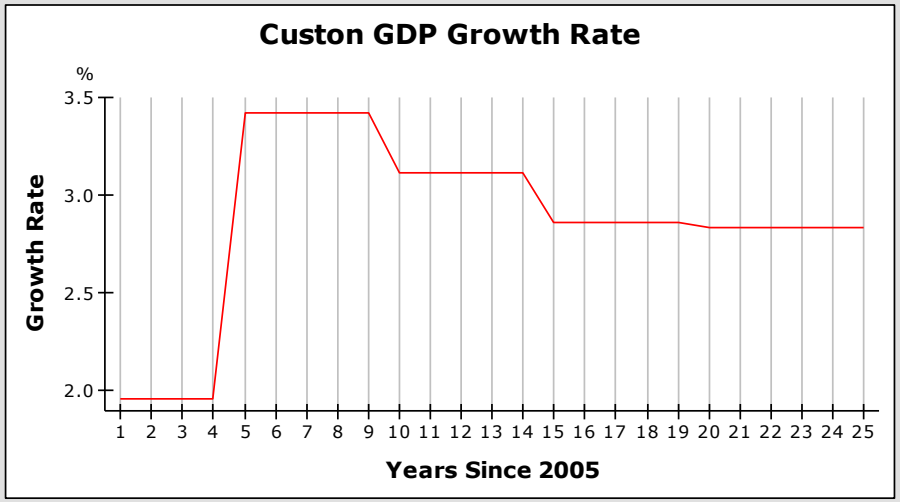
Home

GDP Growth Rate (per year)

- (●) AEO Reference: 3.11%
- ( ) AEO High: 3.4%
- ( ) AEO Low: 2.6%
- ( ) Custom



If custom is selected adjust values as desired in the graph below

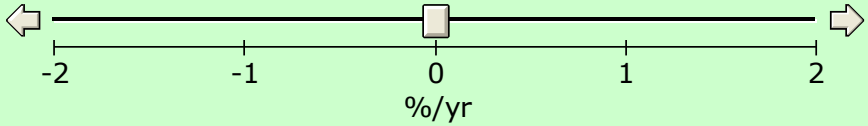
Energy Controls

Water Controls

Population Cont.

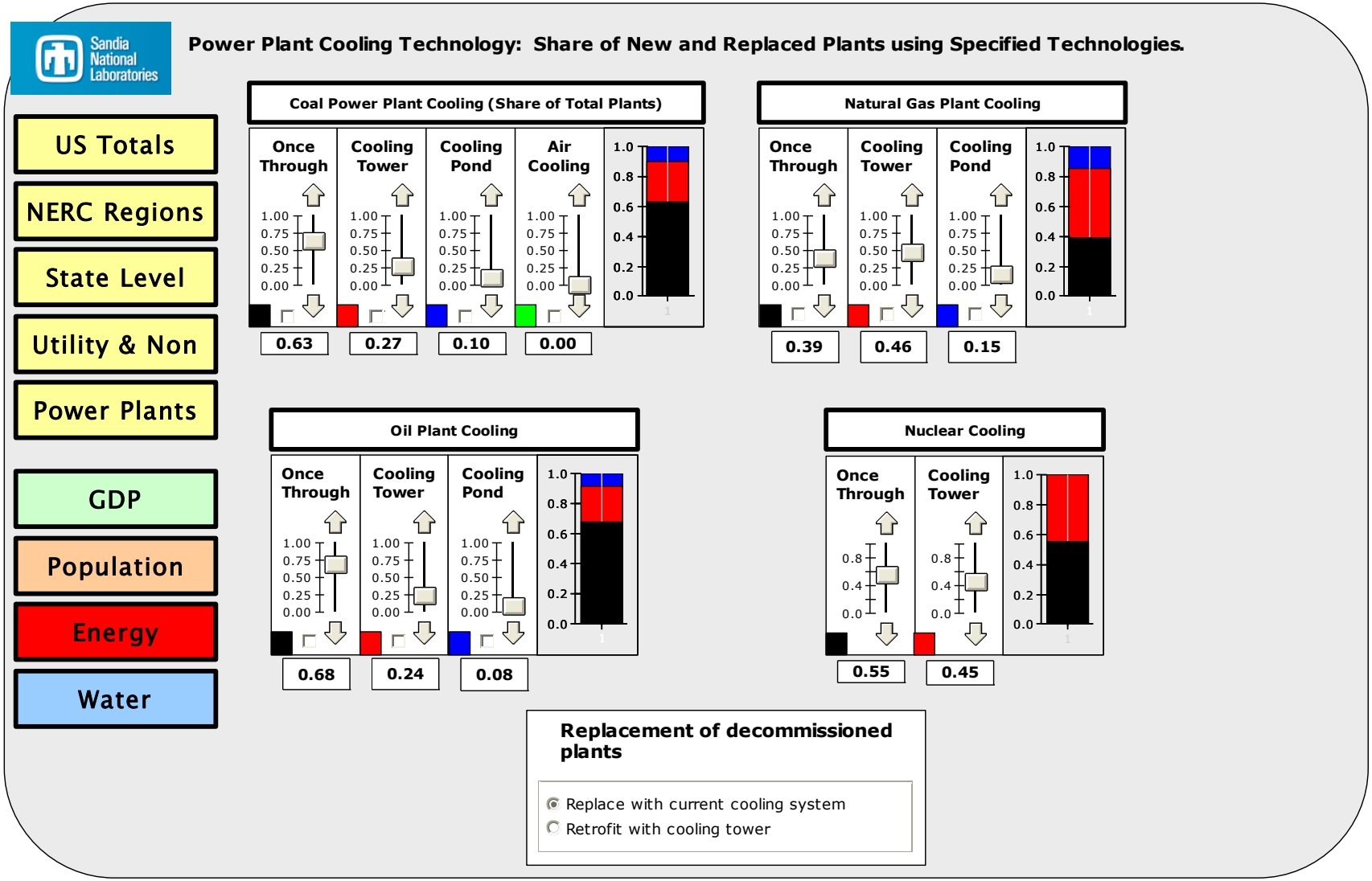
GDP Controls

Population Growth Factor: Change Relative to Baseline



0.00 %/yr

Model Overview



Results By Interconnection

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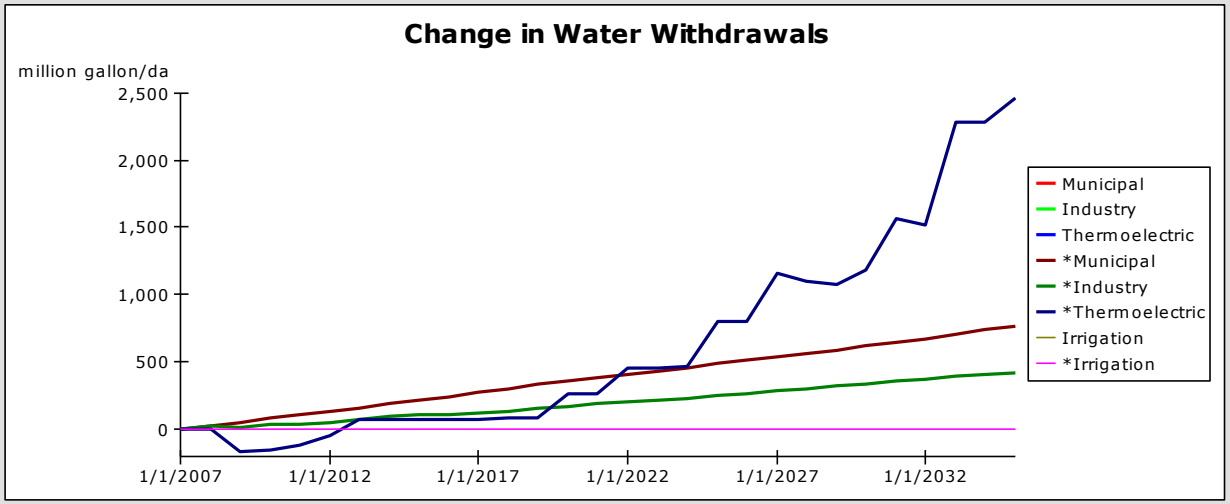
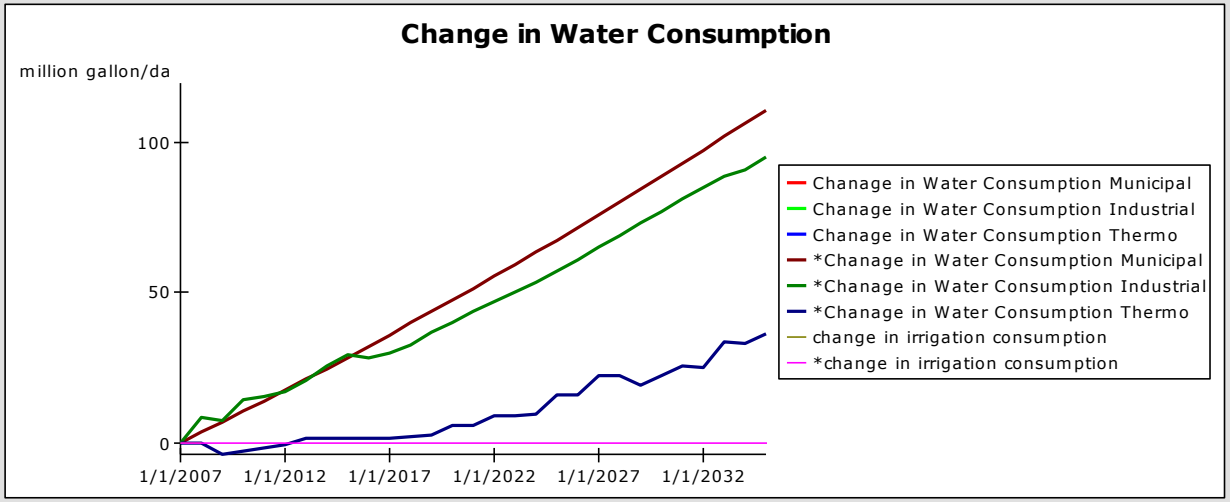
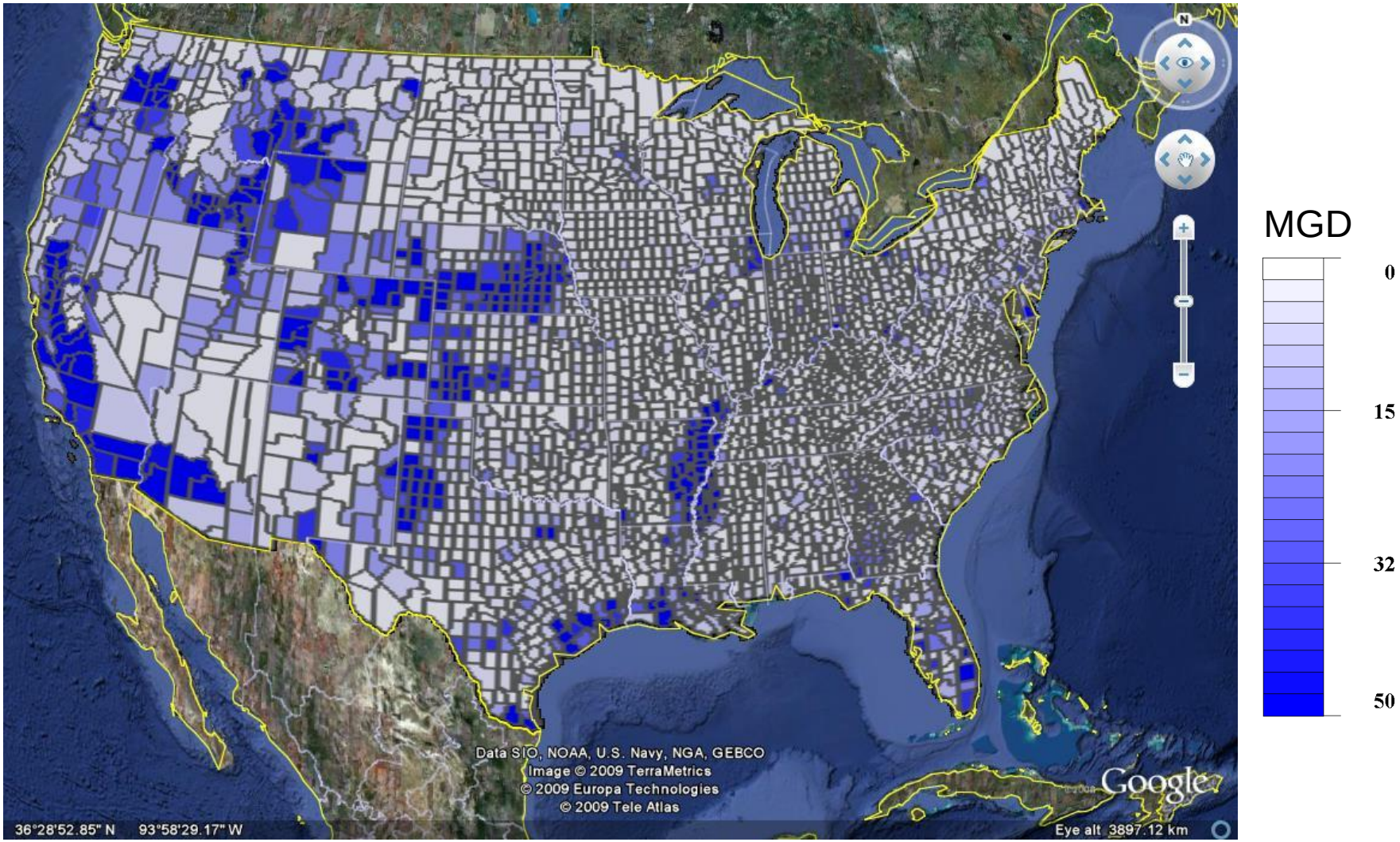
- Home
- National Totals
- Water for Energy
- Plant Renewal
- Water by Supply
- Energy for Water
- Emissions
- Population
- Gross National Product
- Environment

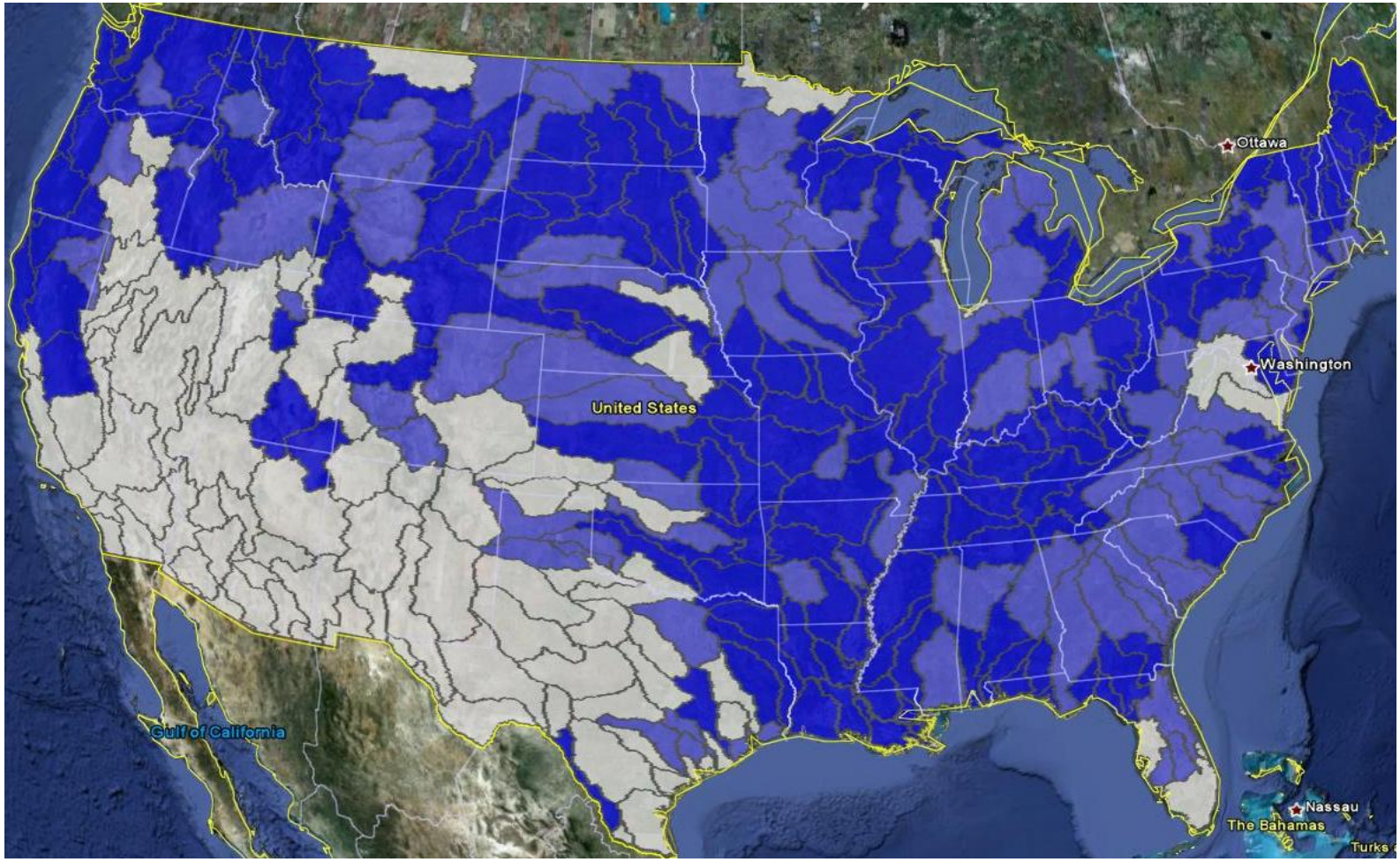




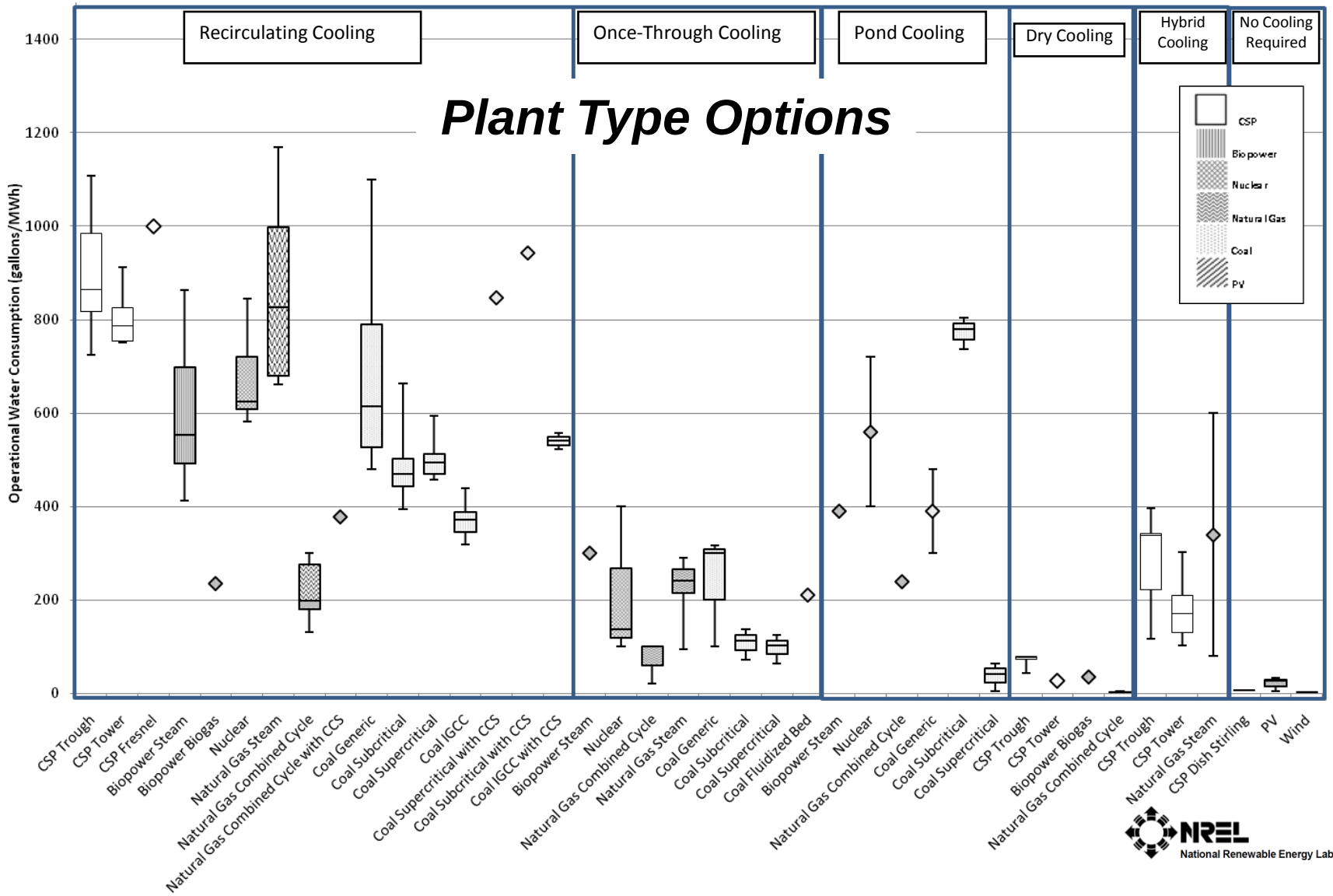
Results By State or County



Results By Watershed



Thermoelectric Water Use



NREL National Renewable Energy Laboratory

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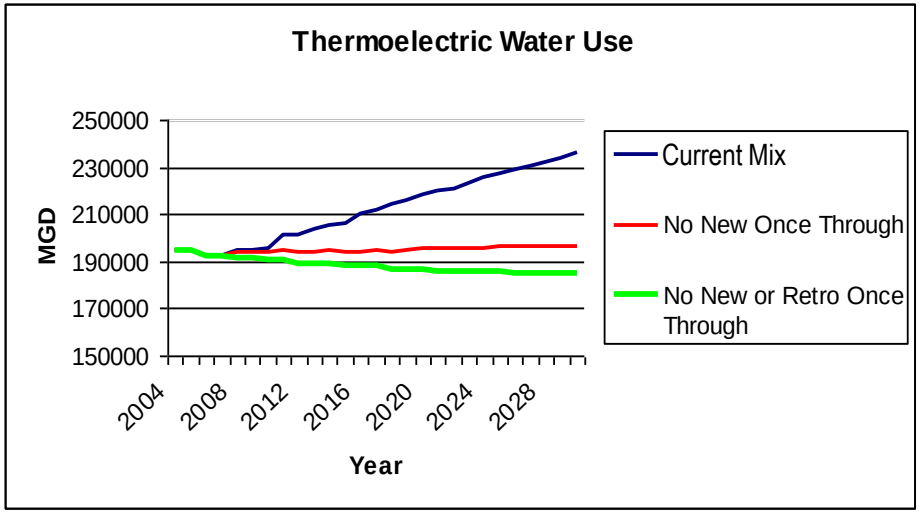
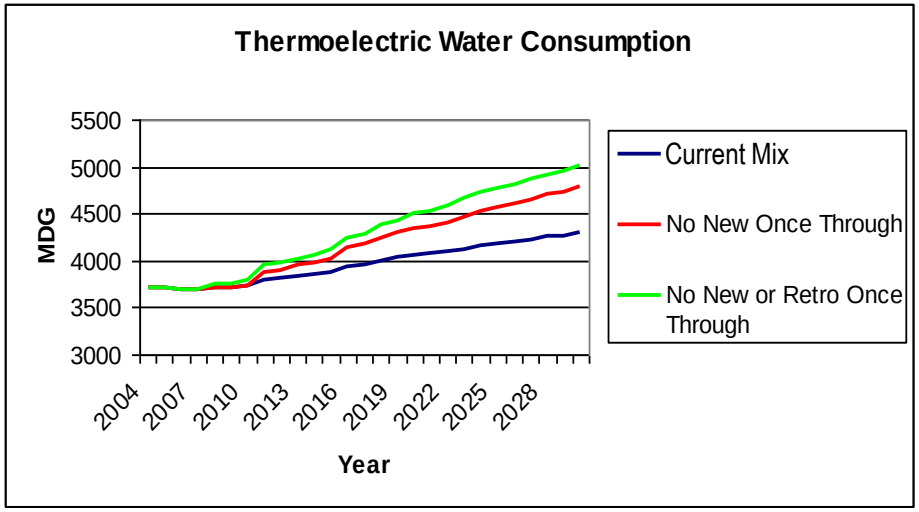
Thermoelectric Water Use

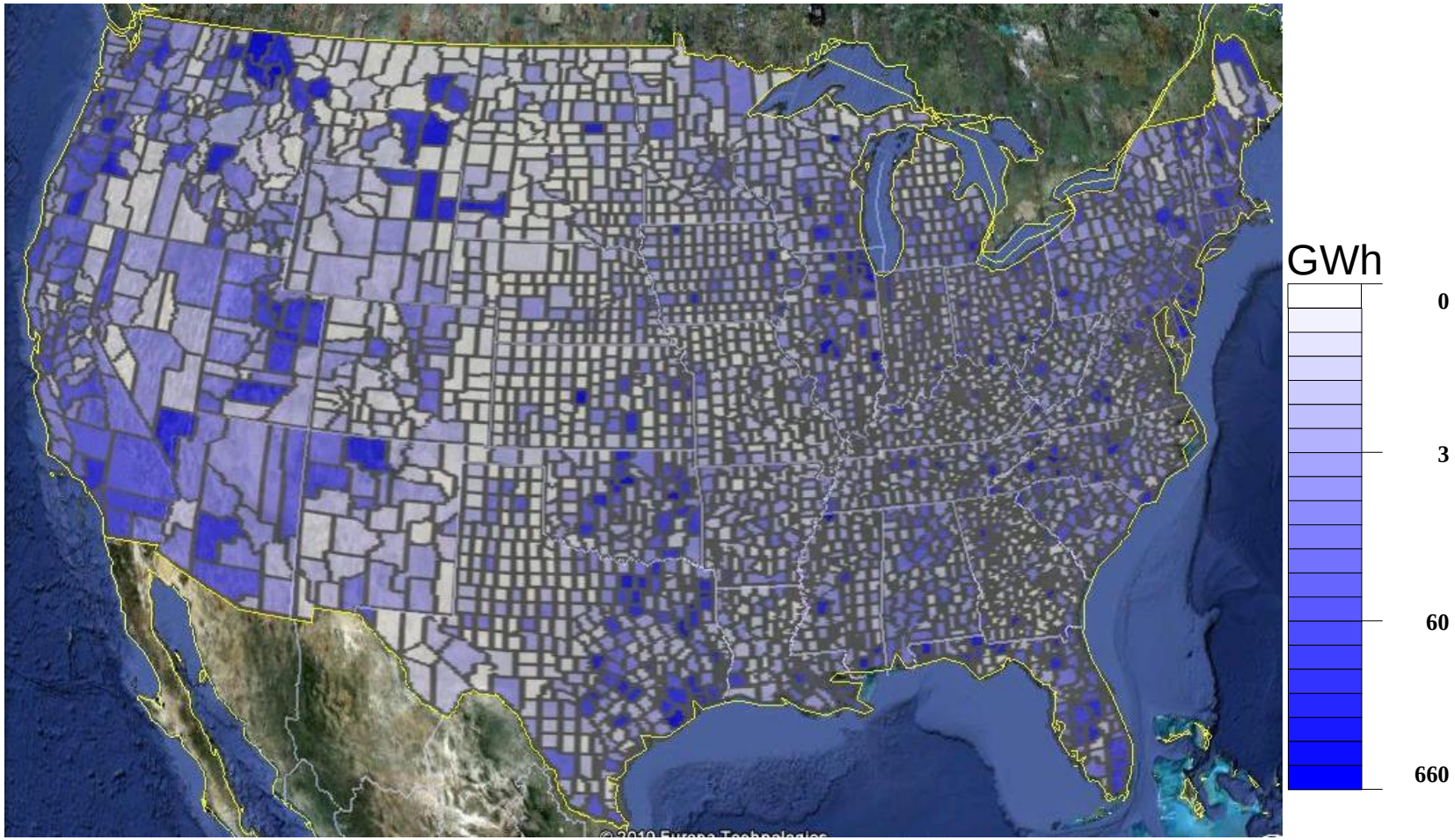




- Current mix has the highest water use, 236.1 BGD in 2030 and lowest water consumption, 4.3 BGD.
- Recirculating cooling towers in all new construction and recommissioned plants has the lowest water use, 184.8 BGD but highest consumption,5.0BGD.

Energy for Water

Projected Increase in Demand for Electricity due to Growing Demand for Water: 2004-2030



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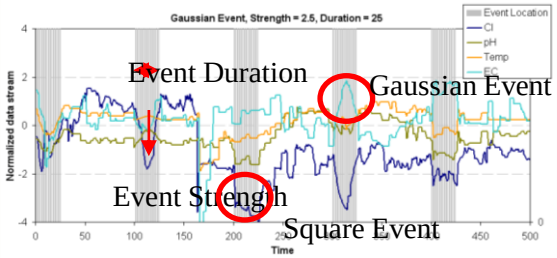
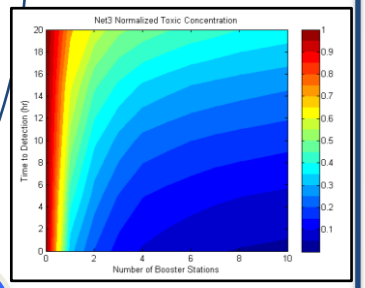
Water Security

CANARY
Real-time event detection



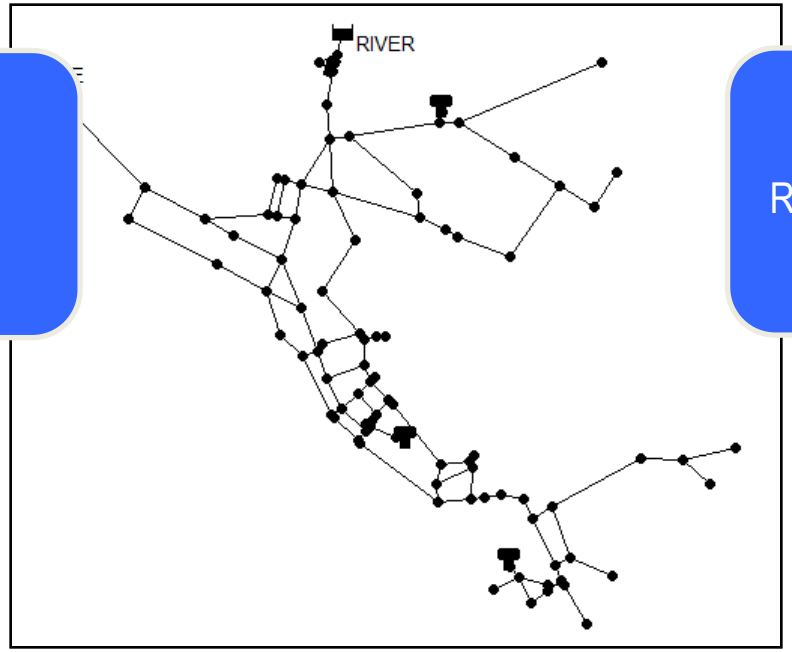
PONI
Real-time Contaminant Source inversion



CWaRK
Response protocol for isolation, flushing, and decontamination booster

TEVA
Contaminant simulation and vulnerability assessment

SPOT
Sensor placement optimization



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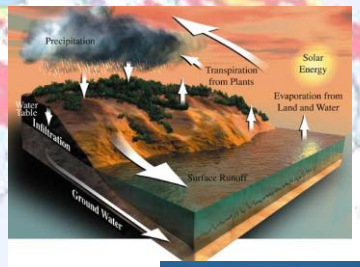
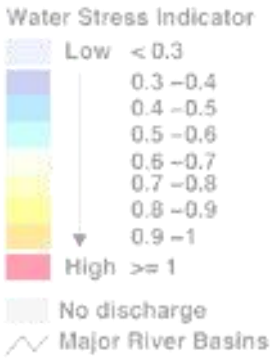
Sandia's Water Program

Treatment Technologies

Modeling & Management



Security Systems



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Information:
John Merson
jamerso@sandia.gov
(505) 844-2756

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