Western and Great Lakes Region Water Constraint Analyses

SAND2011-6862C

Vincent Tidwell, Howard Passell, Barry Roberts and Barbie Moreland

Sandia National Laboratories

Albuquerque, New Mexico

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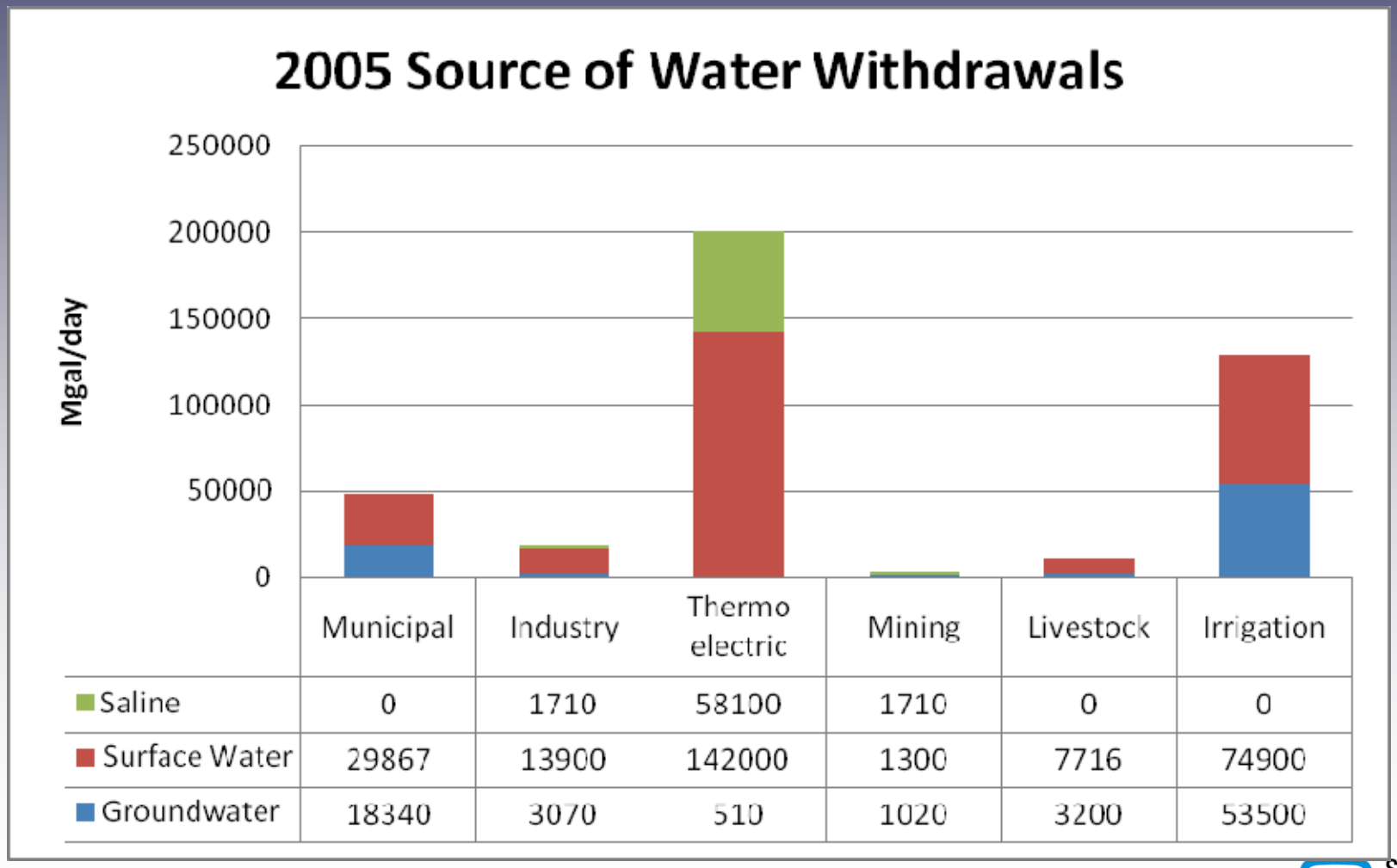
Water for Thermoelectric Power Generation



	Municipal	Industry	Thermo electric	Mining	Livestock	Irrigation
Saline	0	1710	58100	1710	0	0
Surface Water	29867	13900	142000	1300	7716	74900
Groundwater	18340	3070	510	1020	3200	53500

USGS 2005

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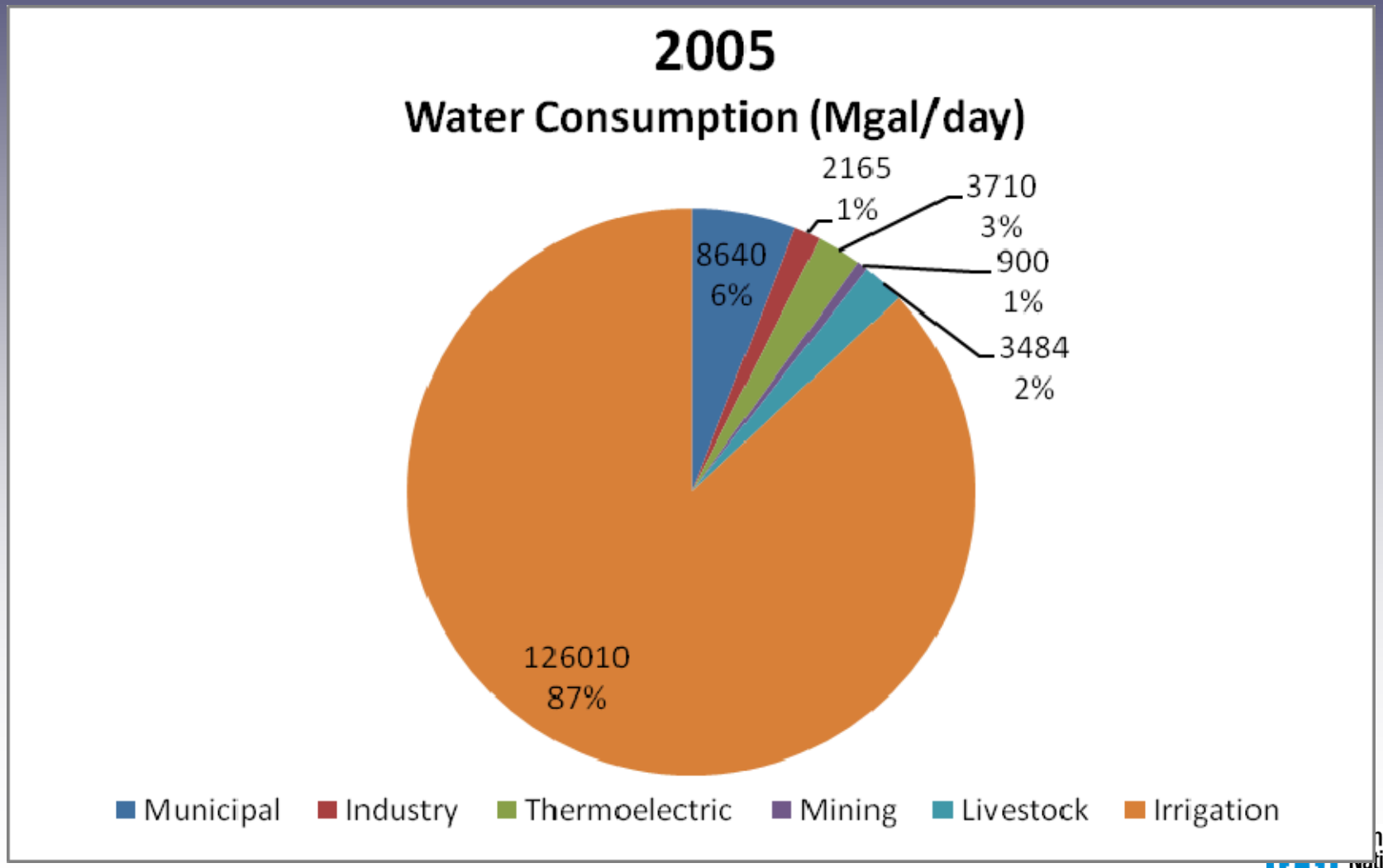
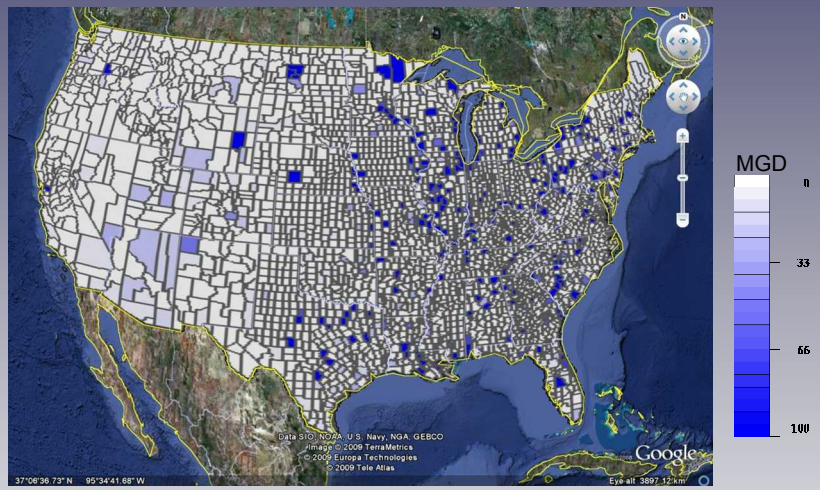
Water for Thermoelectric Power Generation

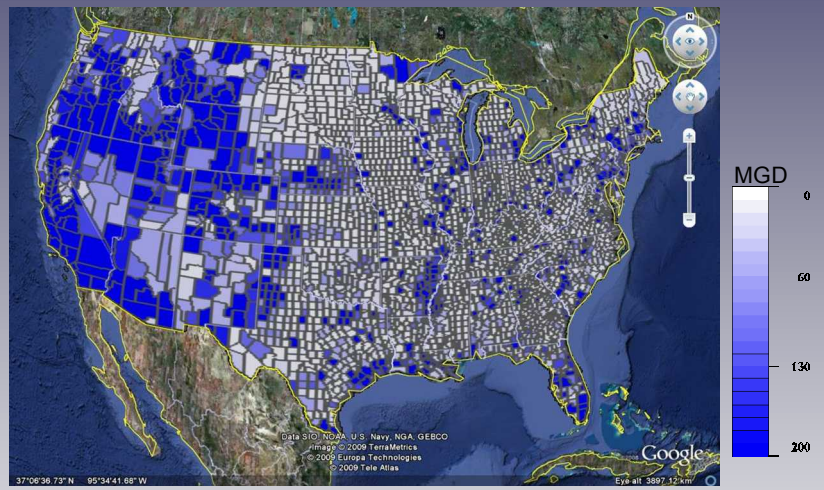


Location Matters

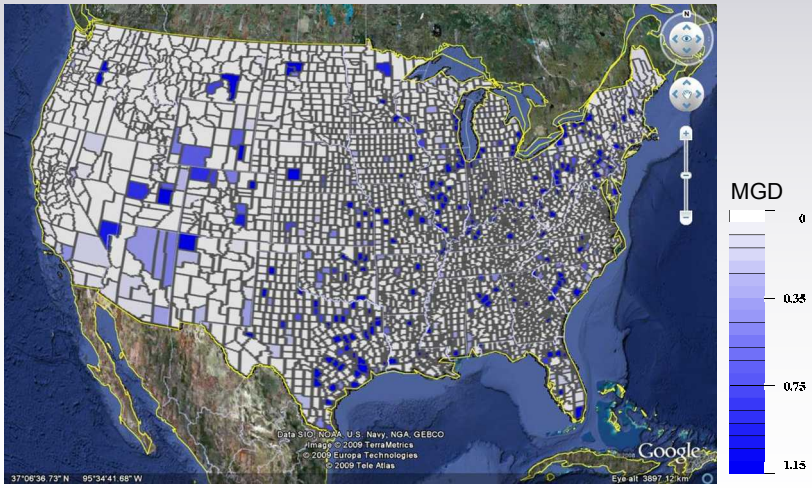
Thermoelectric Withdrawal 2005



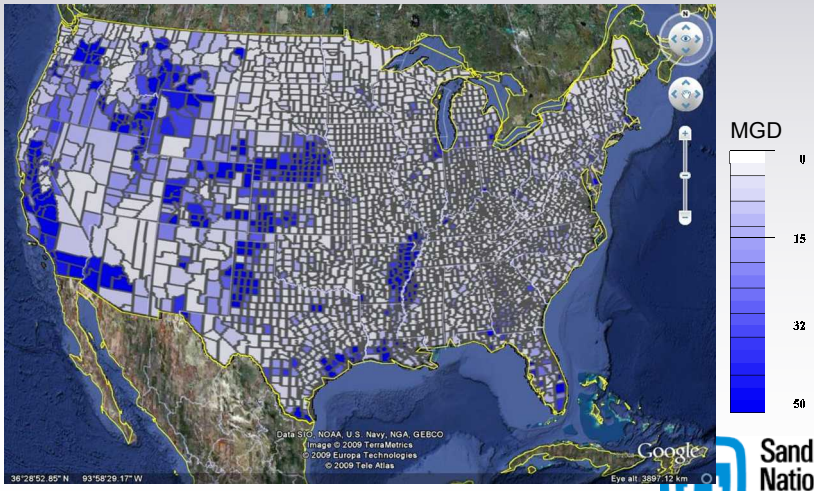
Non-Thermoelectric Withdrawal 2005



Thermoelectric Consumption 2005



Non-Thermoelectric Consumption 2005



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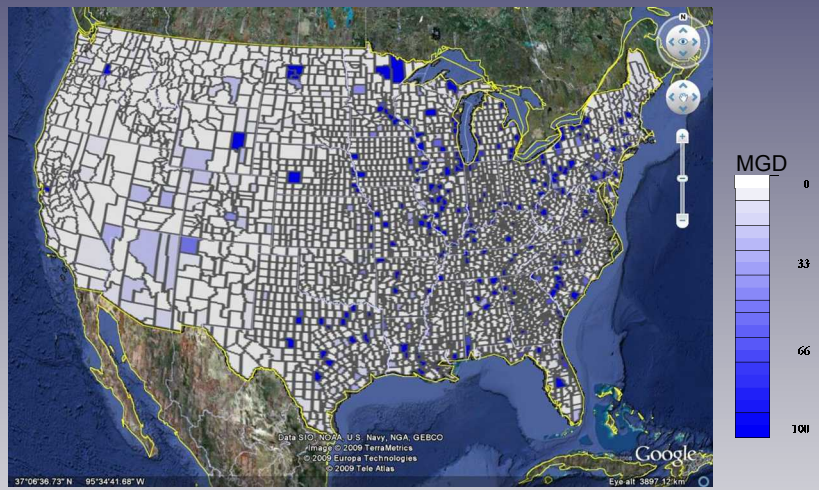
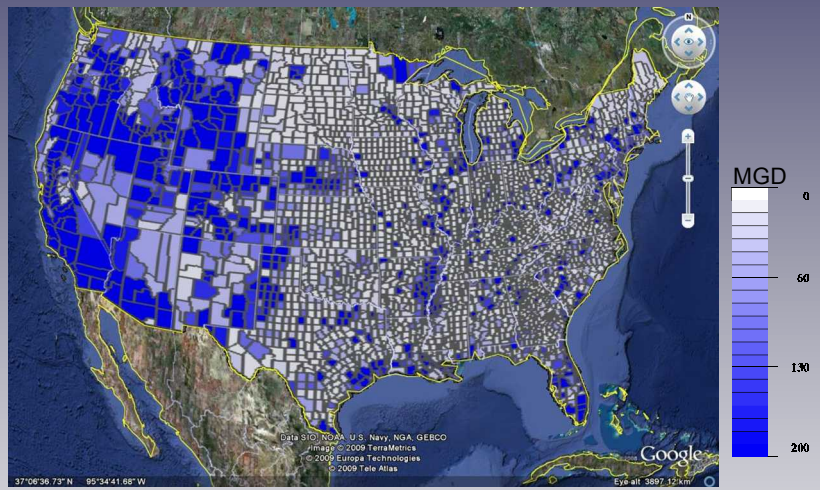
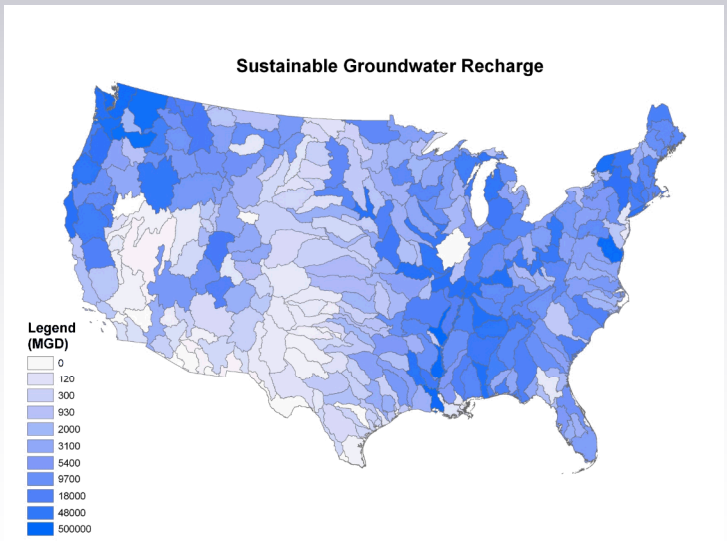
Location Maters

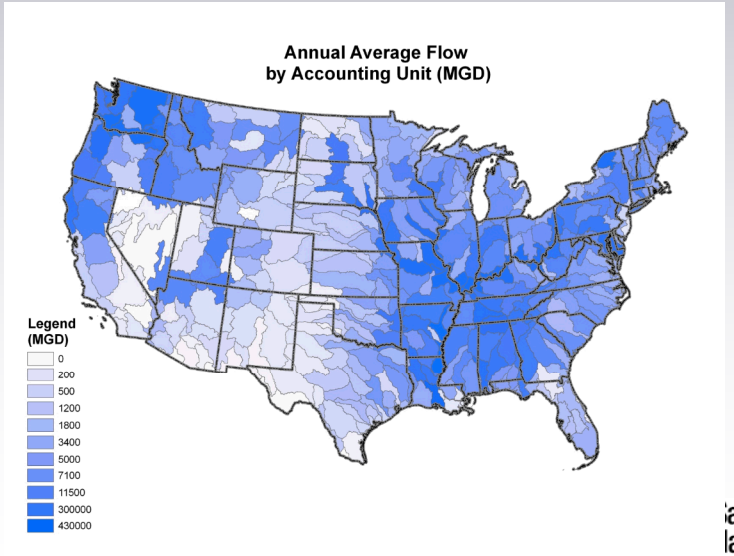
Thermoelectric Withdrawal 2005



Non-Thermoelectric Withdrawal 2005







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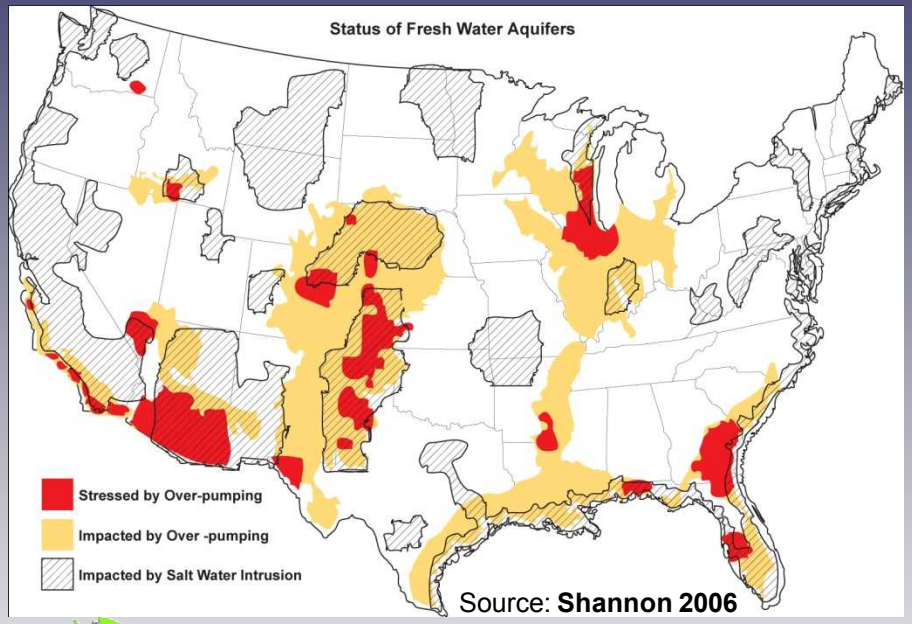
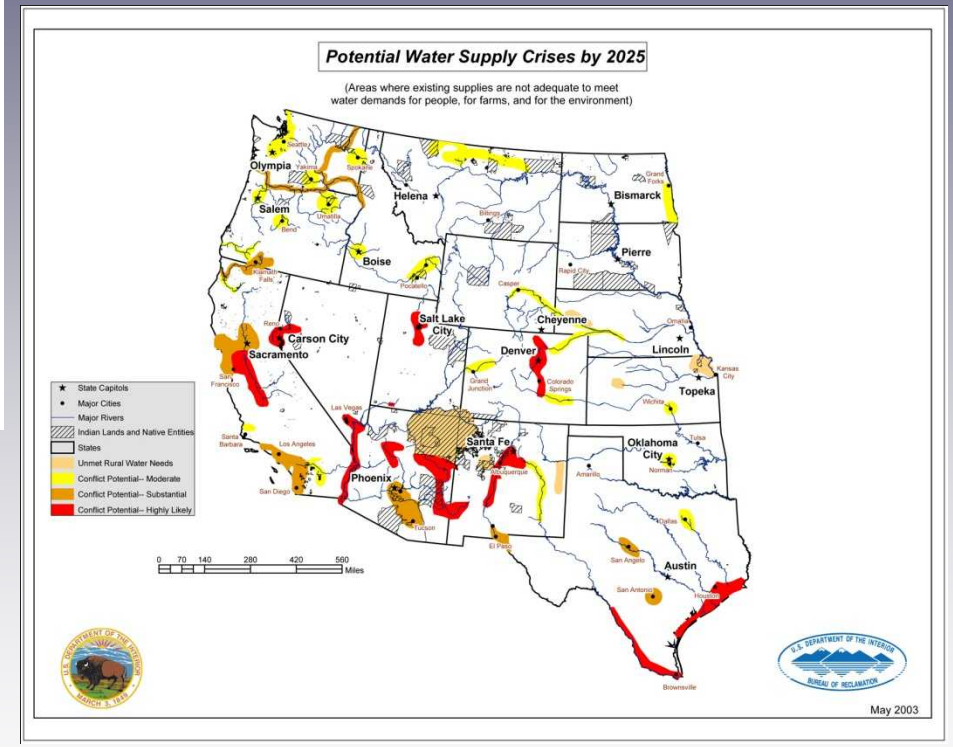
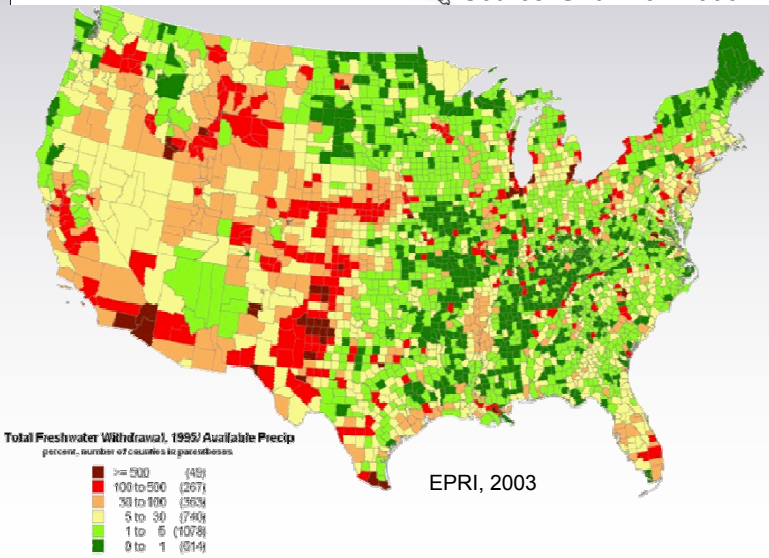
Indications of Water Stress



Source: **Shannon 2006**





EPRI, 2003

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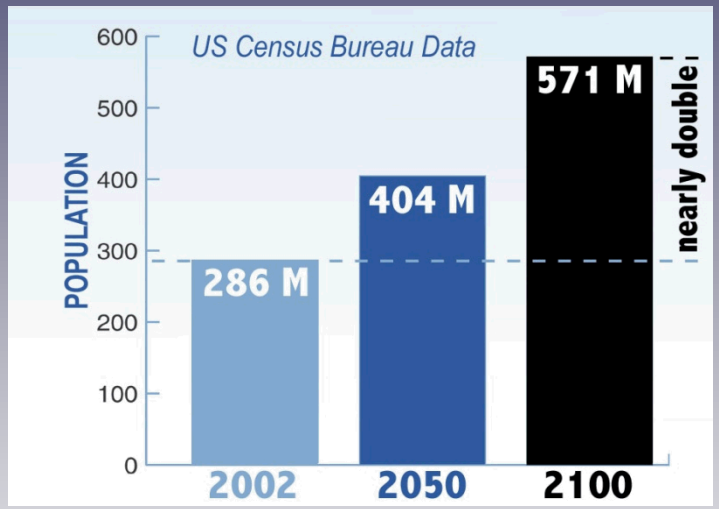
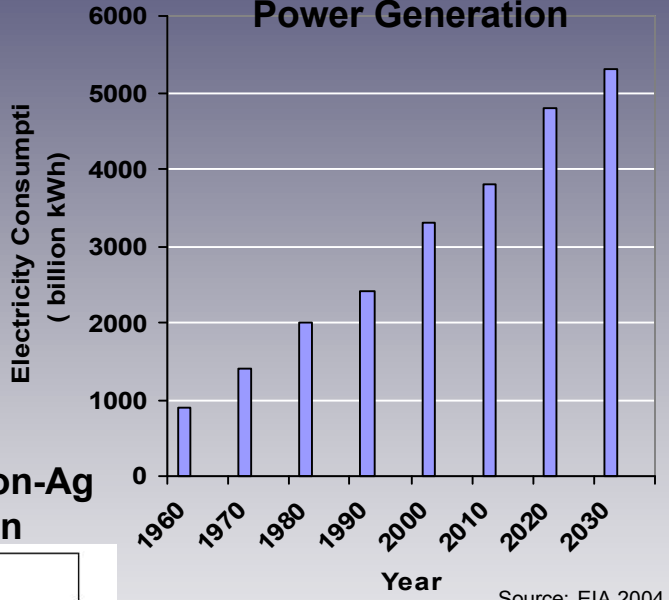
Energy and Water Tomorrow

Projected Population Growth



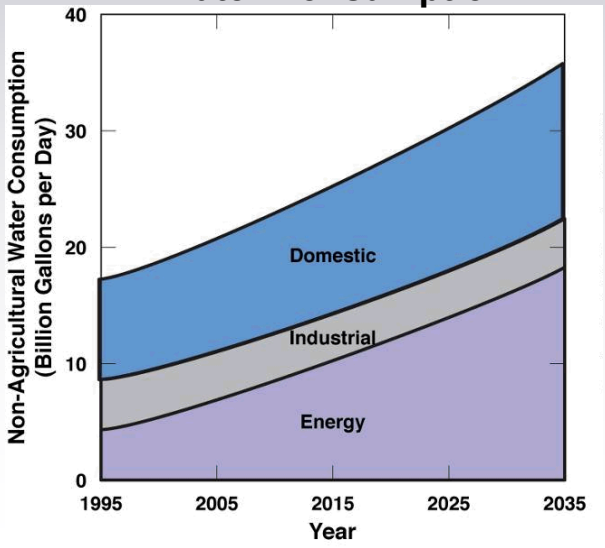
70 million more people by 2030

Projected Growth in Electric Power Generation



Source: EIA 2004

Projected Growth in non-Ag Water Consumption



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Energy-Water-Environment Nexus for the Great Lakes

- Model Objectives:
  - Develop a general framework to support policy analysis around the energy-water-environment nexus,
  - Adopt a Great Lakes regional view while allowing local analysis, and
  - Provide interactive environment for stakeholder/decision maker engagement

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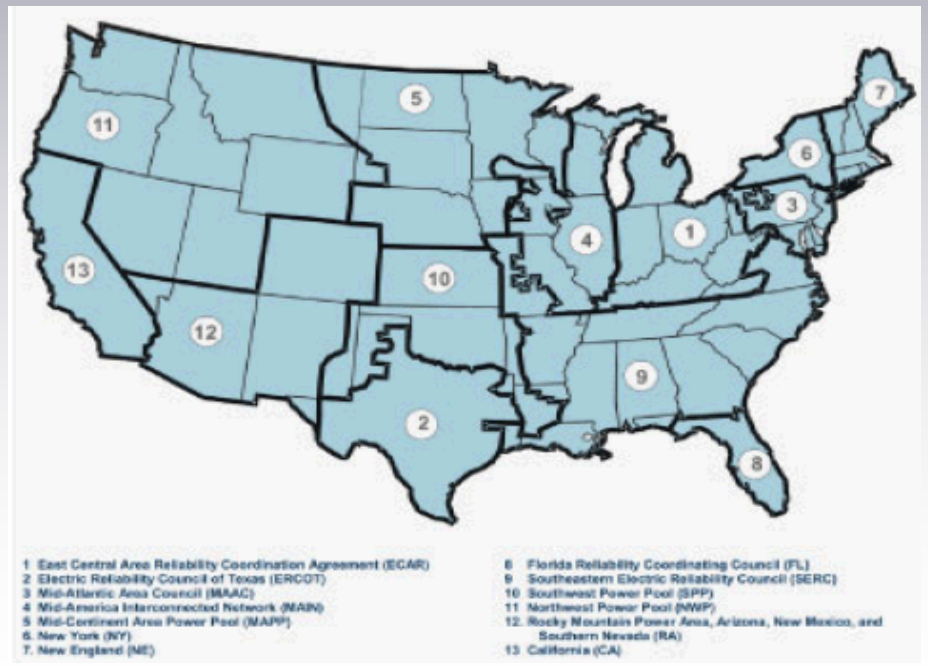
Model Domain



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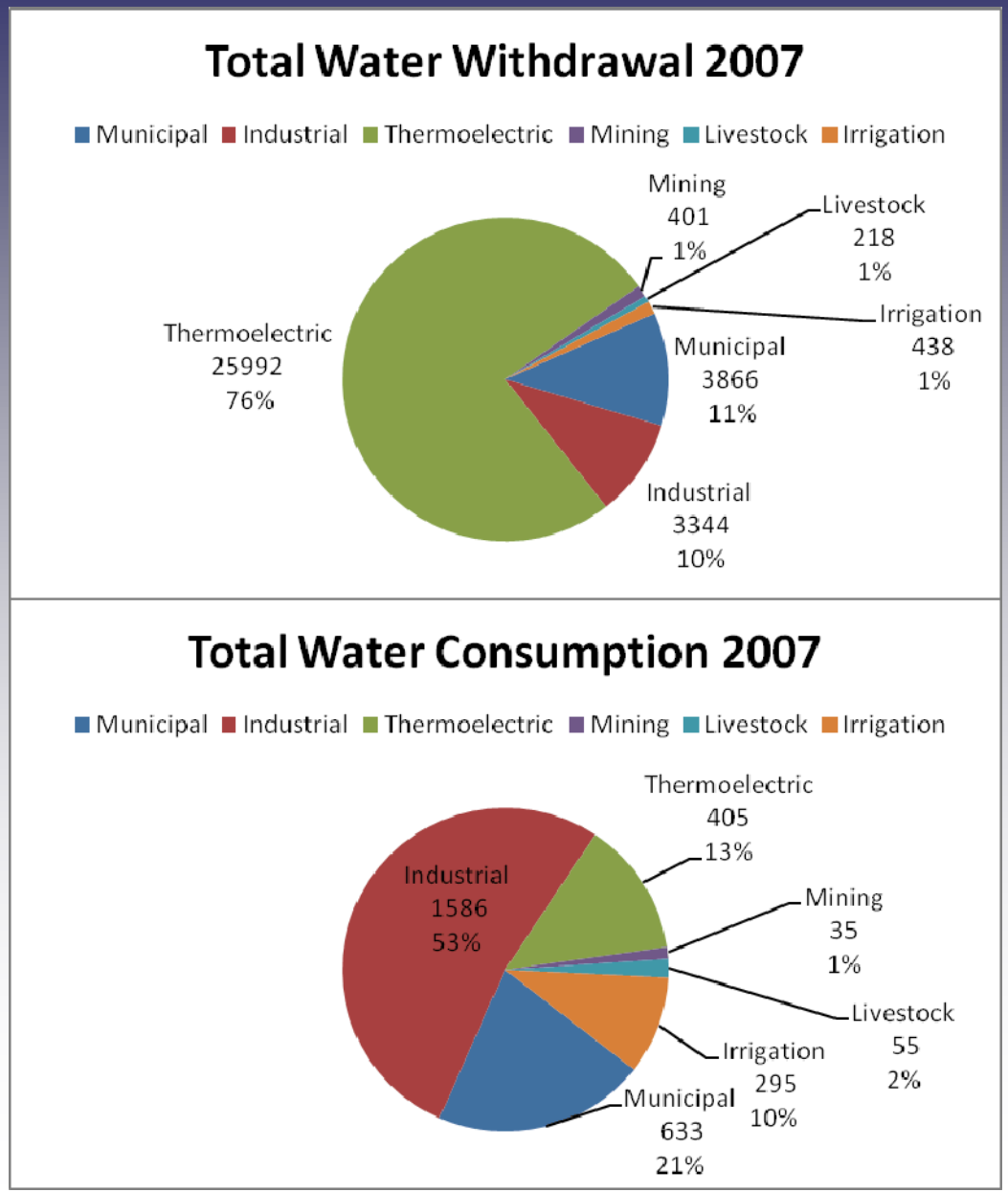
Basin in 2007



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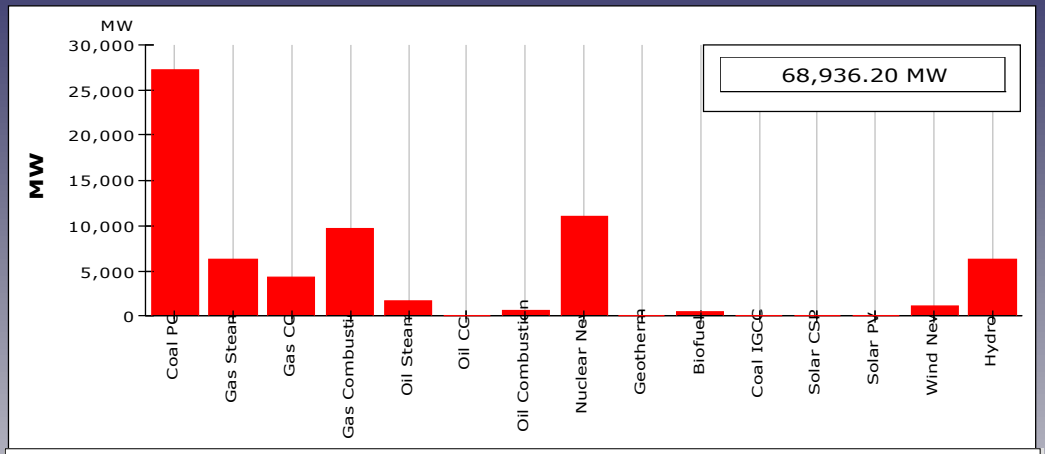
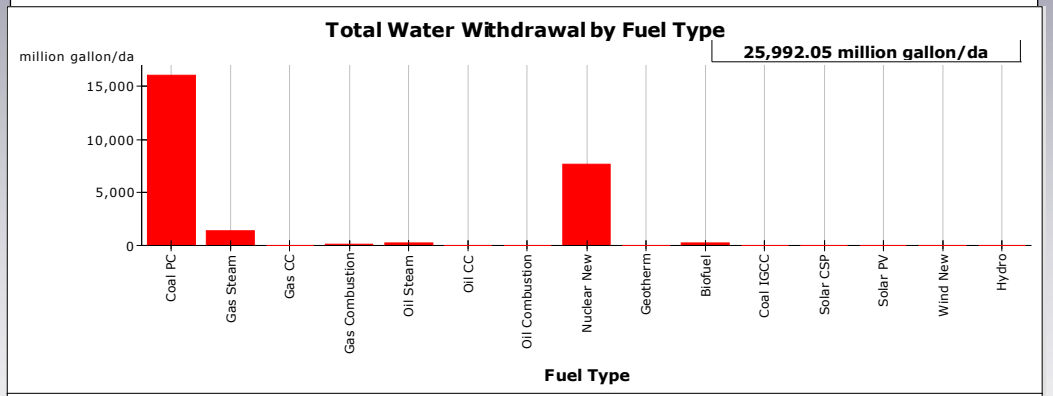
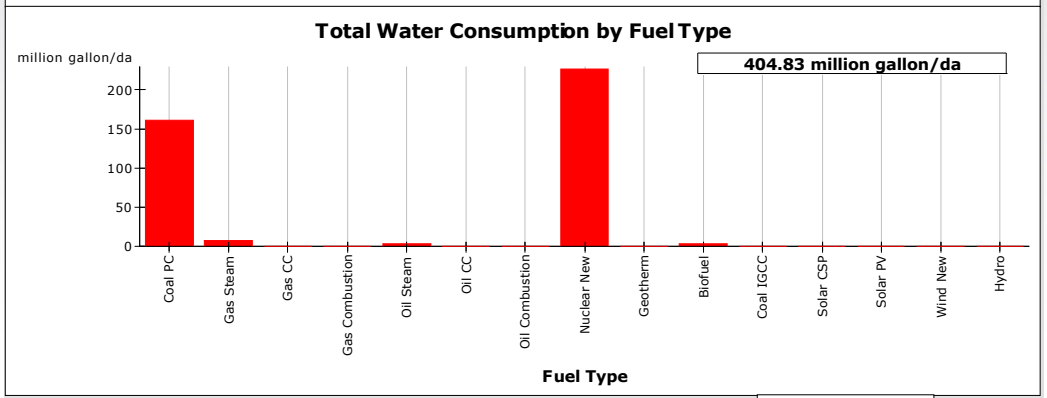
Basin in 2007







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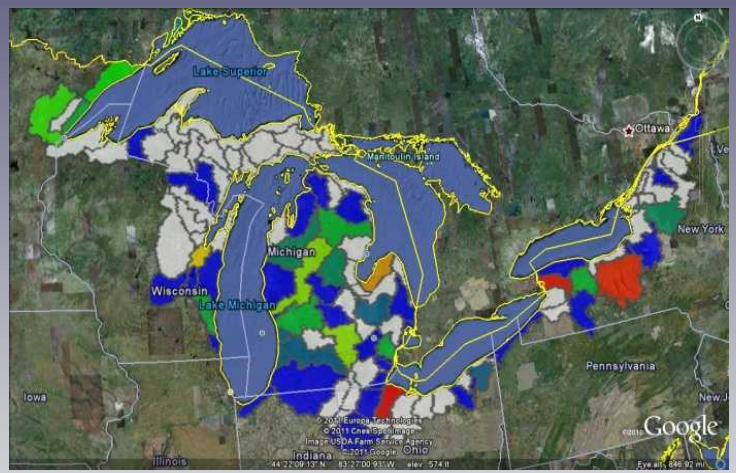
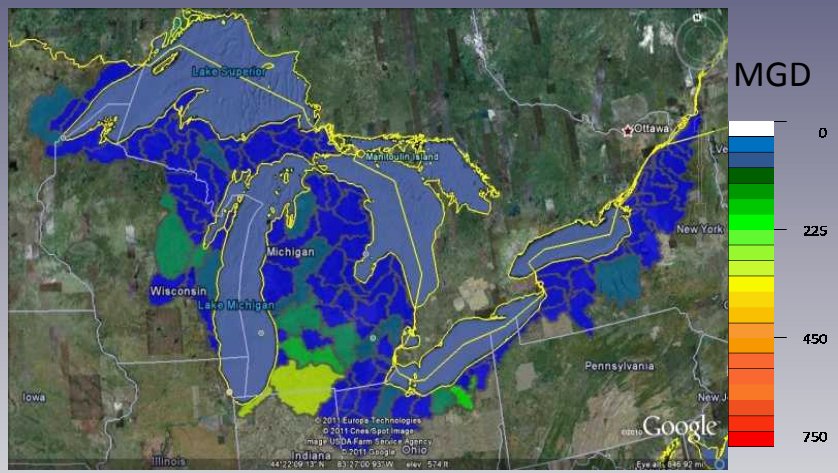
Water Use by Watershed 2007

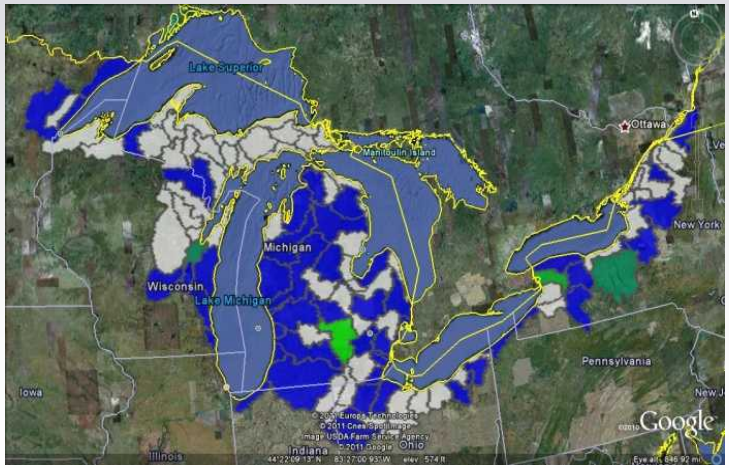
Thermoelectric Withdrawals



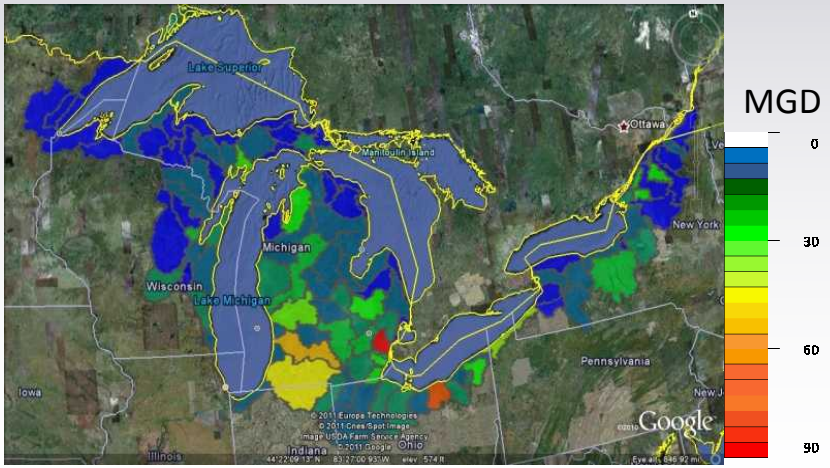
Non-Thermoelectric Withdrawal



Thermoelectric Consumption



Non-thermoelectric Consumption



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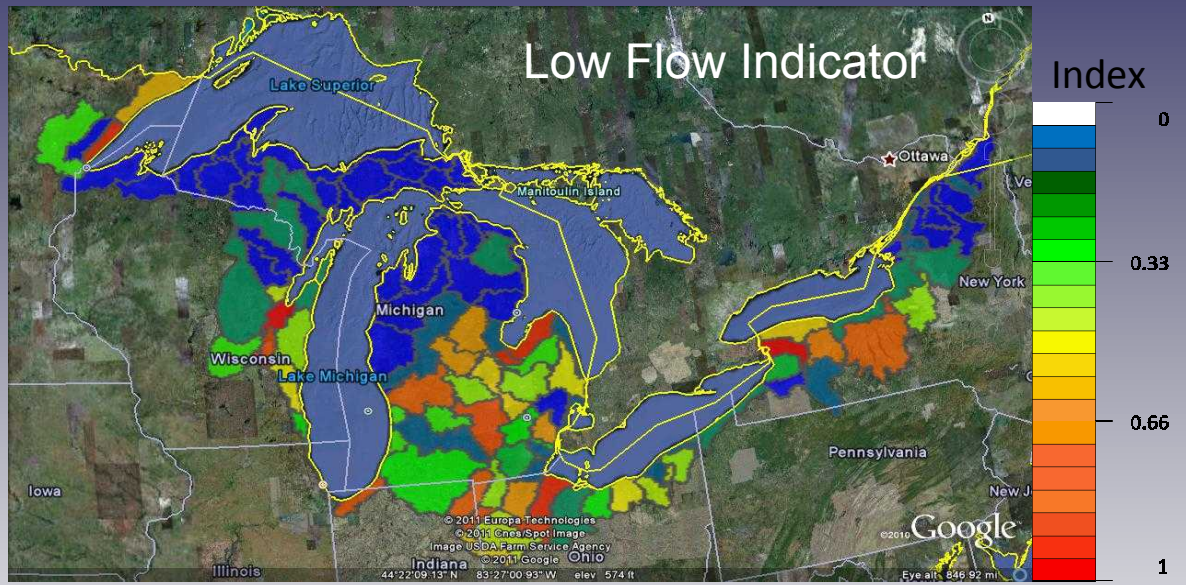
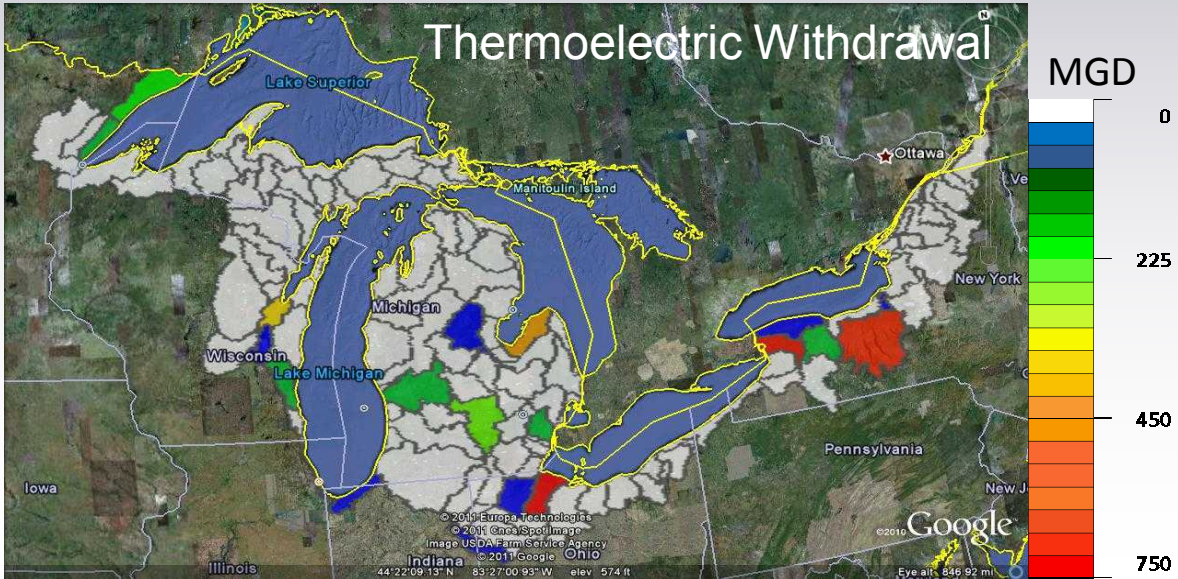
Environmental Quality 2007





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Scenario Analysis

- Business as Usual (BAU)
  - Energy/Water demand follow EIA projections and Census Bureau/BER population and GDP projections
  - New power plants adopt:
    - Current fuel mix,
    - Current mix of cooling technology,
    - Current source water mix, and
    - Siting based on 2005 watershed/EMMR production ratios

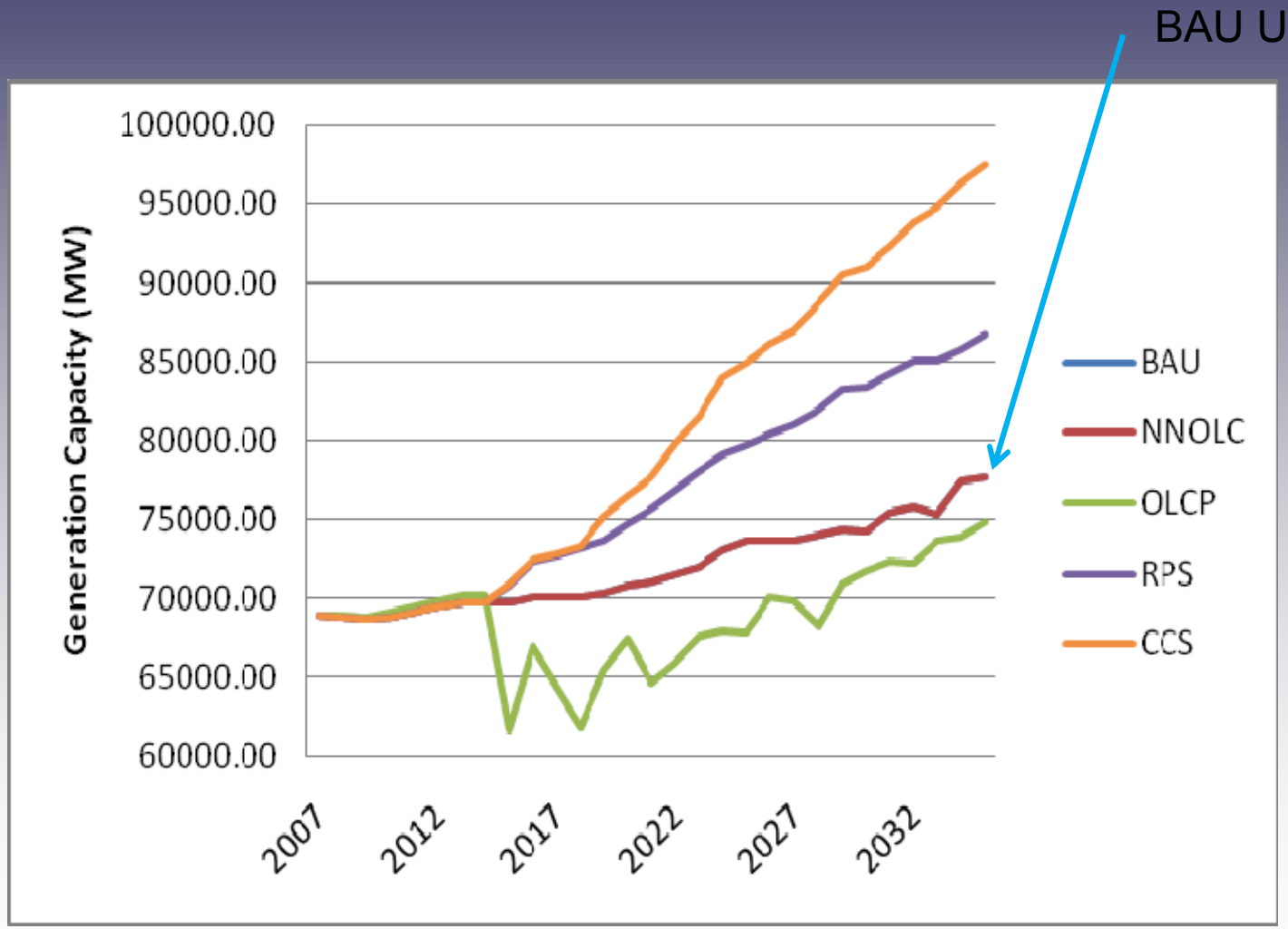
Scenario Analysis

- No New Open Loop Cooling (NNOLC)
  - Same assumptions as BAU except
    - No new open loop cooling
    - Water source mix favors surface water
- Open Loop Cooling Prohibited (OLCP)
  - Same assumptions as NNOLC except
    - Existing plants with OLC are converted
    - Plants older than 35 years with capacity factor below 20% are retired

Scenario Analysis

- Renewable Portfolio Standard (RPS)
  - Same assumptions as NNOLC except
    - Assumes higher penetration of renewables
    - 50% wind, 25% biofuel and 25% NGCC
- Carbon Capture and Sequestration
  - Same assumption as RPS except
    - Carbon cap set at 20% of 2007 levels
    - Takes effect in 2015 and with target date of 2030

Electric Capacity



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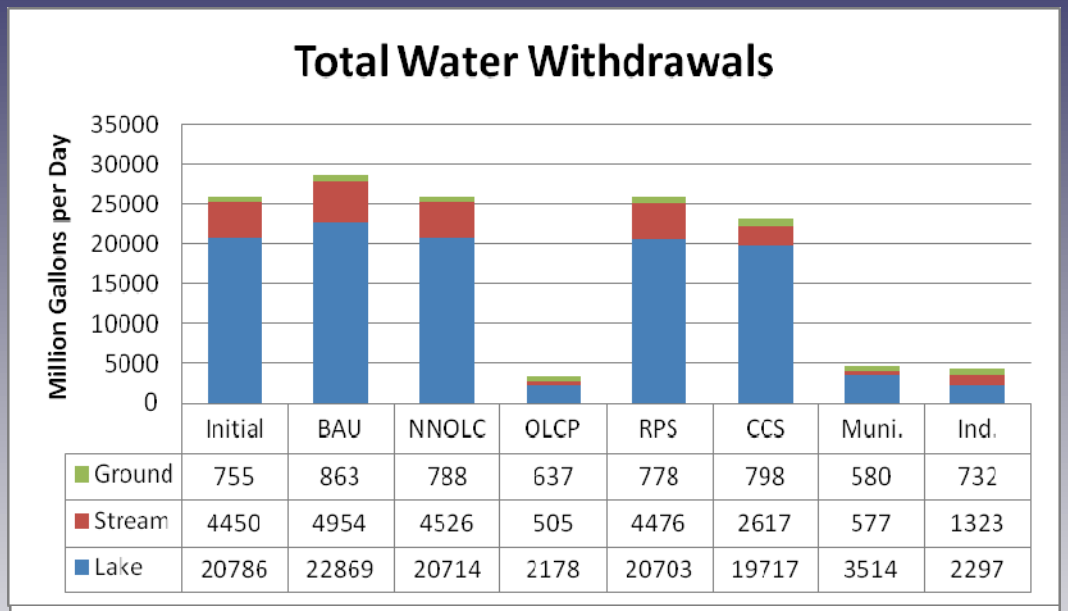
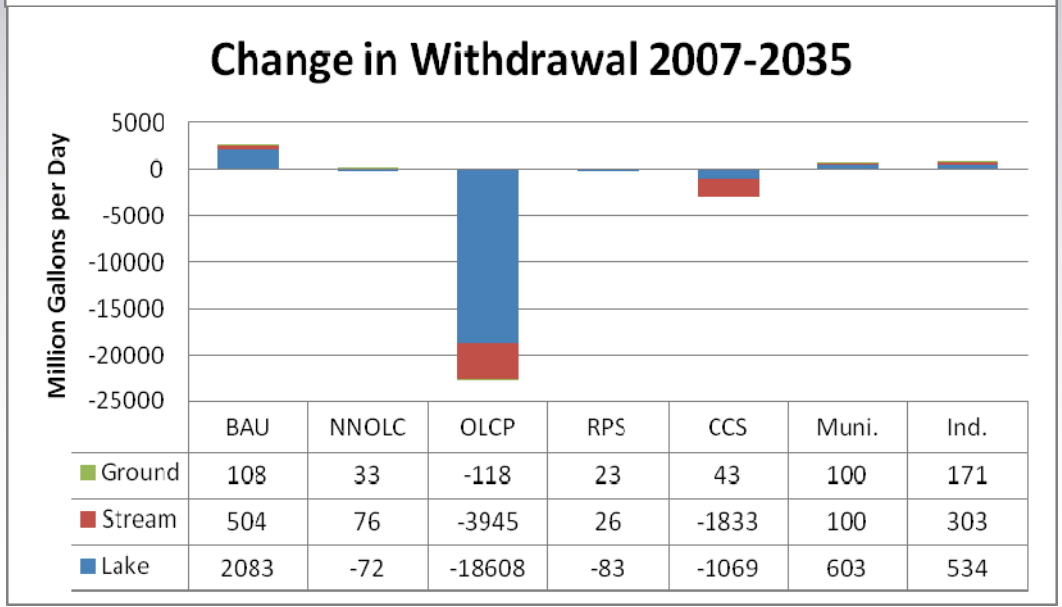
Scenarios: Thermoelectric Withdrawal



	Initial	BAU	NNOLC	OLCP	RPS	CCS	Muni.	Ind.
Ground	755	863	788	637	778	798	580	732
Stream	4450	4954	4526	505	4476	2617	577	1323
Lake	20786	22869	20714	2178	20703	19717	3514	2297



	BAU	NNOLC	OLCP	RPS	CCS	Muni.	Ind.
Ground	108	33	-118	23	43	100	171
Stream	504	76	-3945	26	-1833	100	303
Lake	2083	-72	-18608	-83	-1069	603	534

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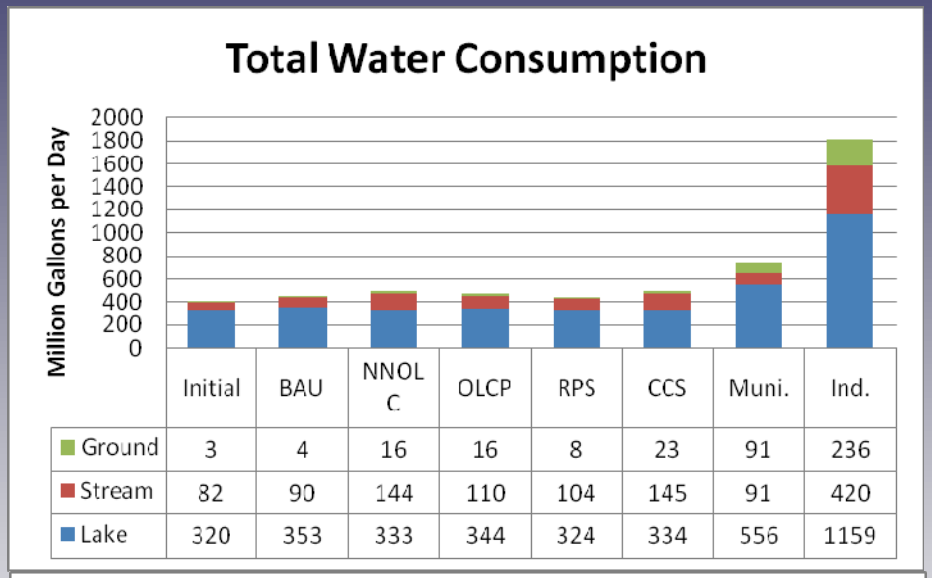
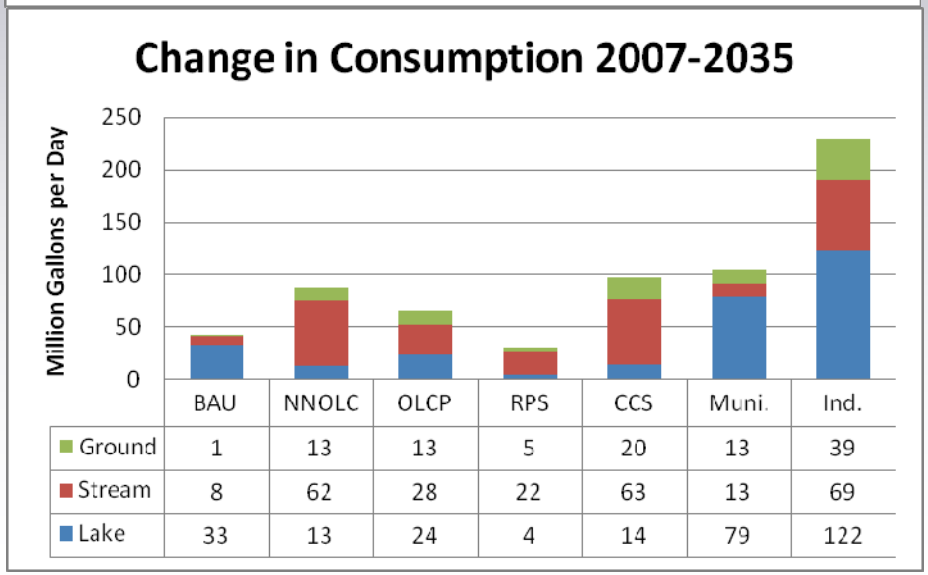
Scenarios: Thermoelectric Consumption



	Initial	BAU	NNOLC	OLCP	RPS	CCS	Muni.	Ind.
Ground	3	4	16	16	8	23	91	236
Stream	82	90	144	110	104	145	91	420
Lake	320	353	333	344	324	334	556	1159



	BAU	NNOLC	OLCP	RPS	CCS	Muni.	Ind.
Ground	1	13	13	5	20	13	39
Stream	8	62	28	22	63	13	69
Lake	33	13	24	4	14	79	122

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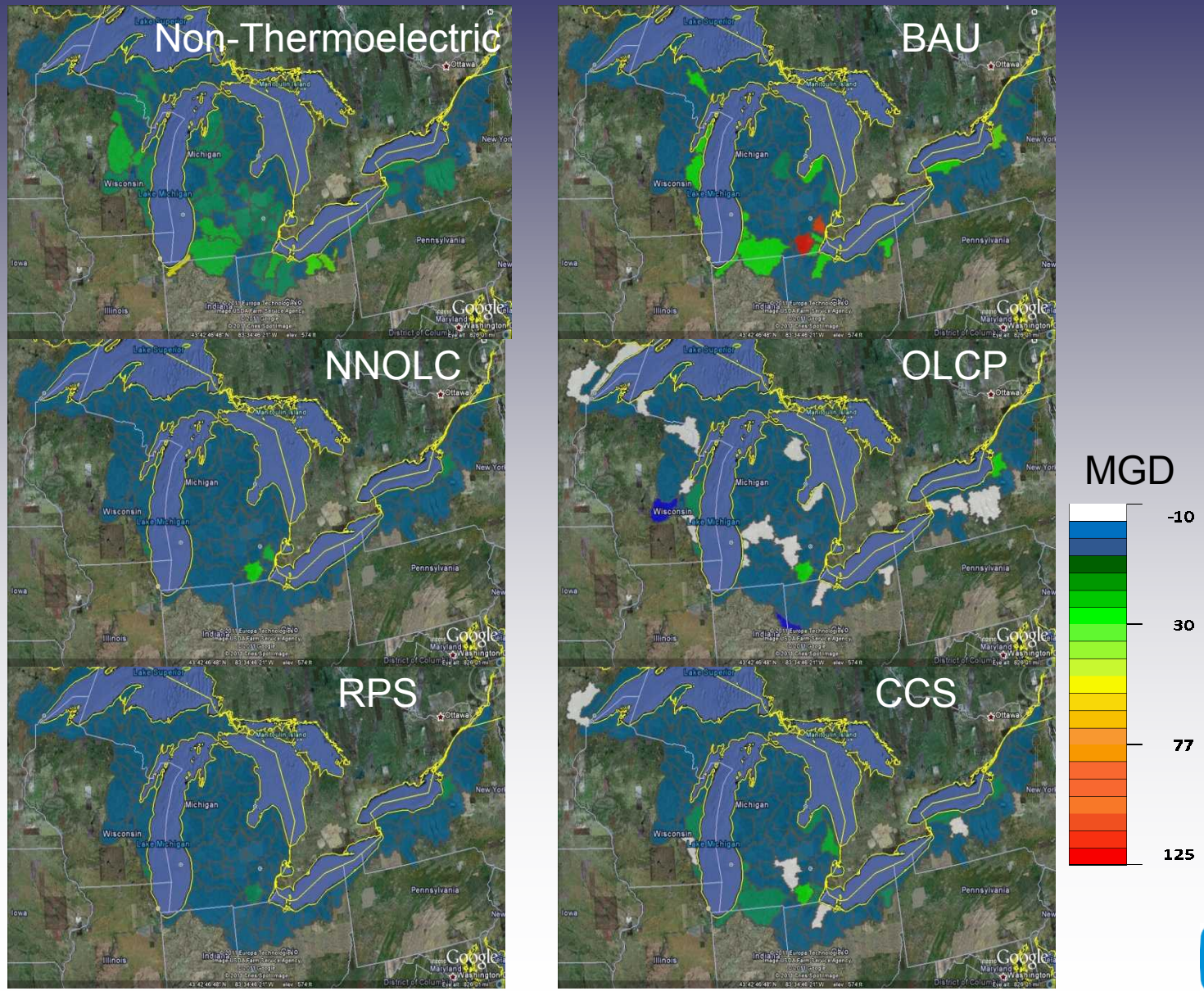
Scenarios: Withdrawals



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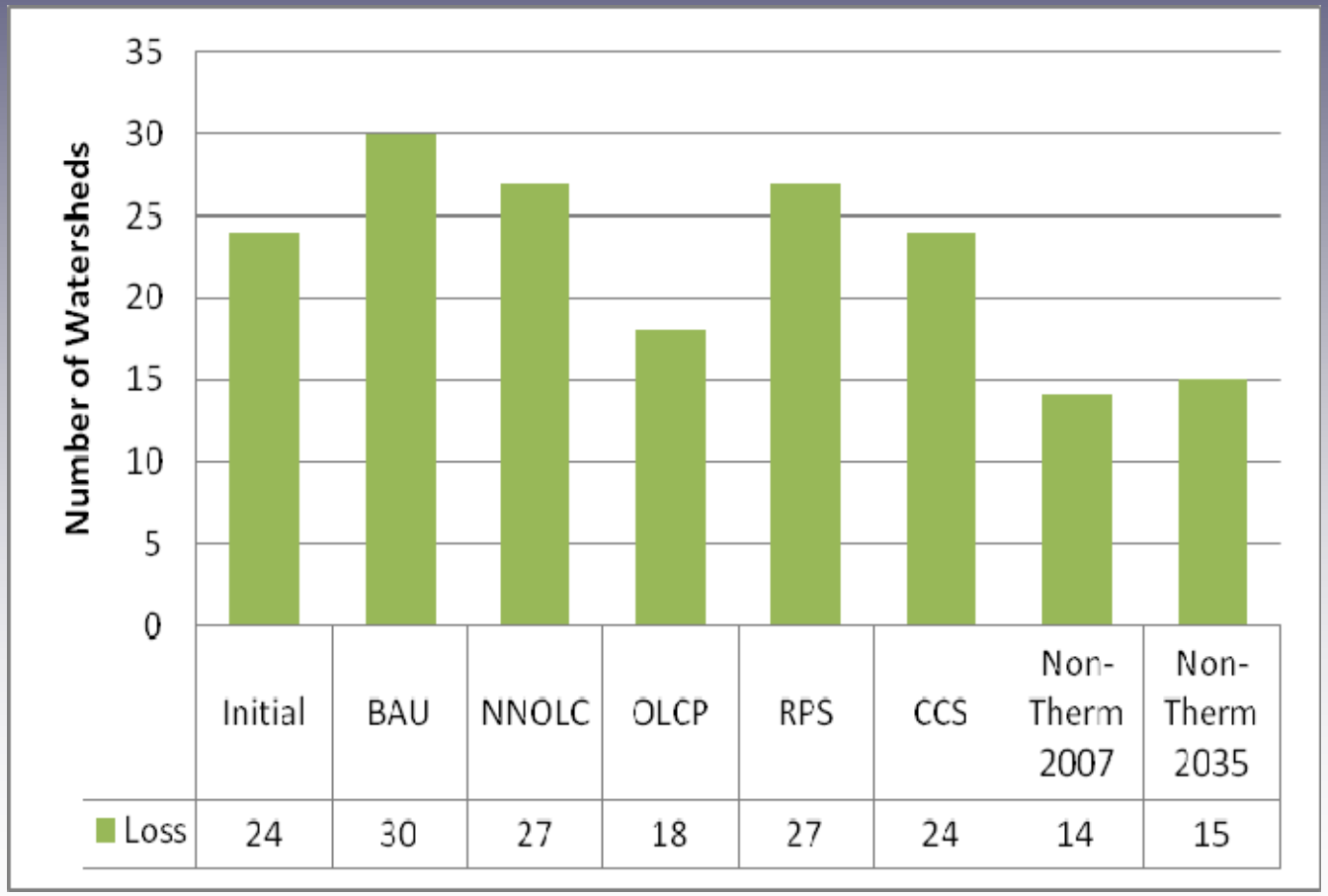
Vulnerable Watersheds



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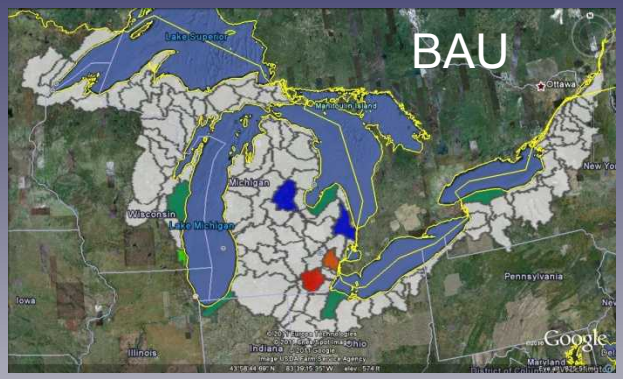
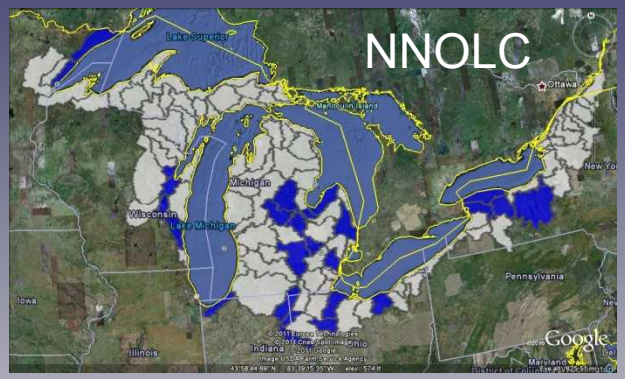
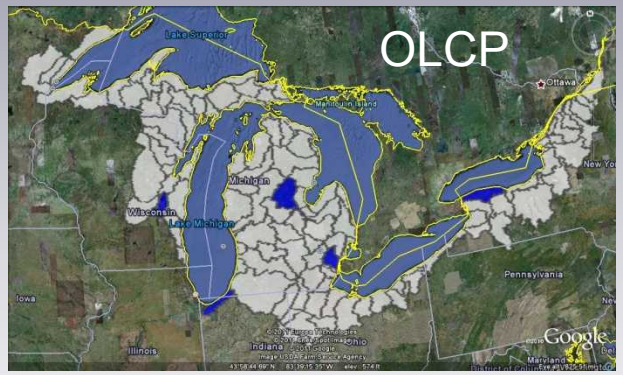
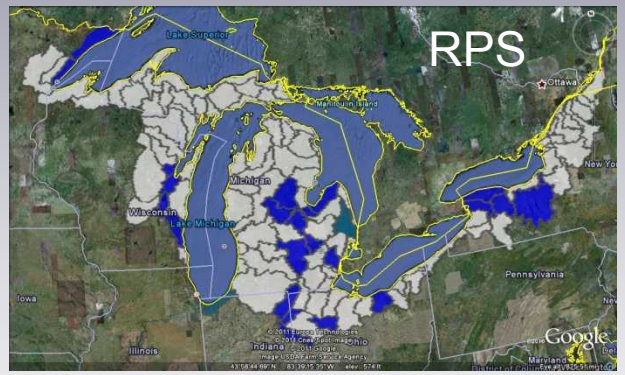
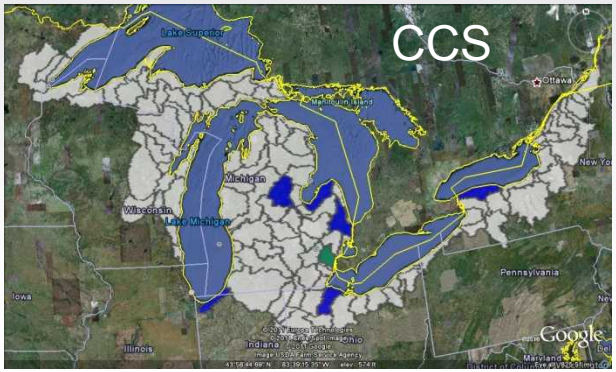
Scenarios: Withdrawal from Vulnerable Watersheds



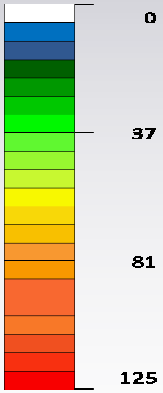








MGD



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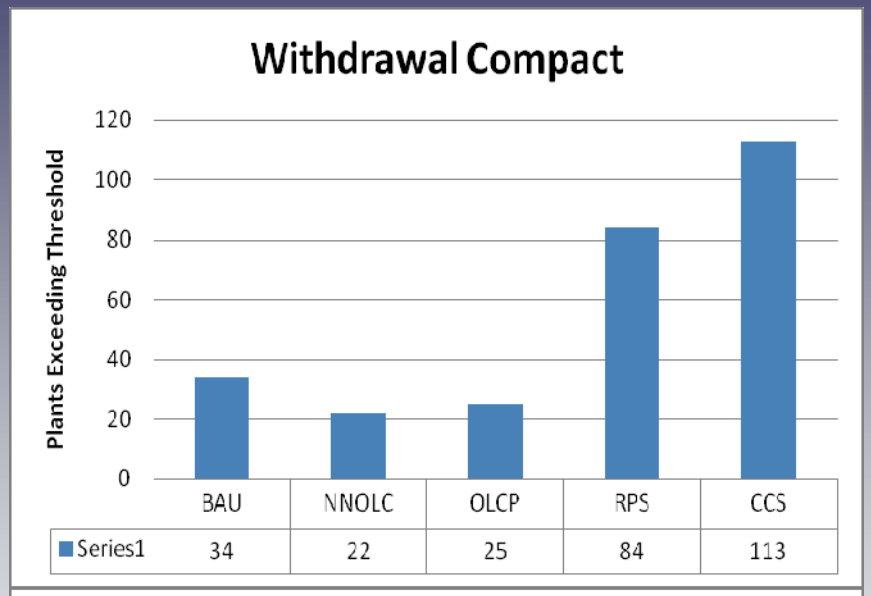
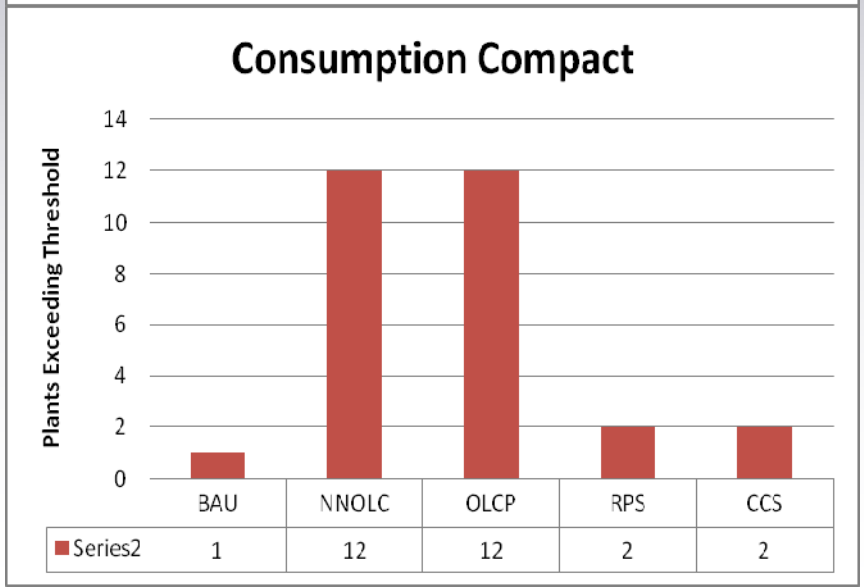
Scenarios: Plants Requiring Permitting Under Compact





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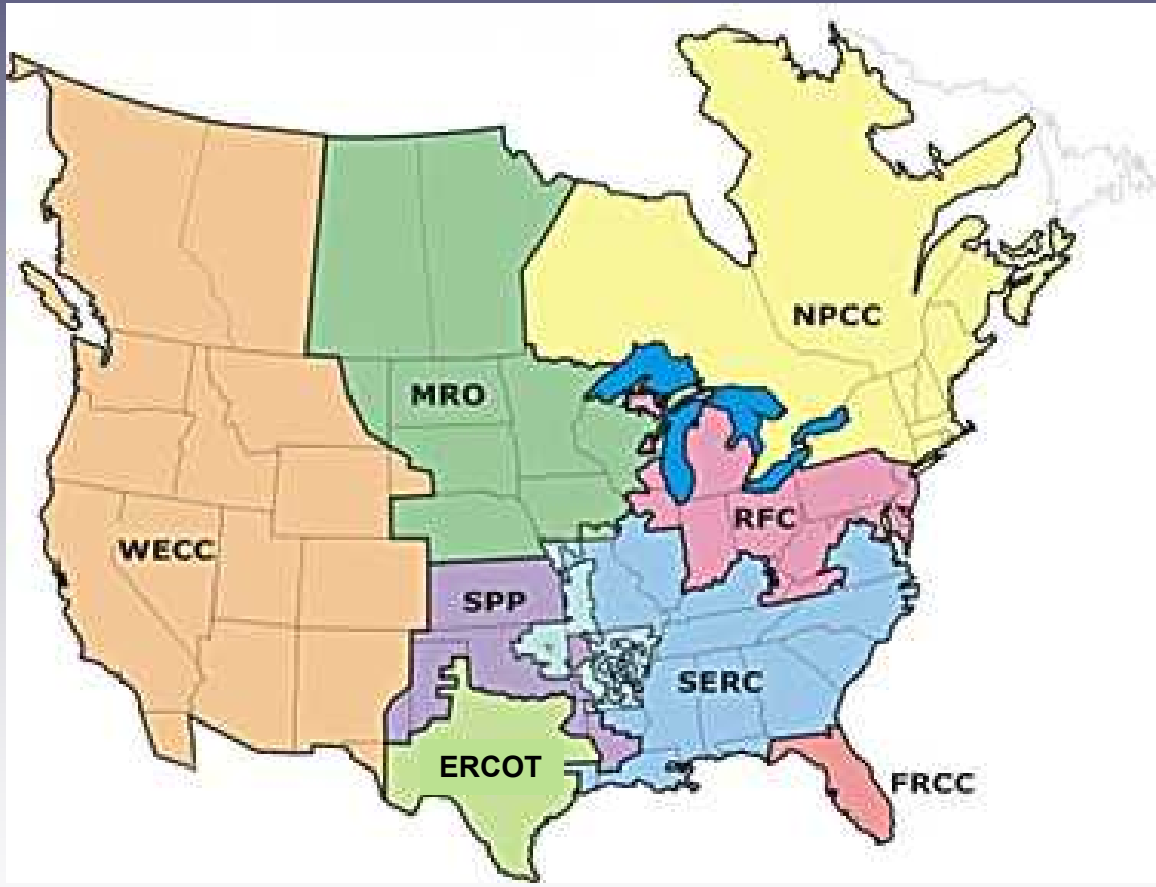
Energy and Water in the Western and Texas Interconnects

- Project duration:
  - 24 months for WECC
  - 18 months for ERCOT
- Planning horizon is to 2030



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Project Partners

- Sandia National Laboratories
  - Vincent Tidwell
  - Barbie Moreland
  - Howard Passell
- Argonne National Laboratory
  - John Gasper
  - John Veil
  - Chris Harto
- Electric Power Research Institute
  - Robert Goldstein
- National Renewable Energy Laboratory
  - Jordan Macknick
  - Robin Newmark
  - Daniel Inman
  - Kathleen Hallett
- Idaho National Laboratory
  - Gerald Sehlke
  - Randy Lee
- Pacific Northwest National Laboratory
  - Mark Wigmosta
  - Richard Skaggs
  - Ruby Leung
- University of Texas
  - Michael Webber
  - Carey King

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Argonne NATIONAL LABORATORY

EPRI ELECTRIC POWER RESEARCH INSTITUTE

NREL National Renewable Energy Laboratory

INL Idaho National Laboratory

THE UNIVERSITY OF TEXAS AT AUSTIN

Pacific Northwest NATIONAL LABORATORY

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Project Objectives

- Reduce the water footprint of electric power production in western North America:
  - Develop tools for quantitative assessment of the energy-water nexus,
  - Engage stakeholders across the energy-water spectrum, and
  - Evaluate water implications of alternative interconnection-wide transmission expansion scenarios.

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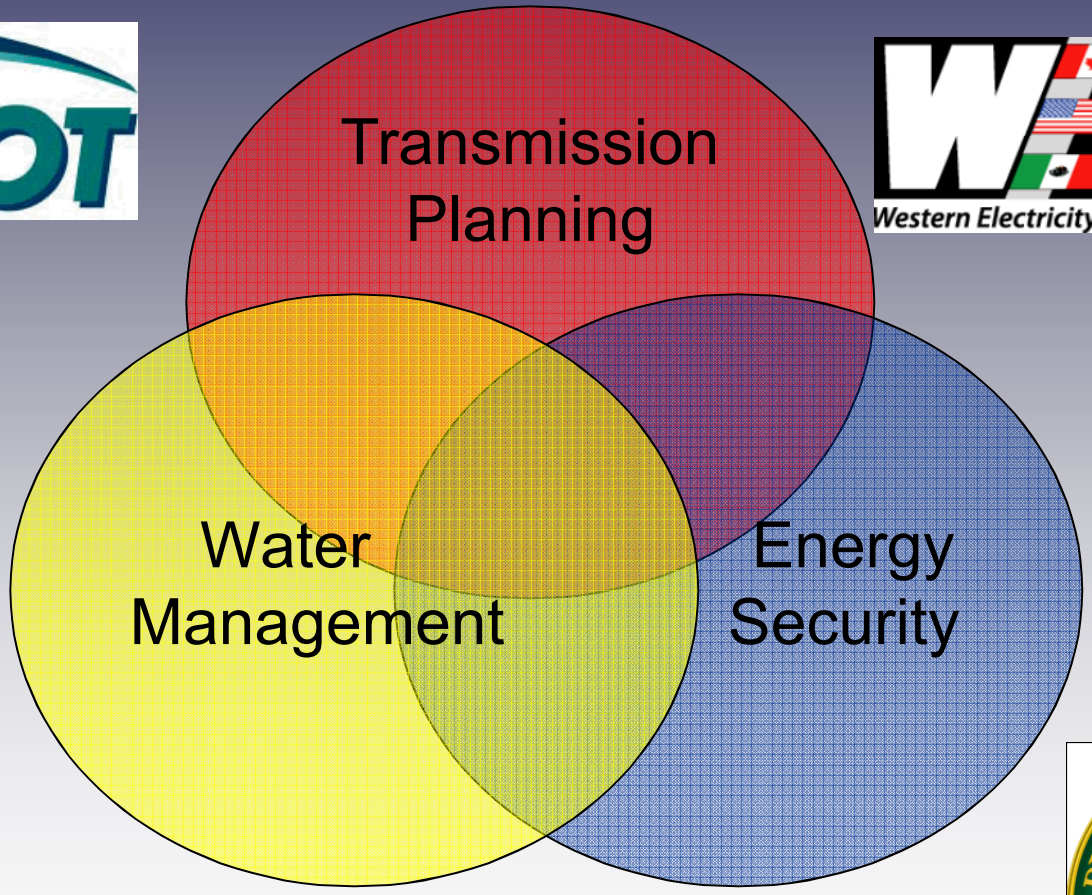
Multi-Stakeholder Process

ERCOT



WECC
Western Electricity Coordinating Council

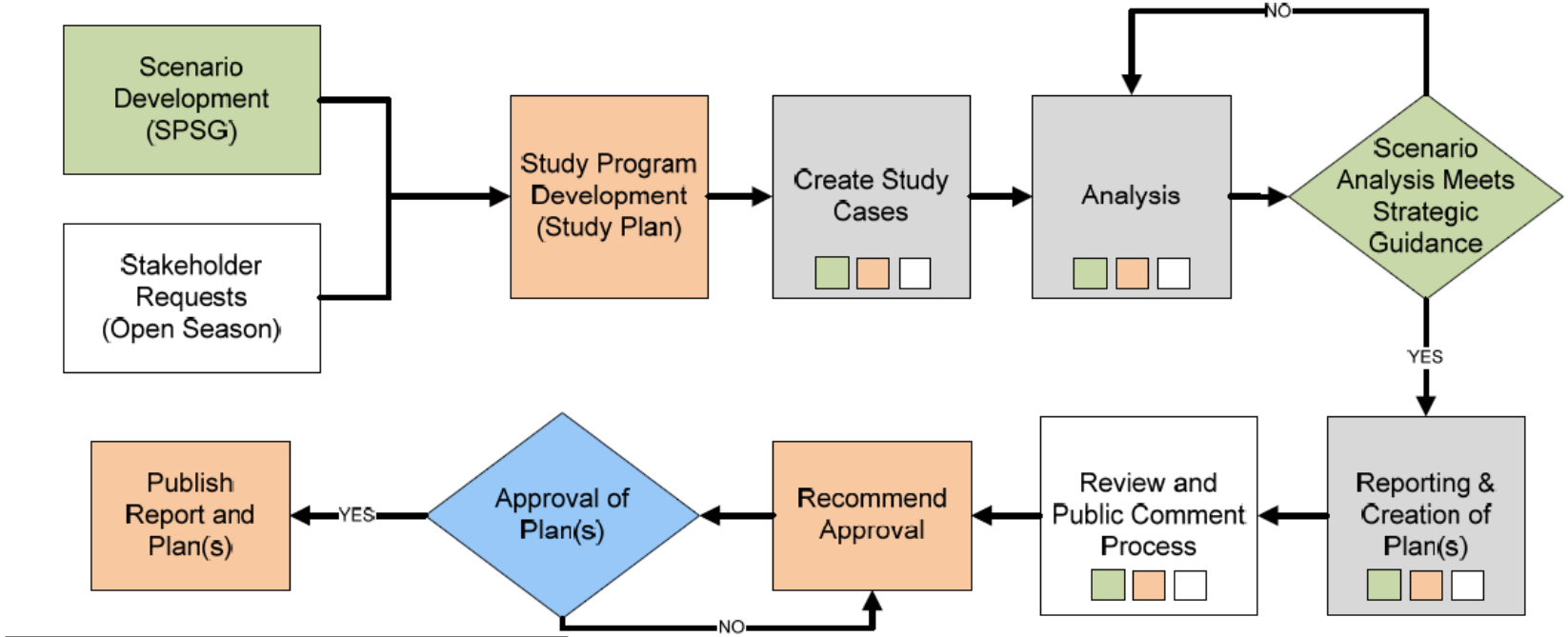
Western Governors' Association
Serving the Governors of 19 States and 3 US-Flag Pacific Islands

WSWC
Western States Water Council

Department of Energy
United States of America

National Laboratories

Transmission Planning Process

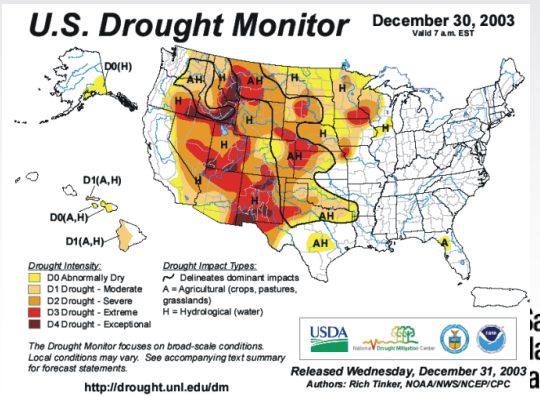


Note – The small boxes represent opportunities for stakeholders to be directly involved in planning processes.

TEPPC Workgroup activities are open to all and decisions are made by consensus. It is at these meetings where many of the details of the planning process are decided.

Scenario Analysis: Examples

- High demand
- Integration of renewables
- High penetration of electric vehicles
- High demand side management
- Extended drought
- Expanded emission controls



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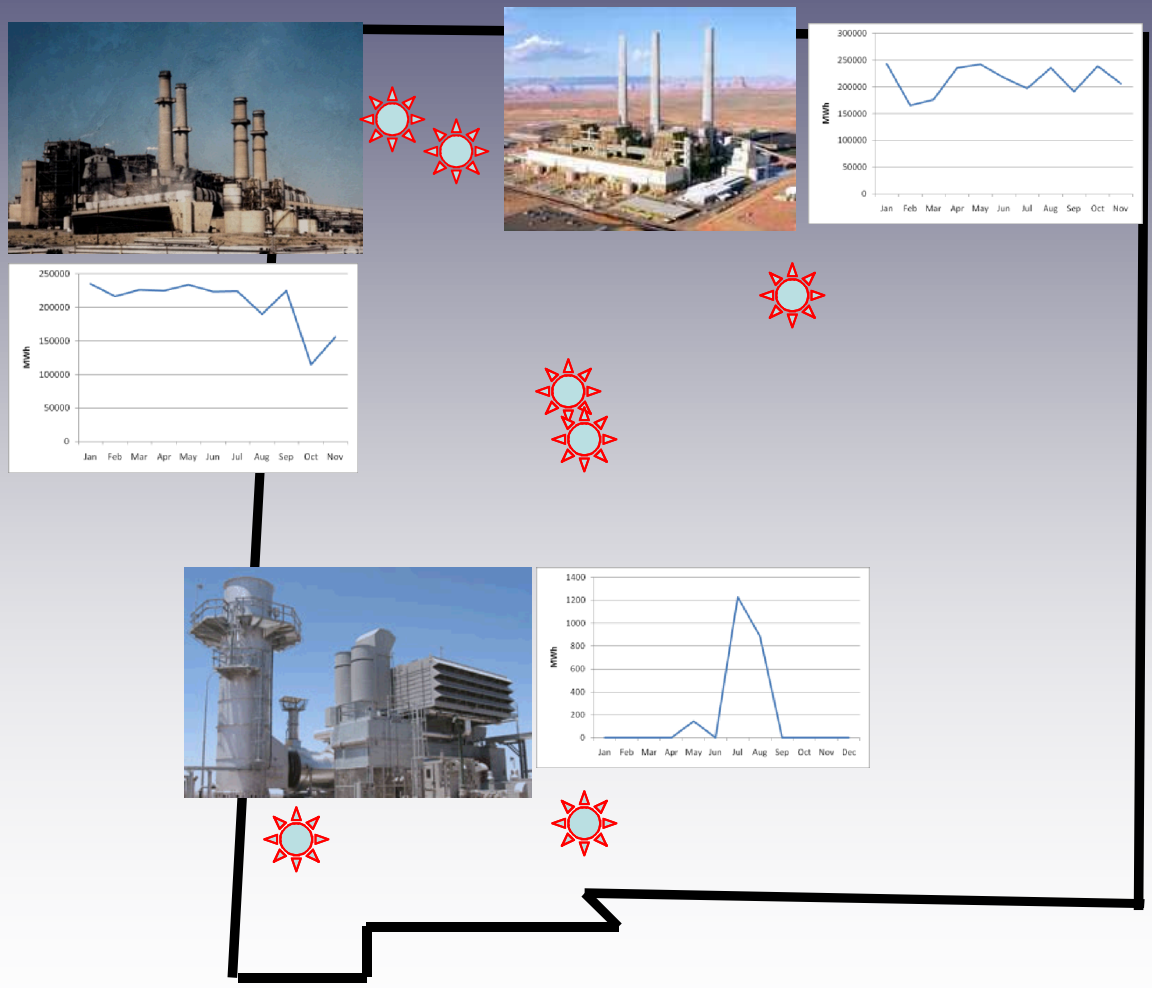
Scenario Analysis: Existing Fleet



- ***Plant Characteristics***
  - ***System upgrades, and***
  - ***Production, or***
  - ***Retirement***

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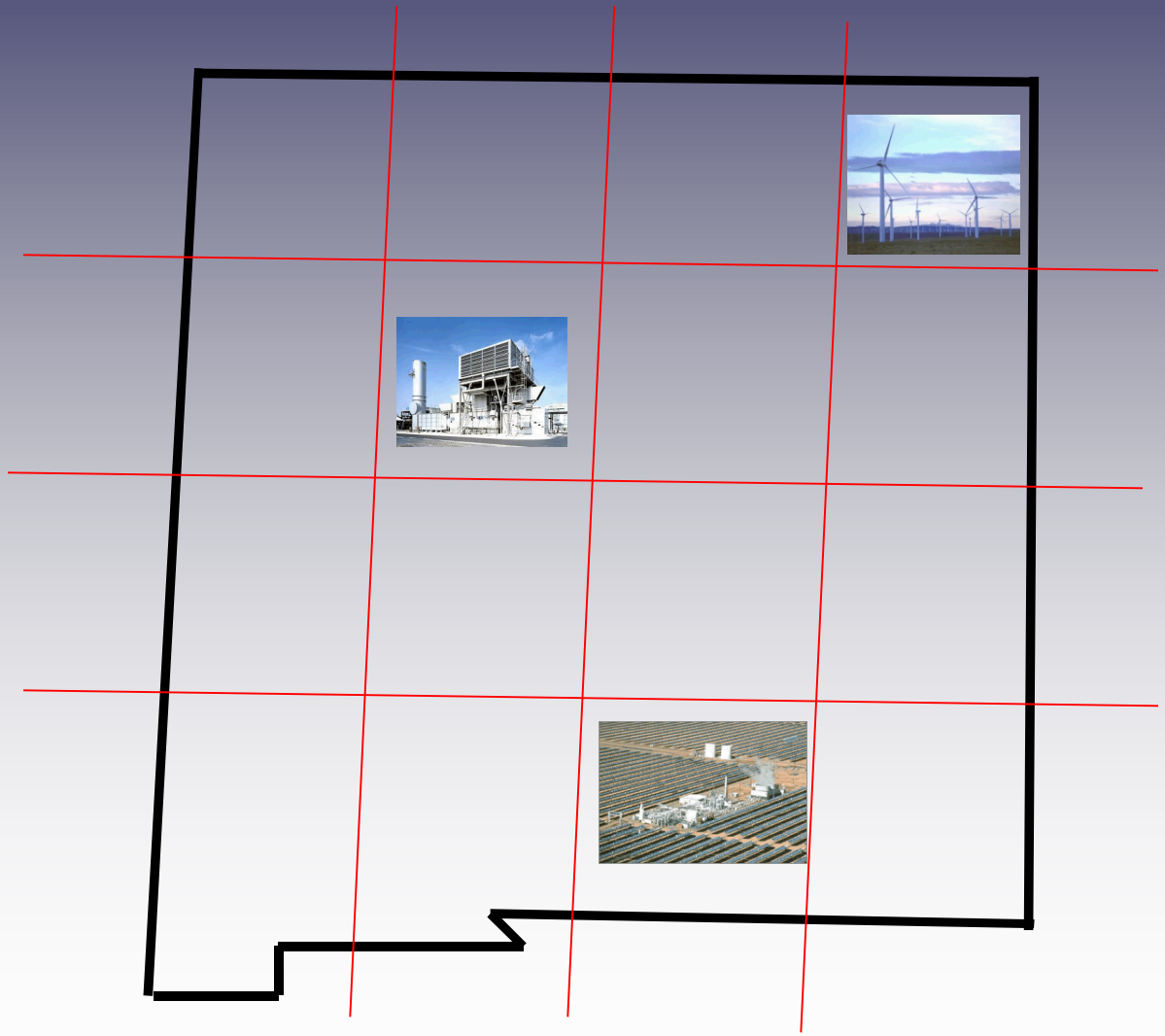
Scenario Analysis: Fleet Expansion



- ***Plant characteristics***
  - ***Location,***
  - ***Fuel type,***
  - ***Size, and***
  - ***Production***

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Thermoelectric Water Use

- ***Water withdrawal and consumption by power plant***
  - ***Current, and***
  - ***Future fleet.***
- ***Potential policy Changes***
  - ***Open loop cooling, and***
  - ***Carbon capture and sequestration***

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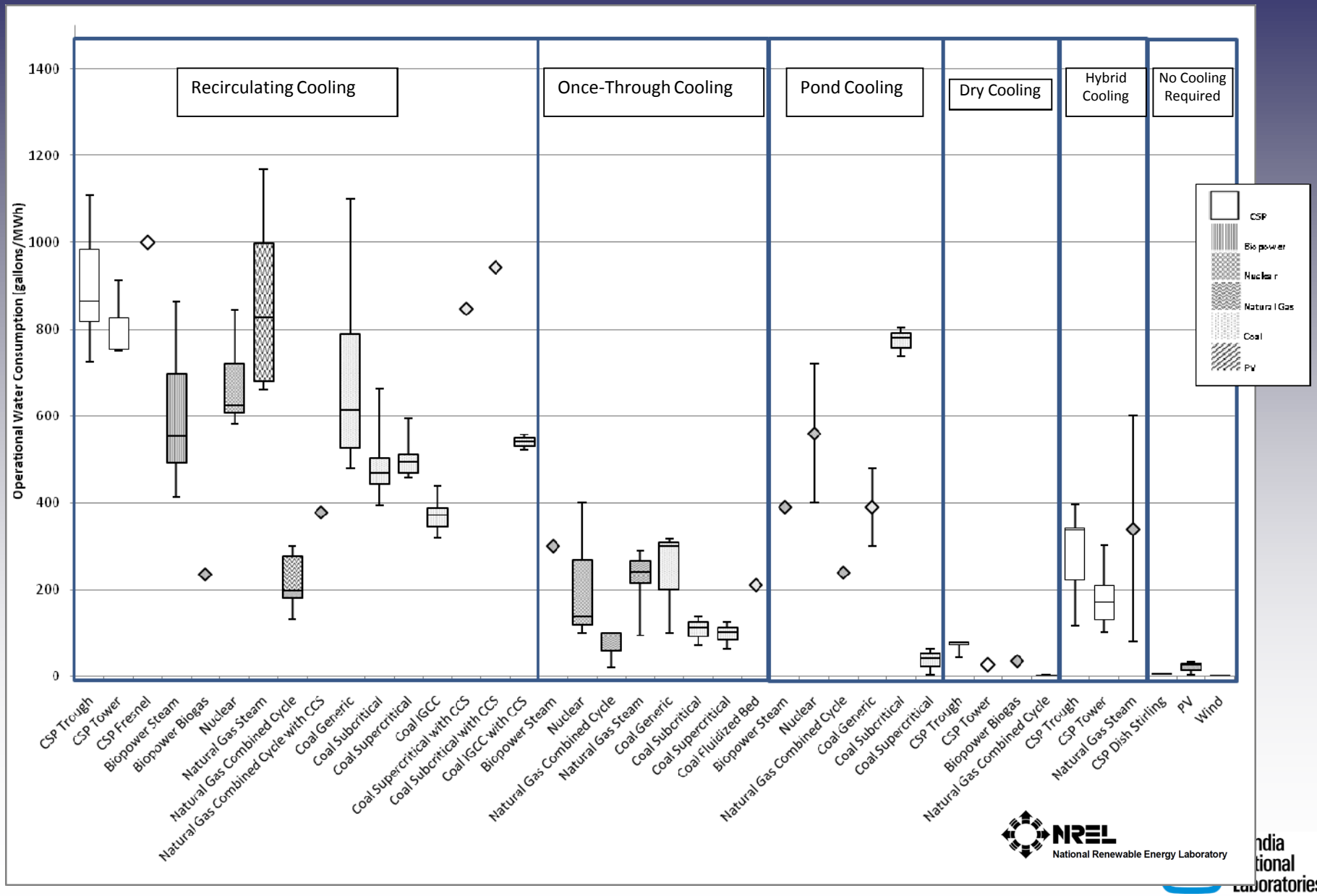
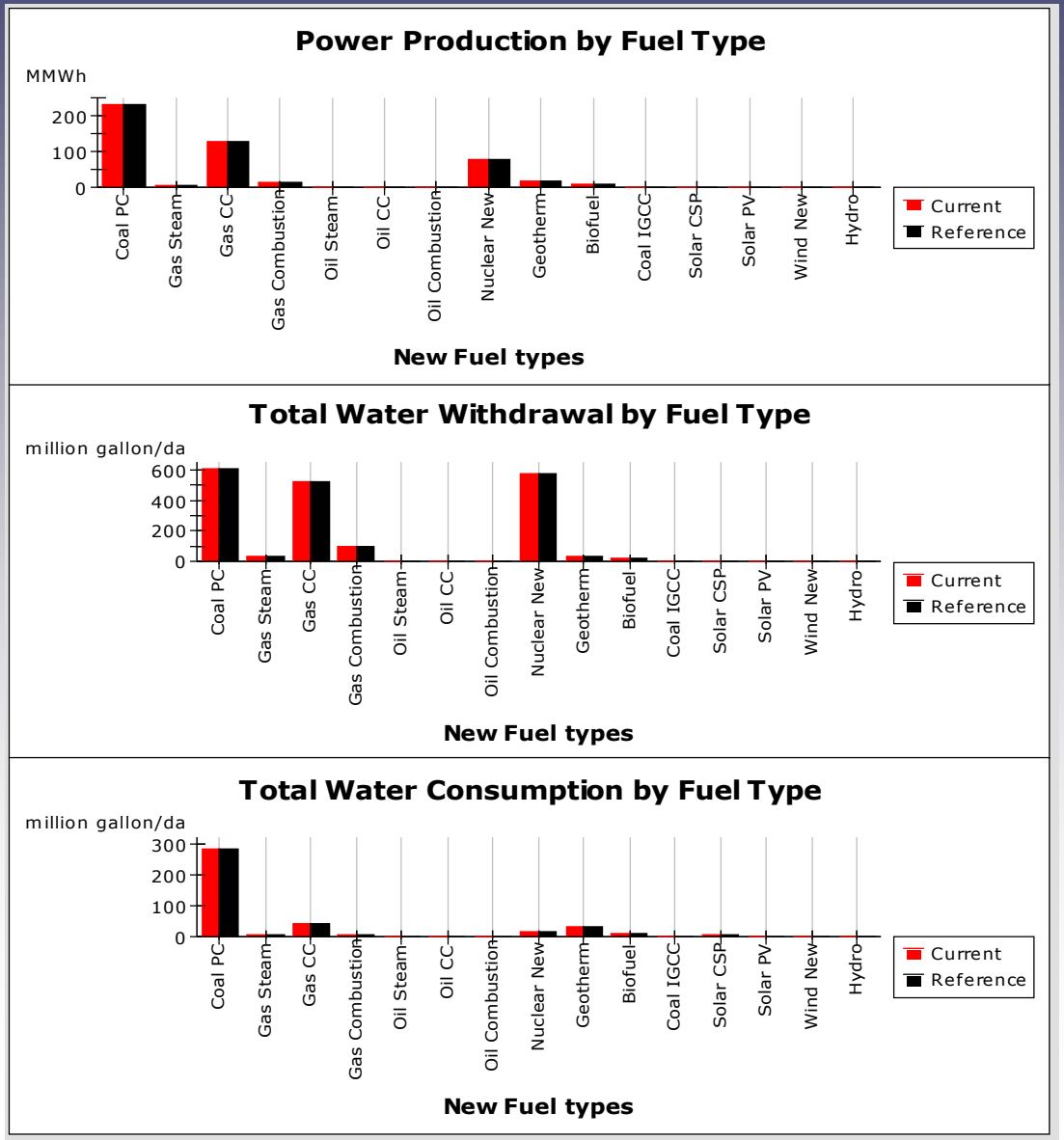
Thermoelectric Water Use



NREL
National Renewable Energy Laboratory

Production and Water Use by Fuel Type



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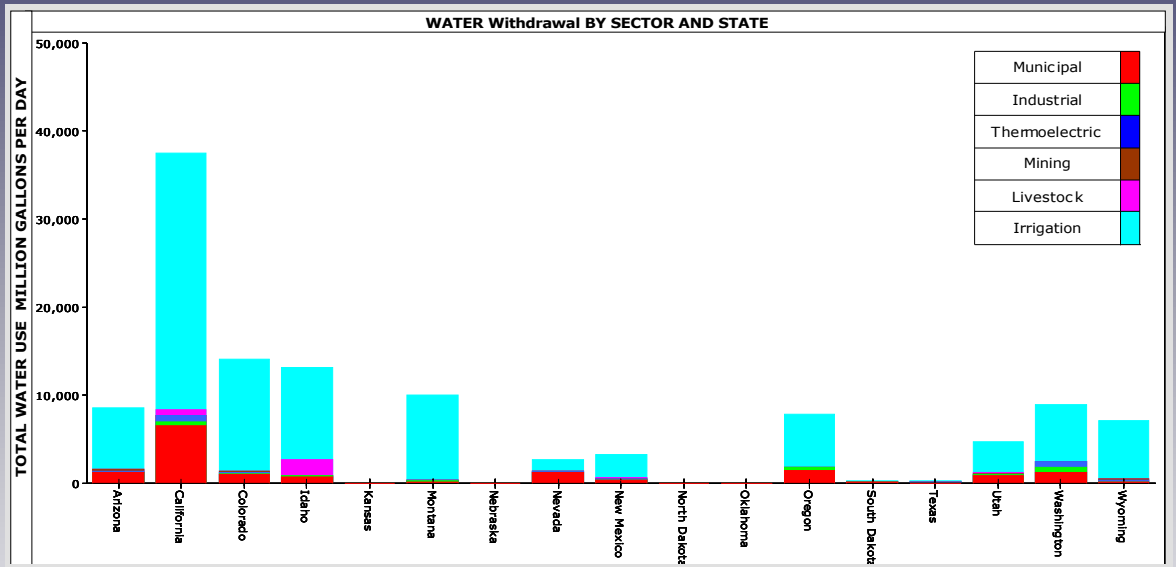
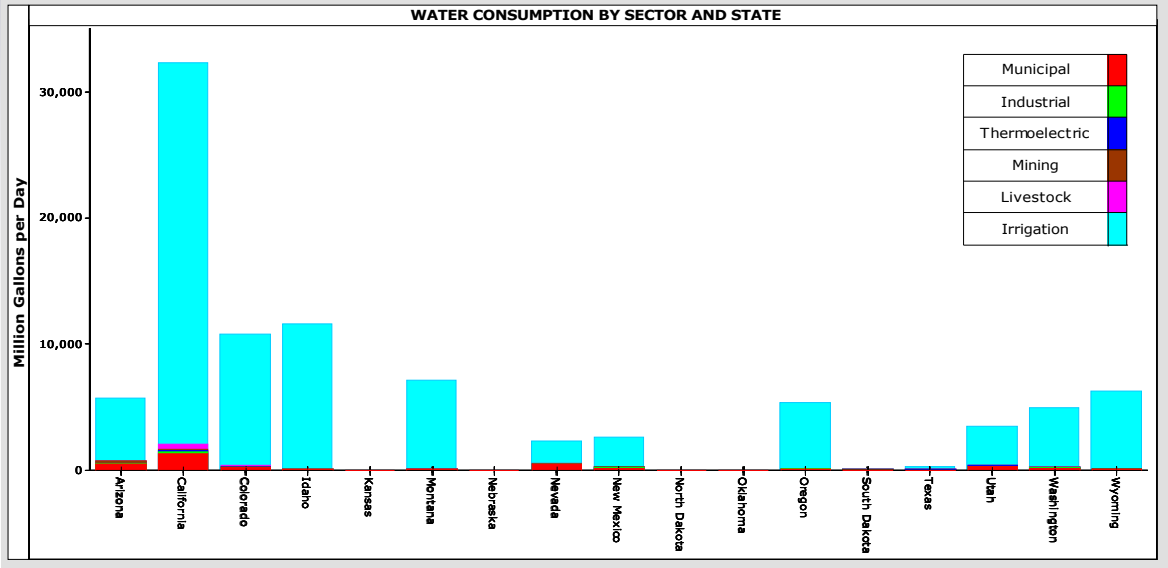
Withdrawal and Consumption by State





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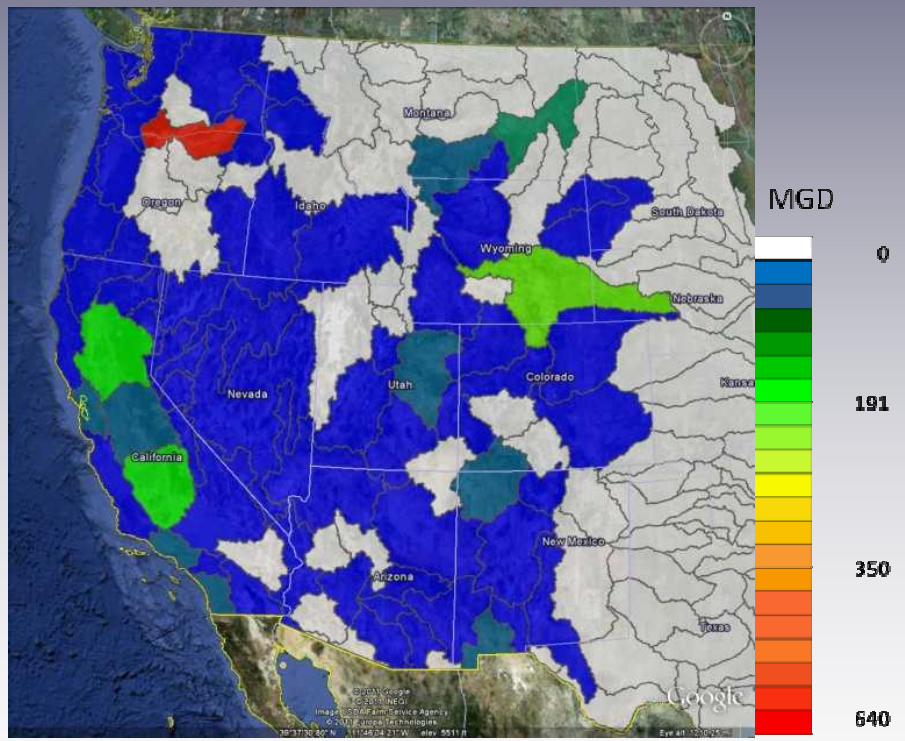
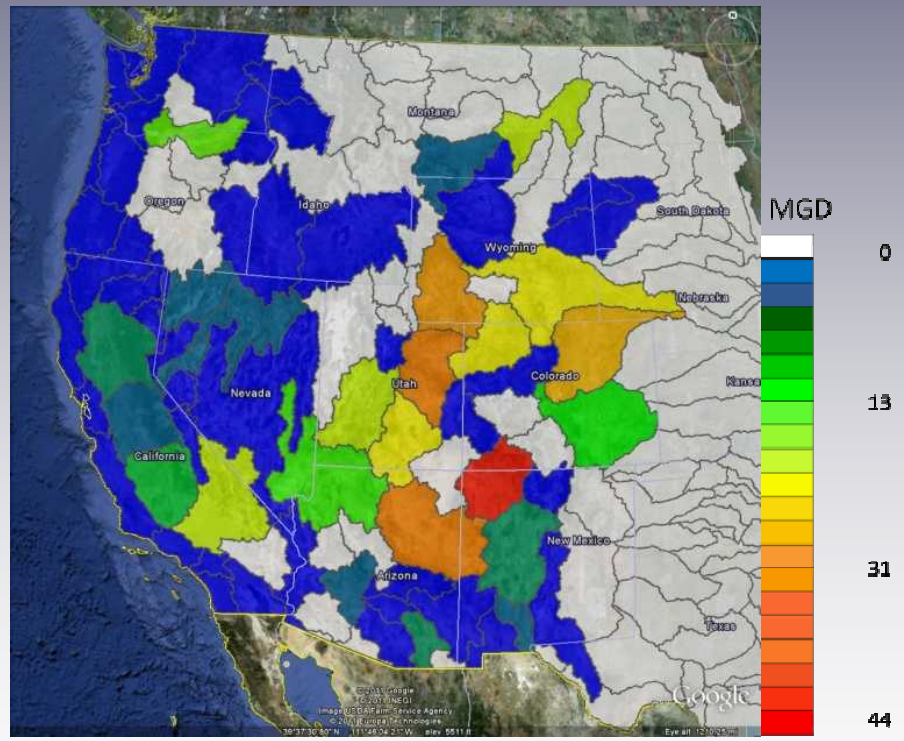
Water Use by Existing Fleet

Thermoelectric
Withdrawal in 2010



Thermoelectric
Consumption in 2010



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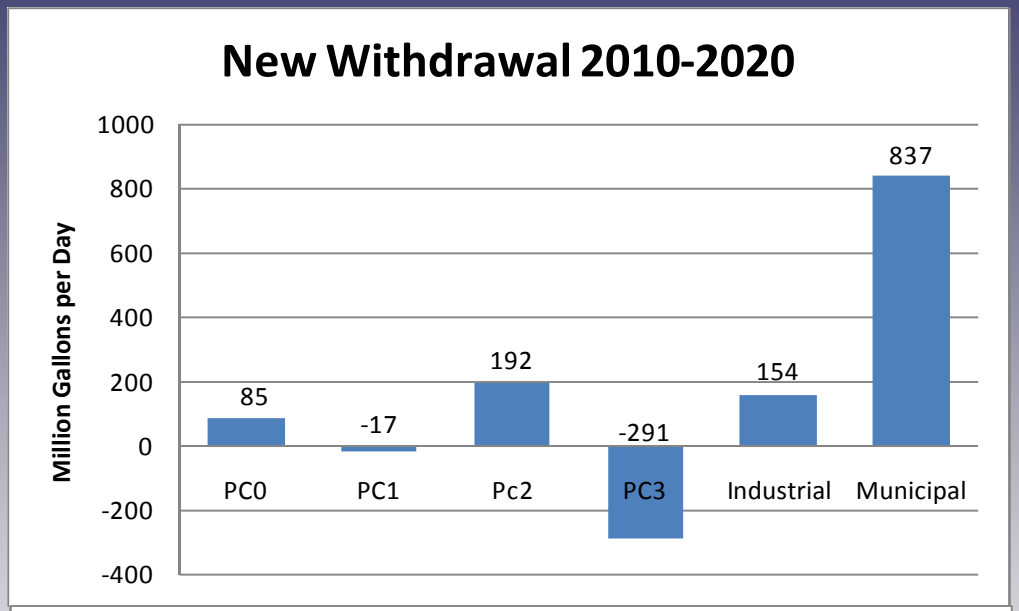
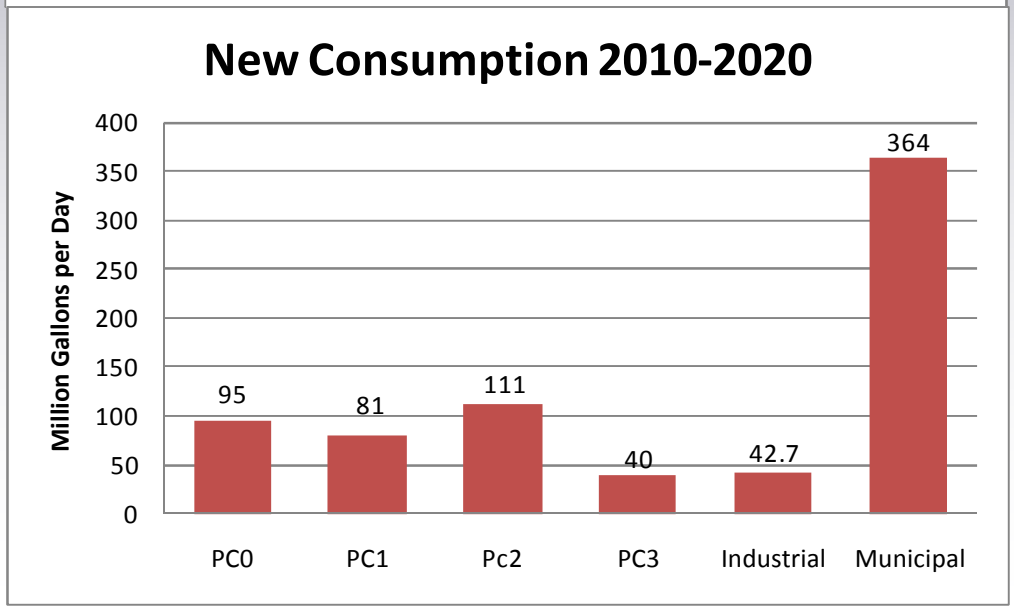
Water Use by Scenario





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Assess Water Availability

- ***How "difficult" would it be to acquire new water in a given basin?***
- ***How "vulnerable" are existing plants to drought related water supply disruptions?***
- ***What limited set of metrics best characterize answers to these questions?***

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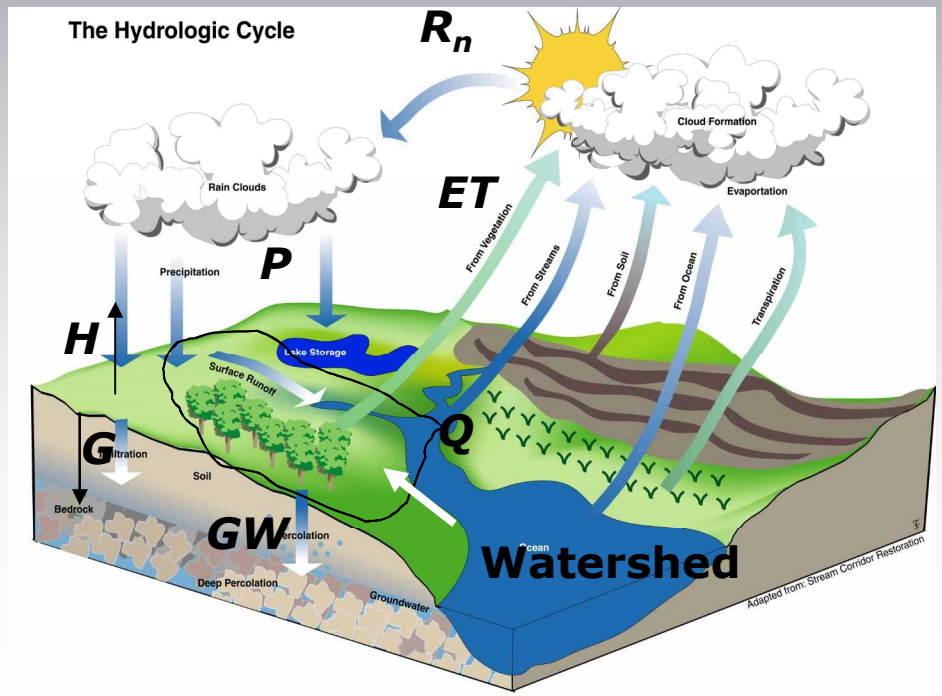
Water Availability Indicators

- ***Water Demand***
- ***Water Supply***
- ***Drought Vulnerability***
- ***Institutional Factors***
- ***Value of Water***

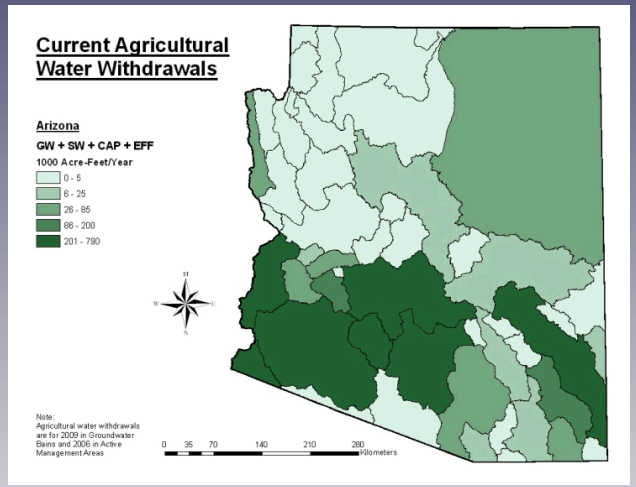
Physical Water Budget

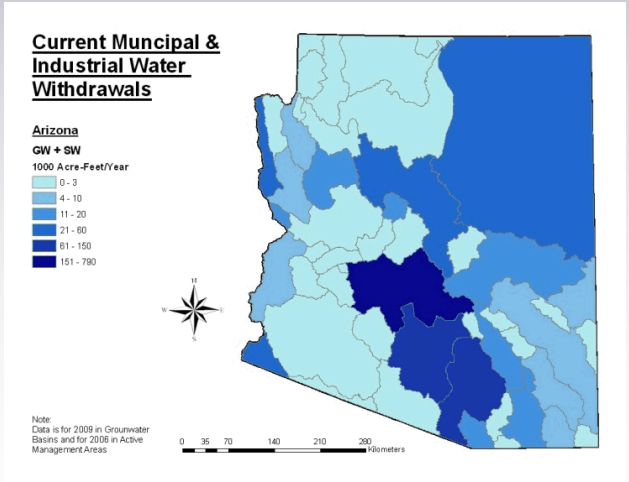
Water Budget

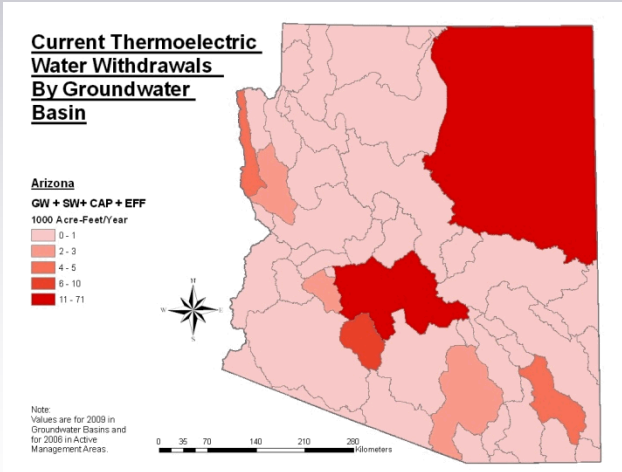


Water Availability Indicators: Demand

- *Focus on withdrawals*
- *Estimate consumption from withdrawals*
- *Disaggregate by:*
  - *8-digit watershed*
  - *Sector*
    - *M&I*
    - *Agriculture*
    - *Evaporative*
    - *Instream*
  - *Water source*







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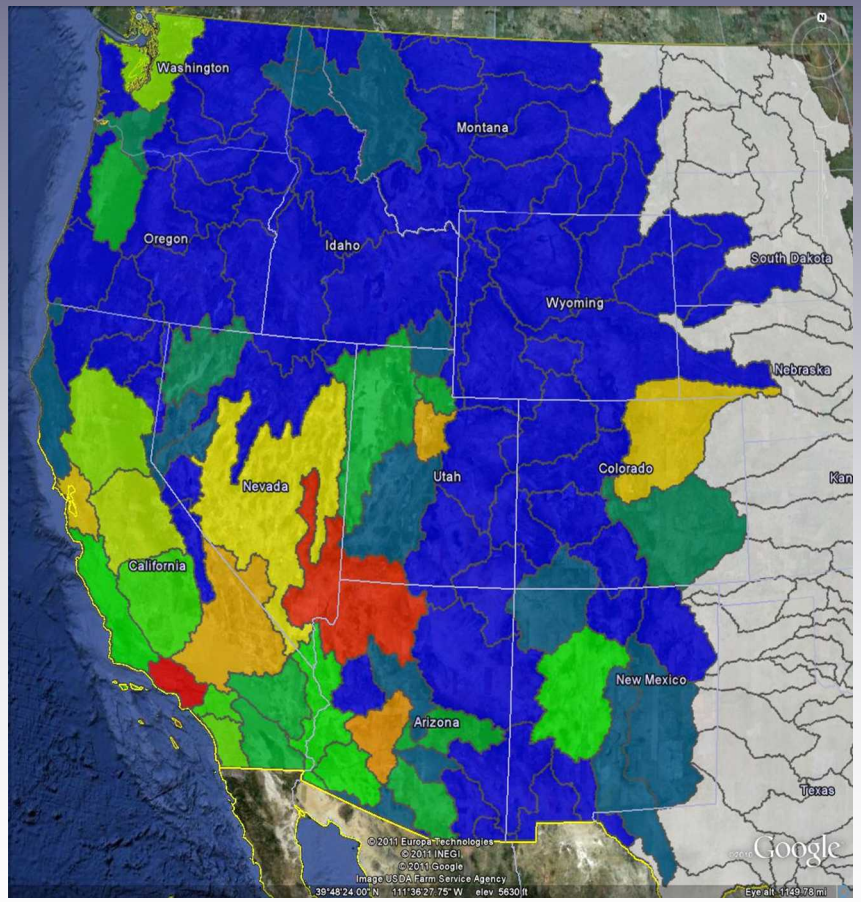
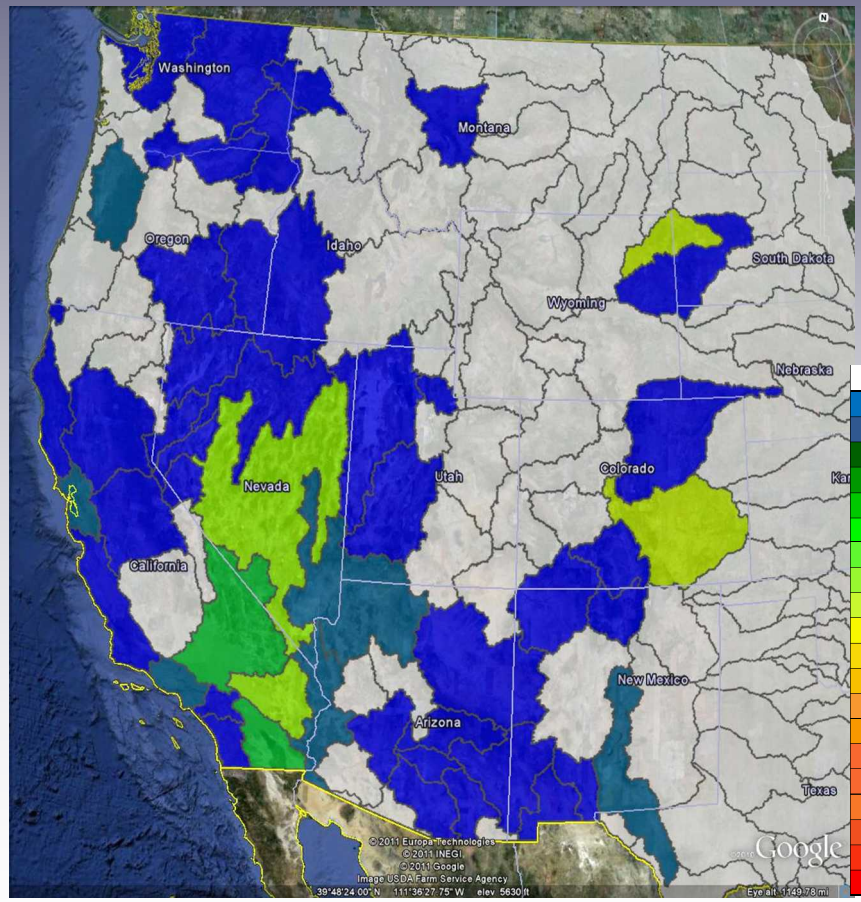
Competition for New Water Use

Non-Thermoelectric Consumption



Thermoelectric Consumption



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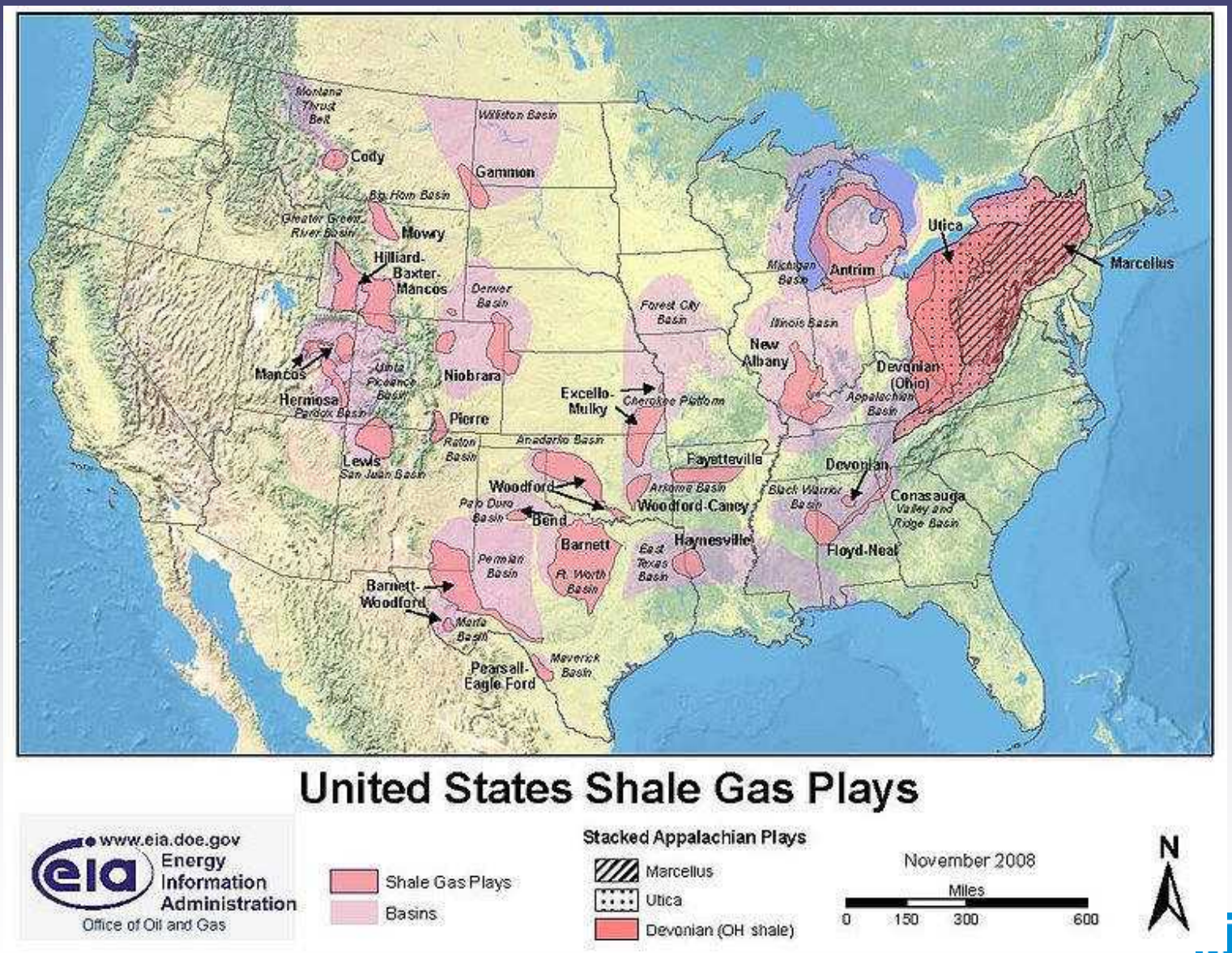
Water Availability Indicators: Demand



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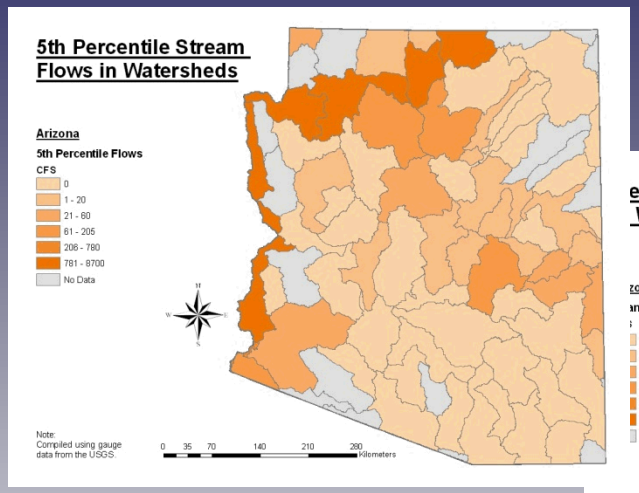
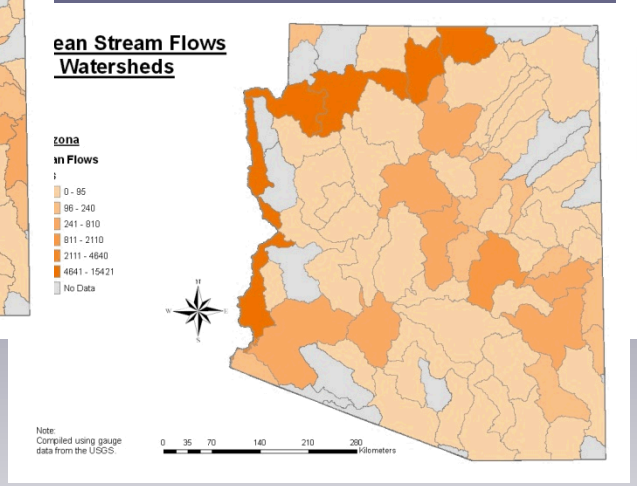
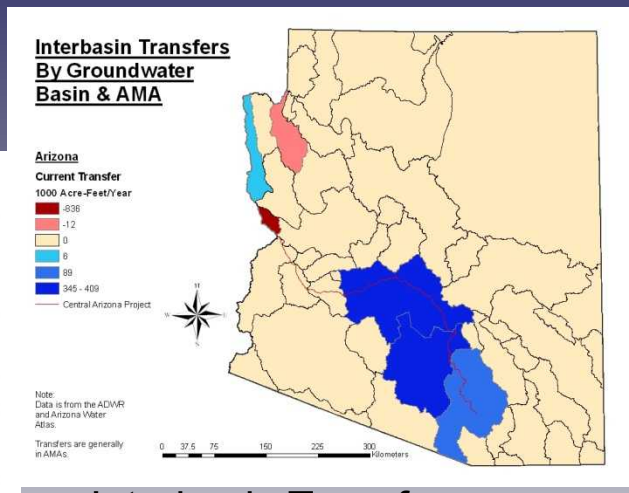
Water Availability Indicators: Supply



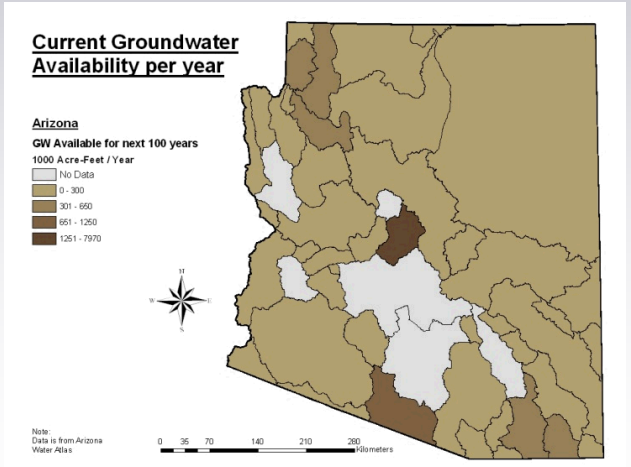
Mean Gauged Streamflow



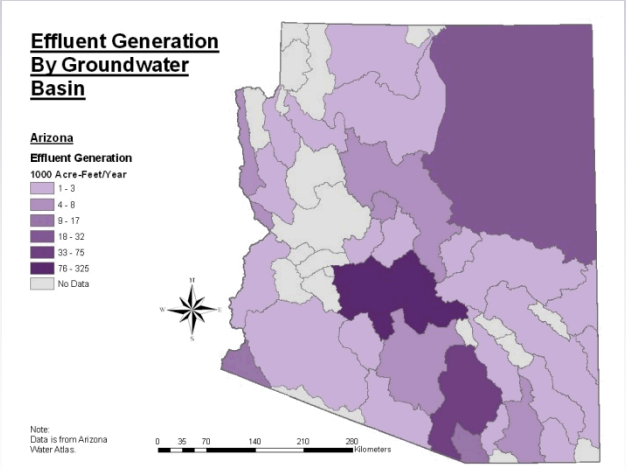
Annual Low Flow



Interbasin Transfers



Non-Tributary Groundwater



Accessible Non-Potable Sources

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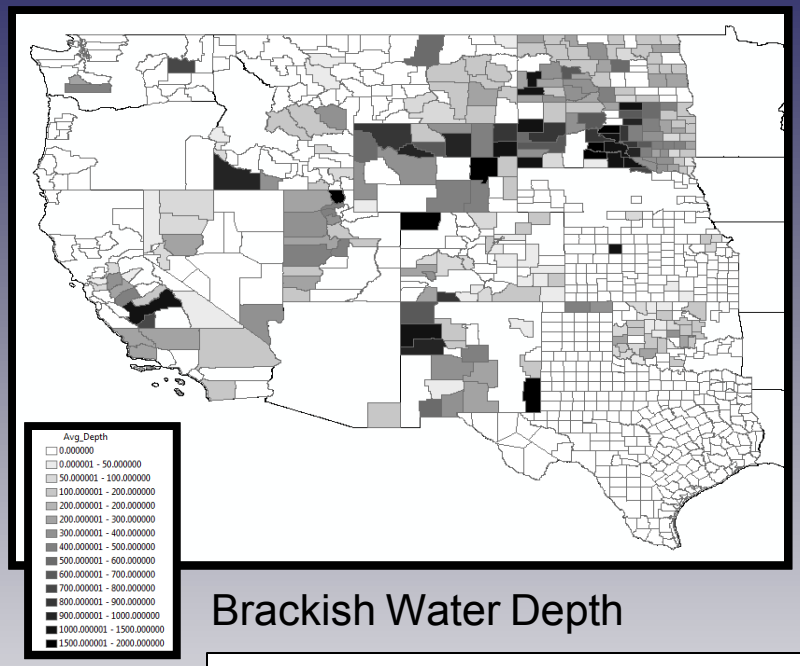
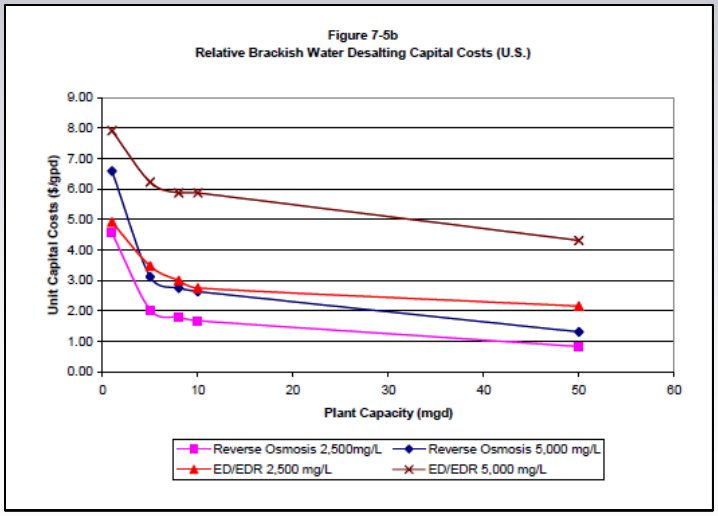
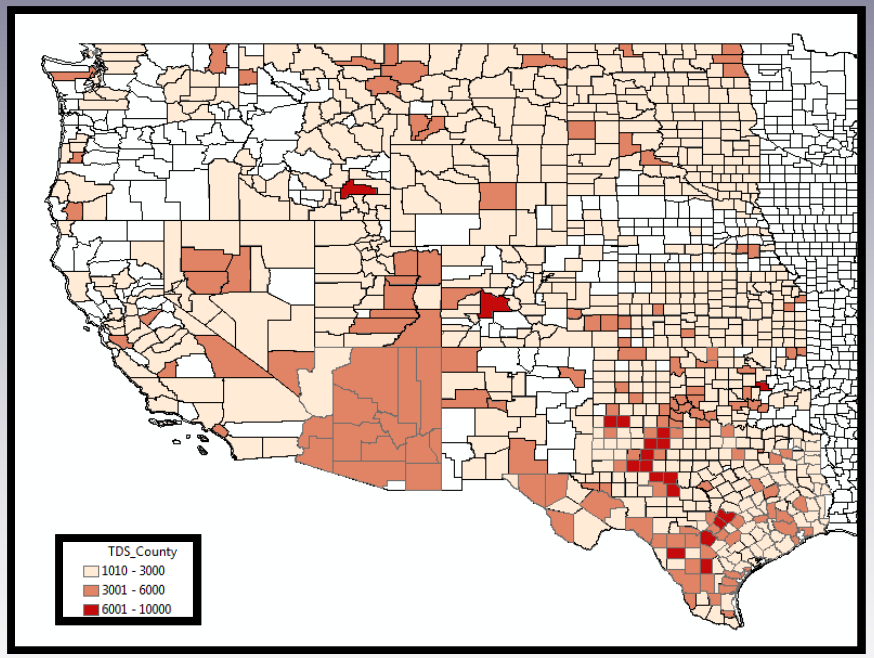
Water Availability Indicators: Supply



Brackish Water Depth



Brackish Water Treatment



Brackish TDS Levels

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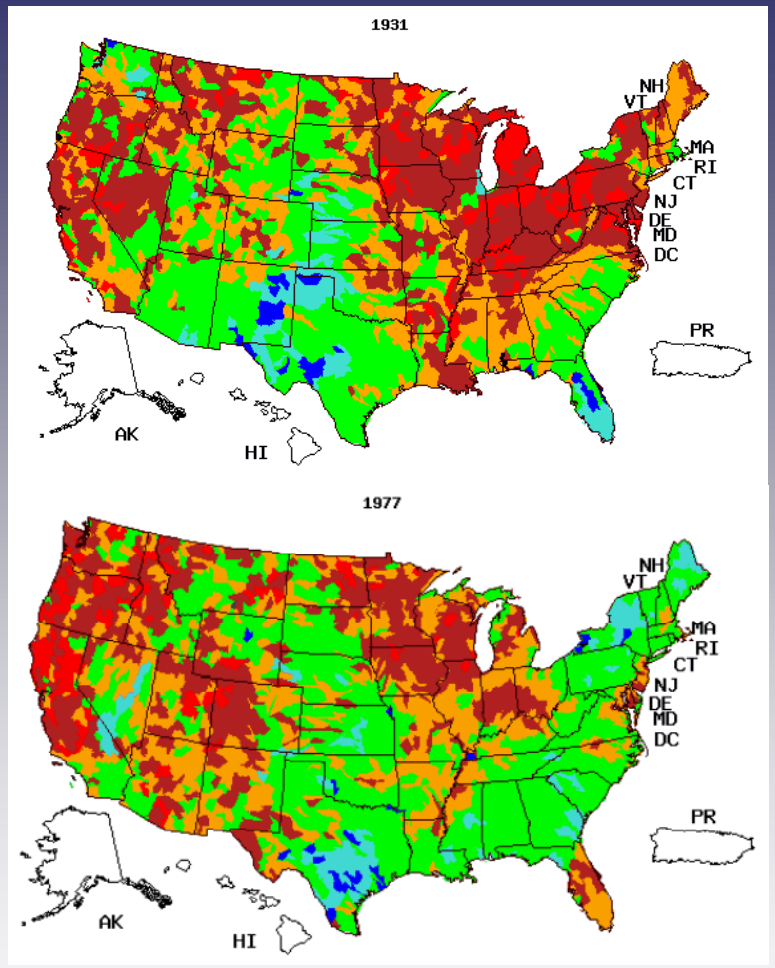
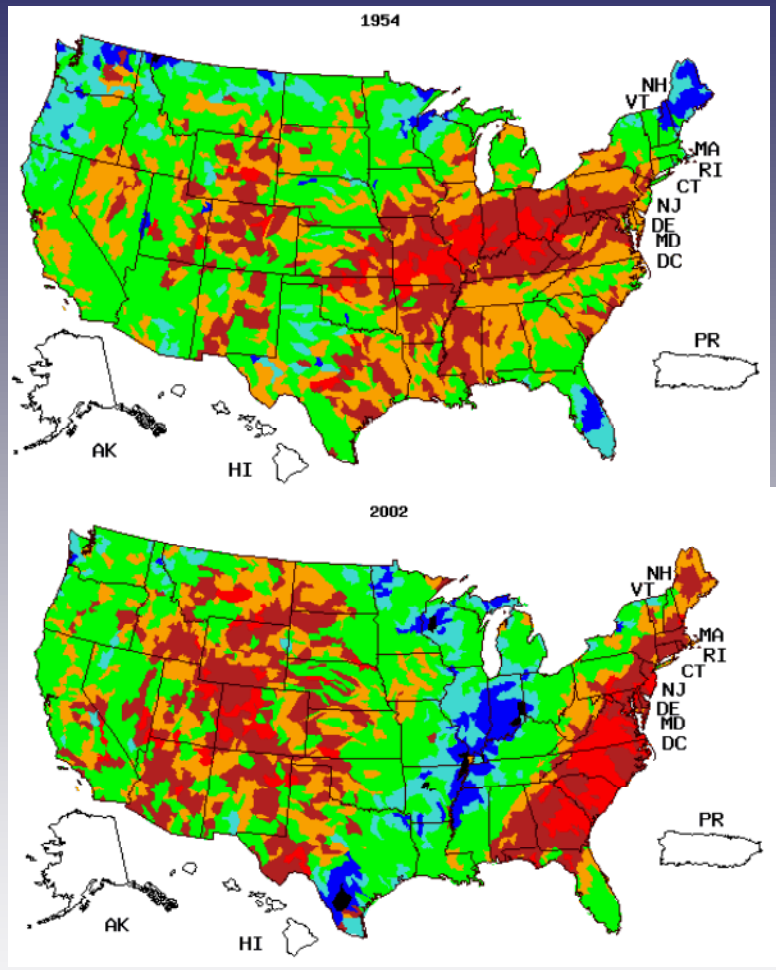
Regional Pattern of Severe Drought





Explanation -- Percentile Range							
Lowest	< 10	10 - 24	25 - 75	76 - 90	>90	Highest	No data

Eugene Yan, 2011

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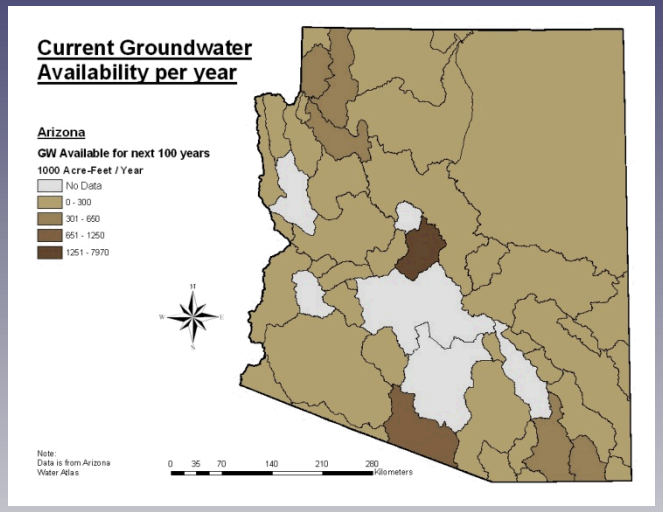
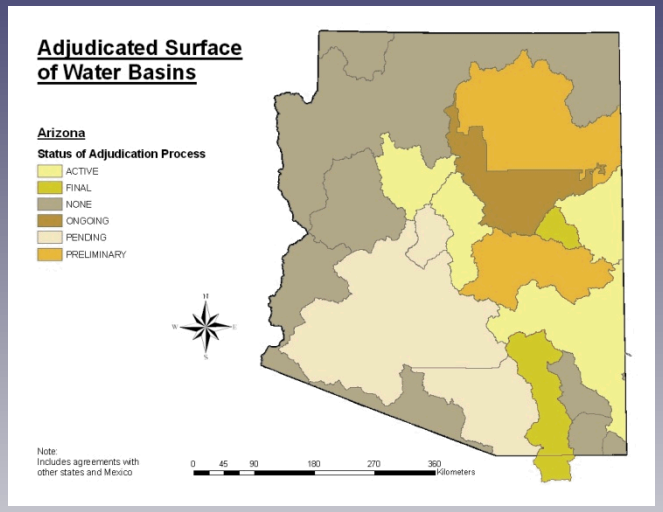
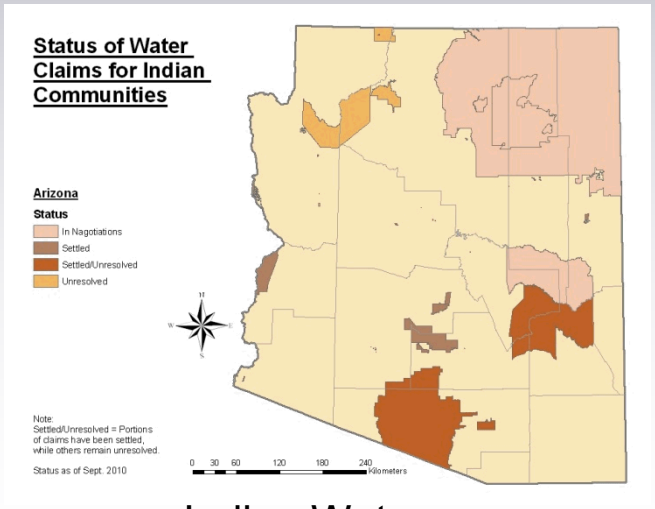
Water Availability Indicators: Institutional Factors



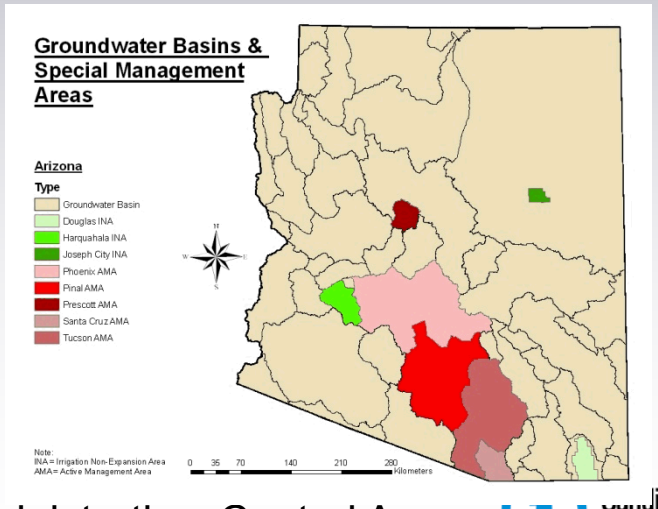
Unappropriated Water



Adjudication Status



Indian Water



Administrative Control Areas

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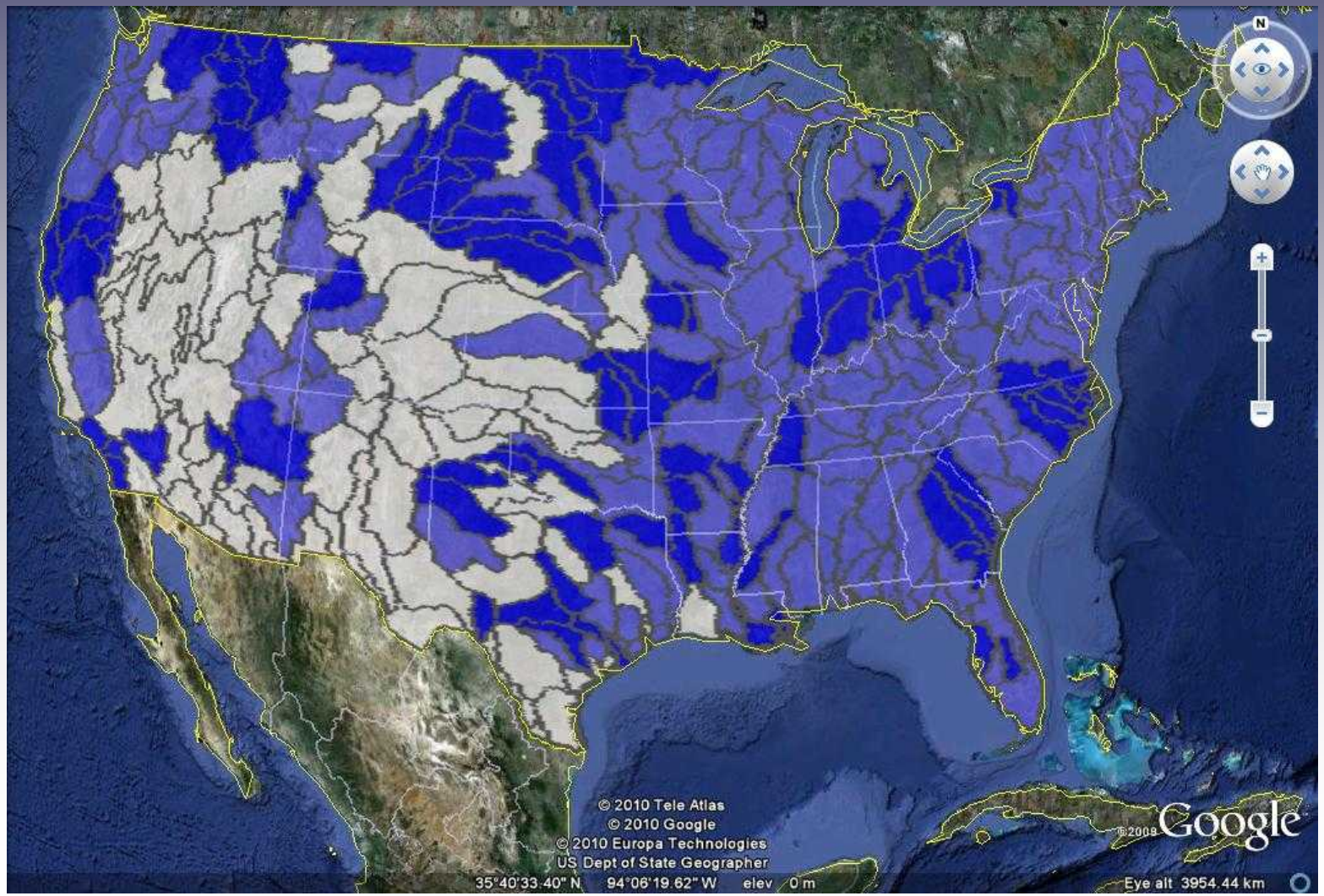
Water Availability Indicators: Environmental Flows

Ratio of Mean Stream Flow to Environmental Flow Requirements: 2004



Mean Flow
Env. Flow

- **<1**
- **1-1.25**
- **>1.25**

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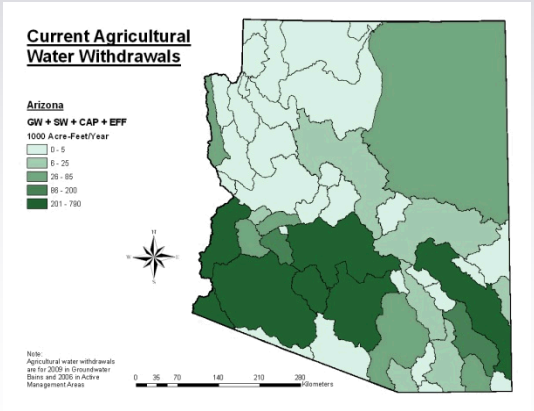
Water Availability Indicators: Value of Water

- Historic value of leased and sold water rights
- Economic value of water
- Cost of backstop technology



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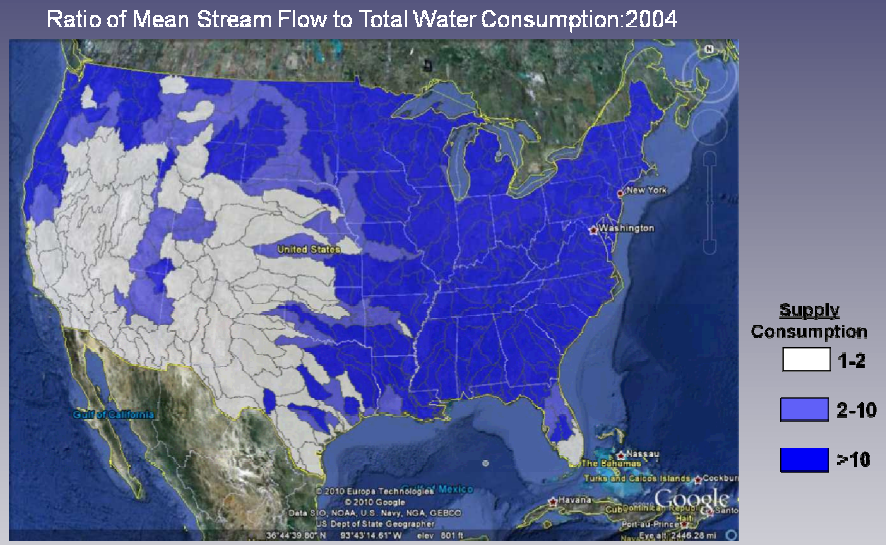
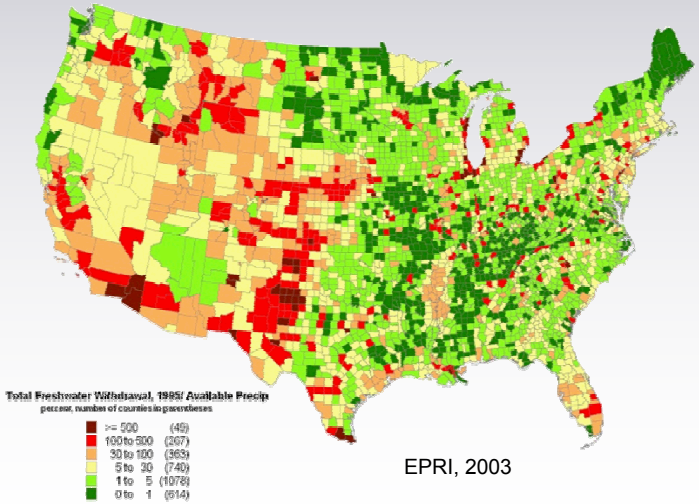
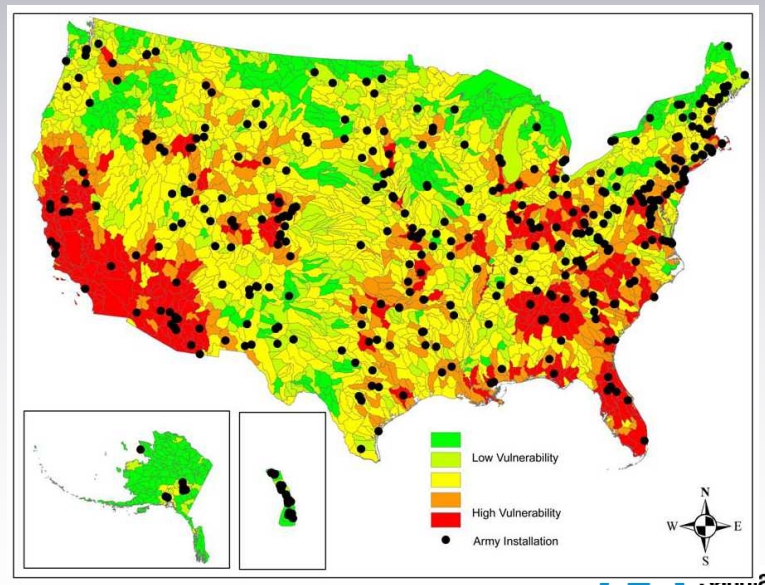
Water Availability Indicators





EPRI, 2003

- No perfect metric
- Need to develop consensus metric(s)
- Propose to establish a working group



USACE, 2009

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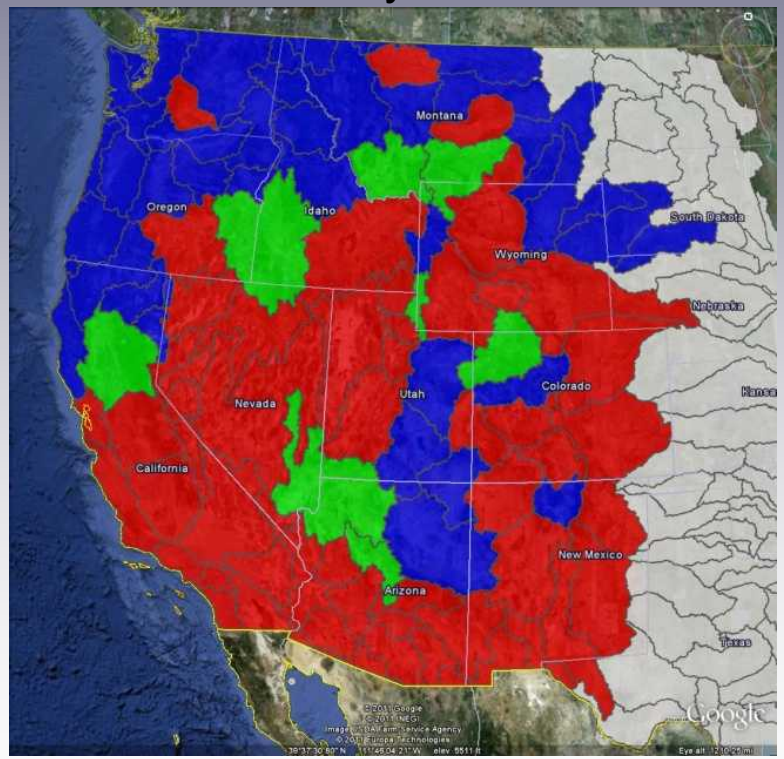
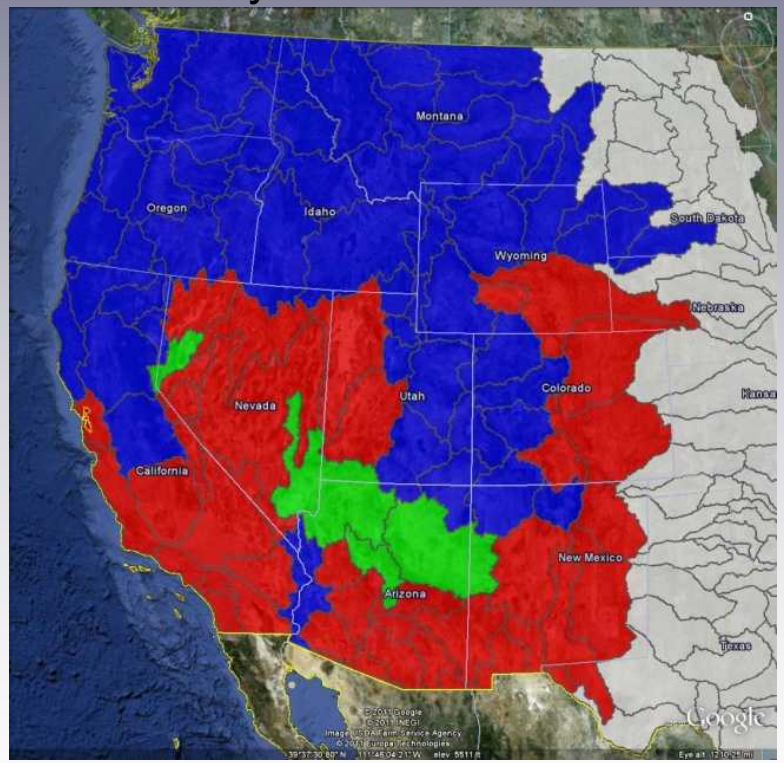
Water Availability for Development

Basins with Limited Surface Water Availability



Basins with Limited Groundwater Availability



Supply
Consumption
1-2
2-3
>3

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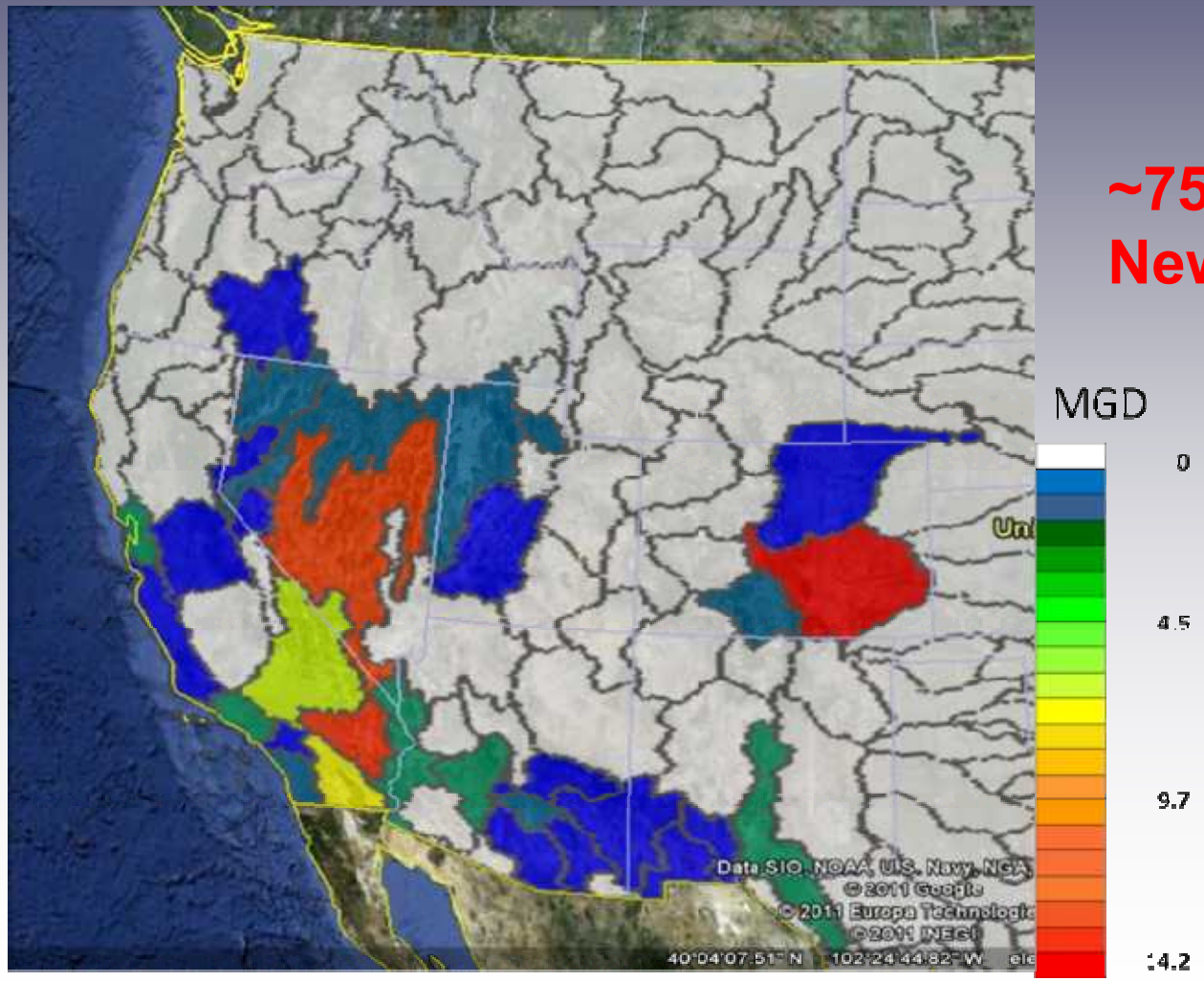
Vulnerable Planned Thermoelectric Development



~75% of All New Development

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Integrated Energy-Water Planning
EPRI Contact – Robert Goldstein

Context: Thermoelectric power production is the largest user of water in the United States and is also one of the fastest growing sectors in terms of water consumption.

Key findings:

- Projected future consumptive water demand for thermoelectric power production is of similar order to that for other key sectors (e.g., municipal, industrial)
- Much of this future demand is likely to be located in basins experiencing rapid municipal/industrial growth and/or in basins with limited water availability
- Many potential options to relieve associated water stress

Relevance: Integrated energy-water analysis and planning is needed to reduce the thermoelectric water footprint and associated stress over future water development.

What can you do? Accurate data on water withdrawal and consumption is lacking as is information on current power plant cooling technology and water source.

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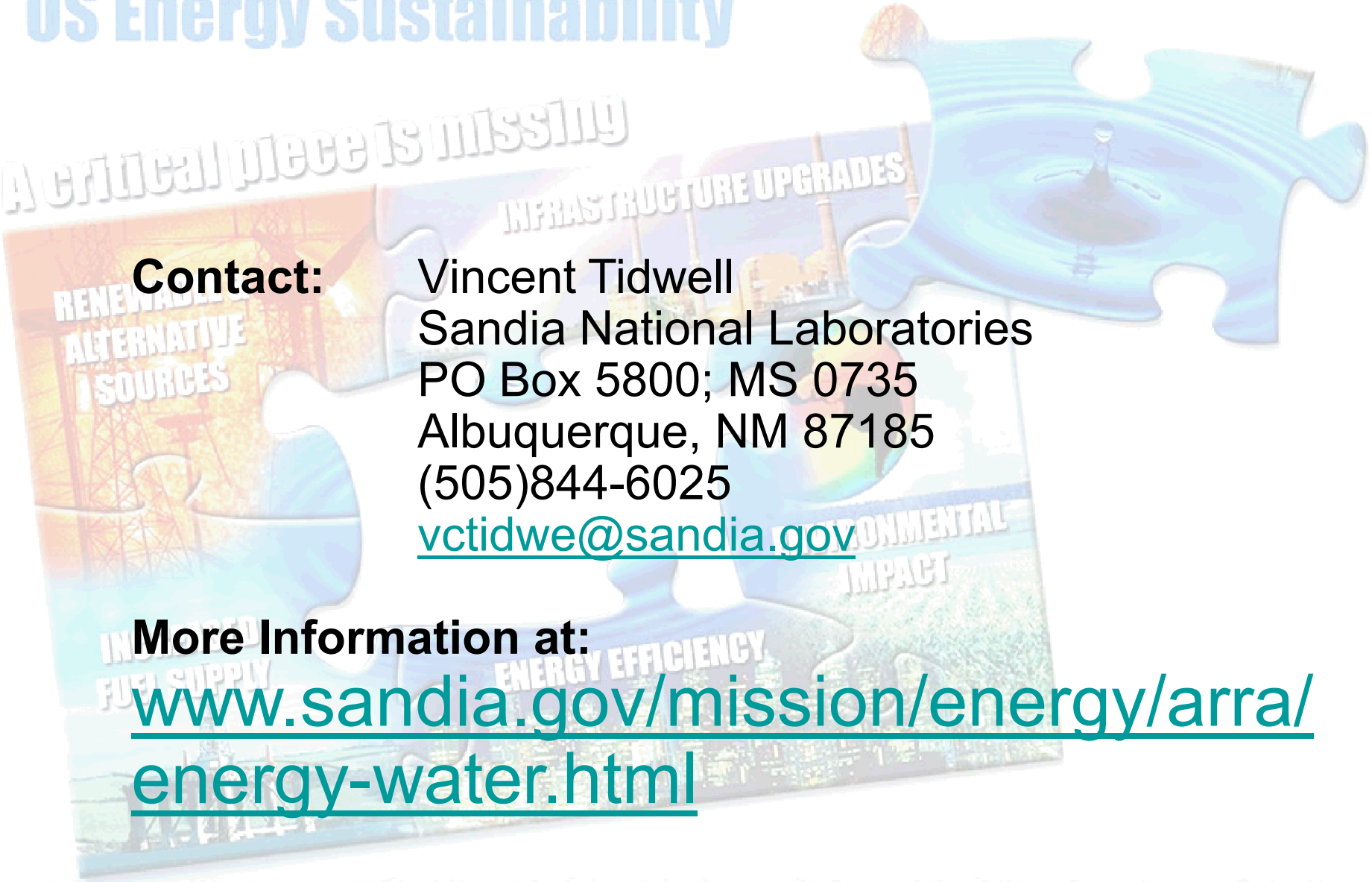
US Energy Sustainability



Contact: Vincent Tidwell
Sandia National Laboratories
PO Box 5800; MS 0735
Albuquerque, NM 87185
(505)844-6025
vctidwe@sandia.gov

More Information at:
www.sandia.gov/mission/energy/arra/energy-water.html

ENERGY and WATER