REINHOLD ENVIRONMENTAL Ltd.

2014 Wastewater-Ash Round Table & Expo Presentation

September 22, 2014, in Birmingham, AL / Hosted by Southern Company

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Water Availability

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Waste Water-Ash/PCUG Conference
September 22, 2014

2003 Heat Wave Impact on French Generation System

- Loss of 7 to 15% of nuclear generation capacity for 5 weeks
- Loss of 20% of hydro generation capacity
- Purchase of large amount of electricity on wholesale power market
- Large-scale load shedding and shut off transmission to Italy
- Sharp increase of spot-market prices

Bort-les-Orgues Reservoir

August 27, 2003

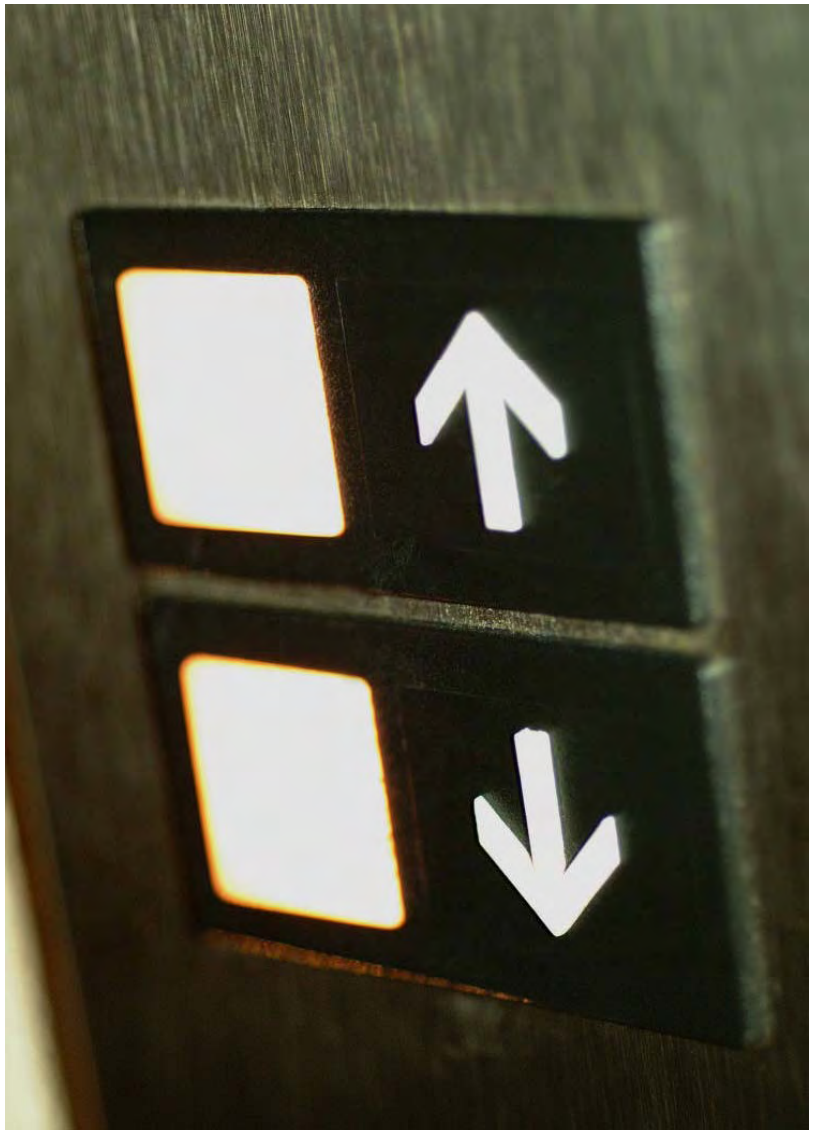
Normal conditions

in August

Selected Key EPRI Products

- Survey of water use and sustainability (1005474, 2003)
- Energy/water sustainability research program (1015371, 2007)
- Water use for electric power generation (1014026, 2008)
- Alternative water sources for cooling (1014935, 2008)
- Water resource trends and implications (1019866, 2010)
- Water disclosure (1023279, 2011)
- National water withdrawal assessment (1023676, 2011)
- Stormwater use (1021124, 2010 and 1023774, 2012)
- National water consumption assessment (3002001154, 2013)
- Electricity use in municipal water supply and wastewater treatment (3002001433, 2013)
- WARMF (http://www.epa.gov/athens/wwqtsc/html/warmf.html)
- Water Prism (1023771, 2012 and 3002002120, 2013)
- Knowledge Center for Electric Power/Water Resources Sustainability (Program 55 website)

Approaches to Reaching Water Resource Sustainability



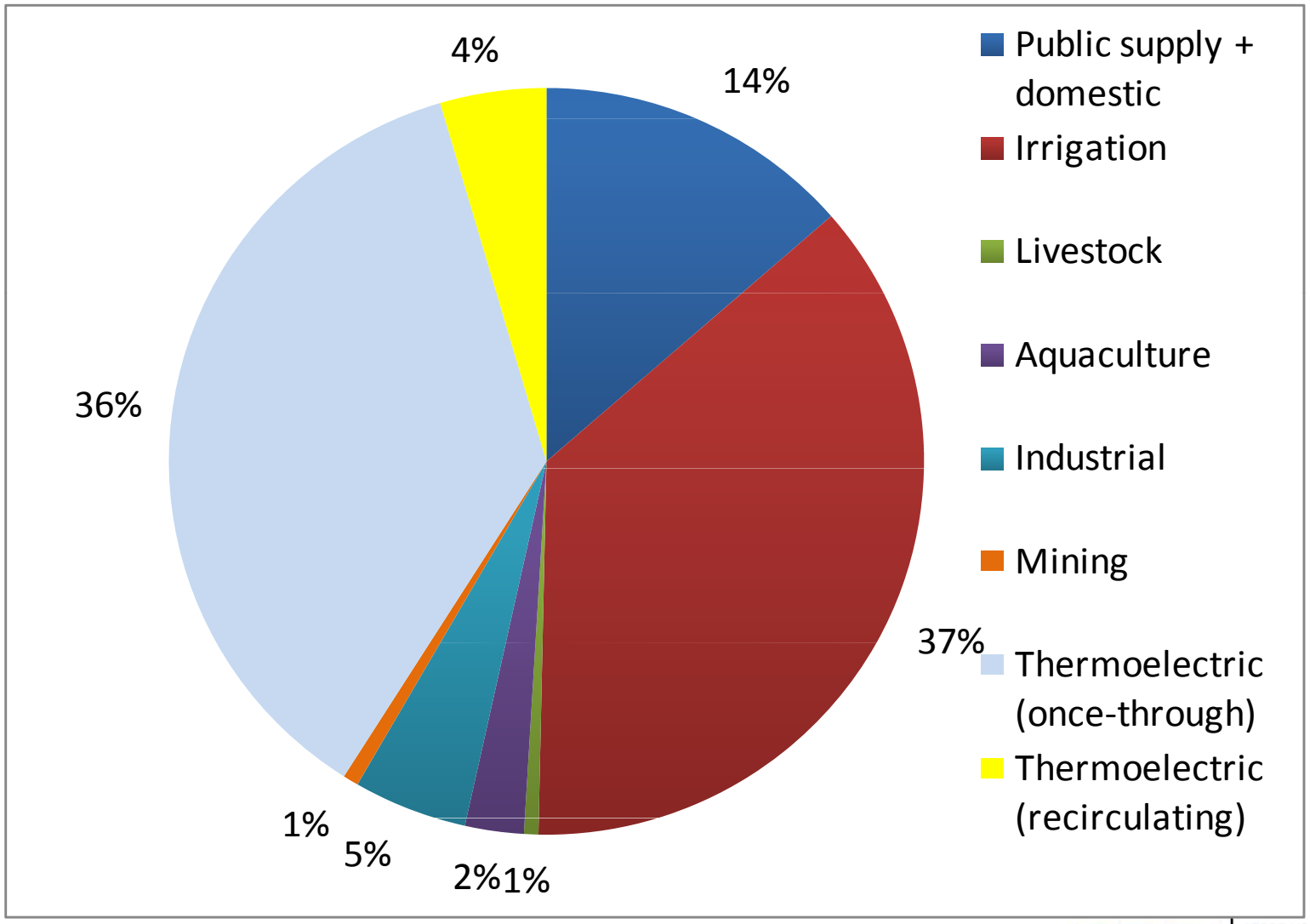
- Top down
  - Community/region/watershed -based
  - Considers all stakeholder demands
  - Matches aggregate water demands to supply
- Bottom up
  - Sector/Facility-based
  - Objectives
    - Increase water use efficiency
    - Conservation

Value and Caveats of Scoping Assessments

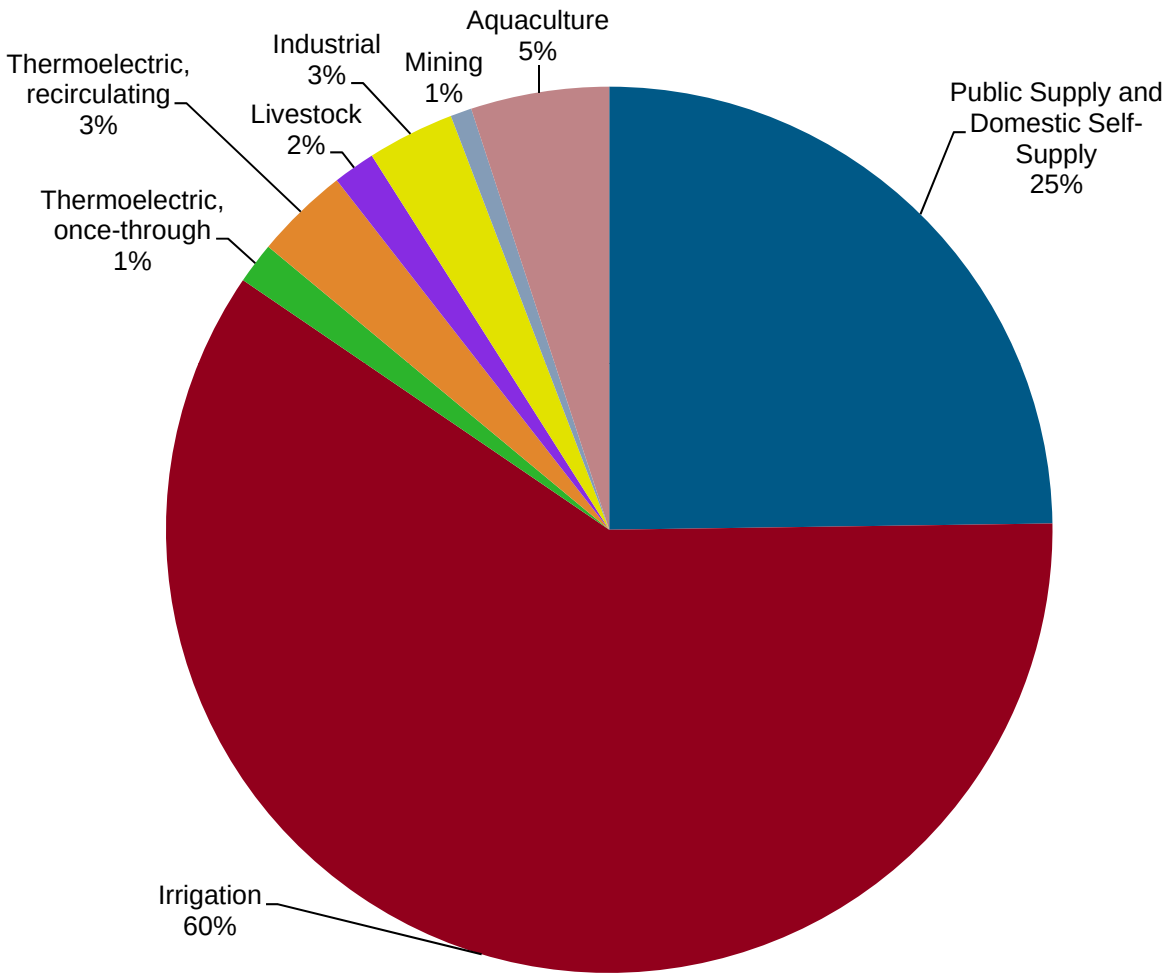
- Value
  - Uses ready available internet data bases
  - Maps high level response space
  - Identifies localities of concern
  - Illustrates water using sectors' interdependencies
  - Identifies trends
- Caveats
  - Bounding or scoping analysis
  - Many interacting, nonlinear factors affecting water use
  - Many nuances and subtleties
  - Many assumptions and simplifications
  - Looks simple but is not
  - One should carefully read text before using illustrations

USGS National Water Withdrawals (2005)

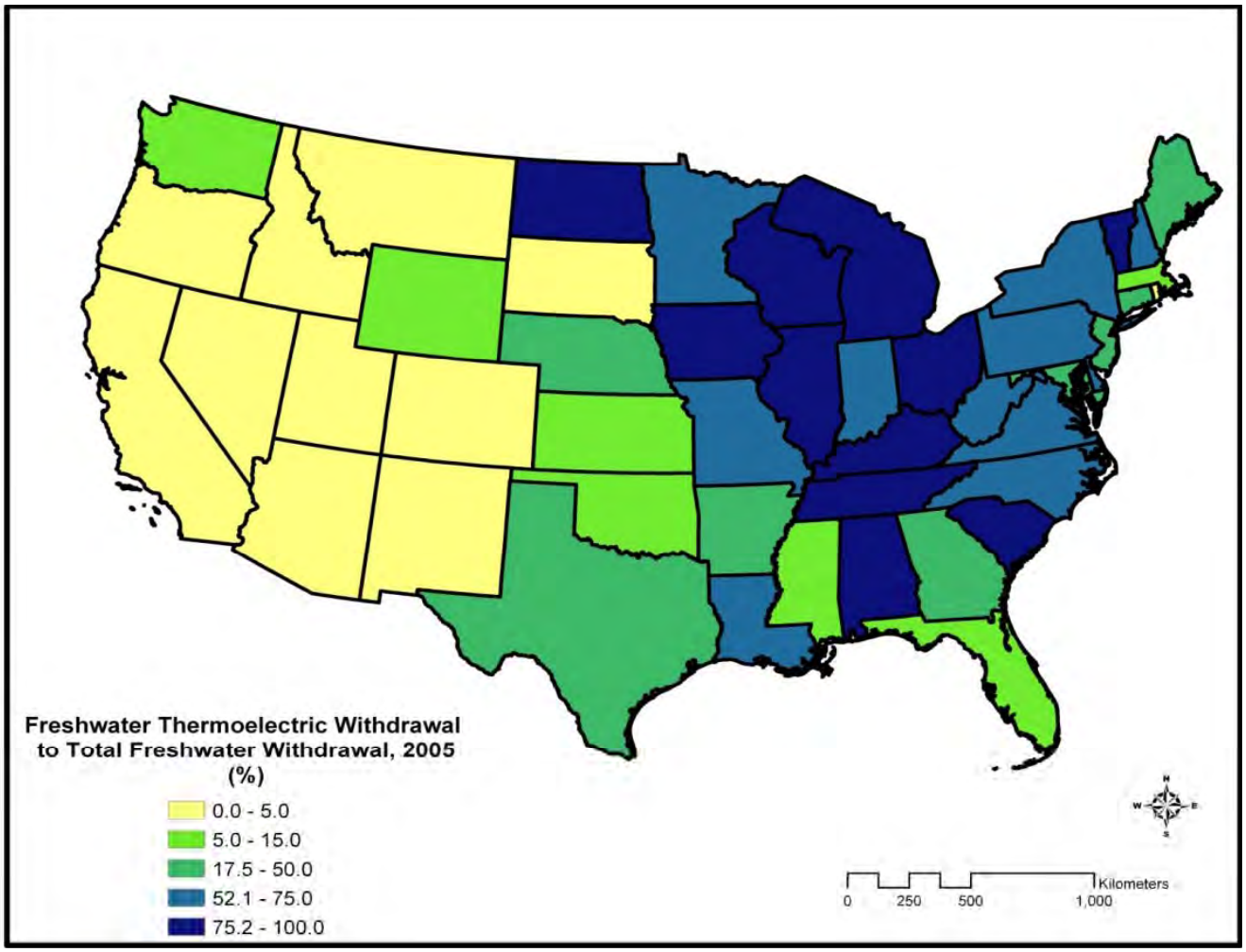
(Source: EPRI Report 1023676)



EPRI Consumption Assessment

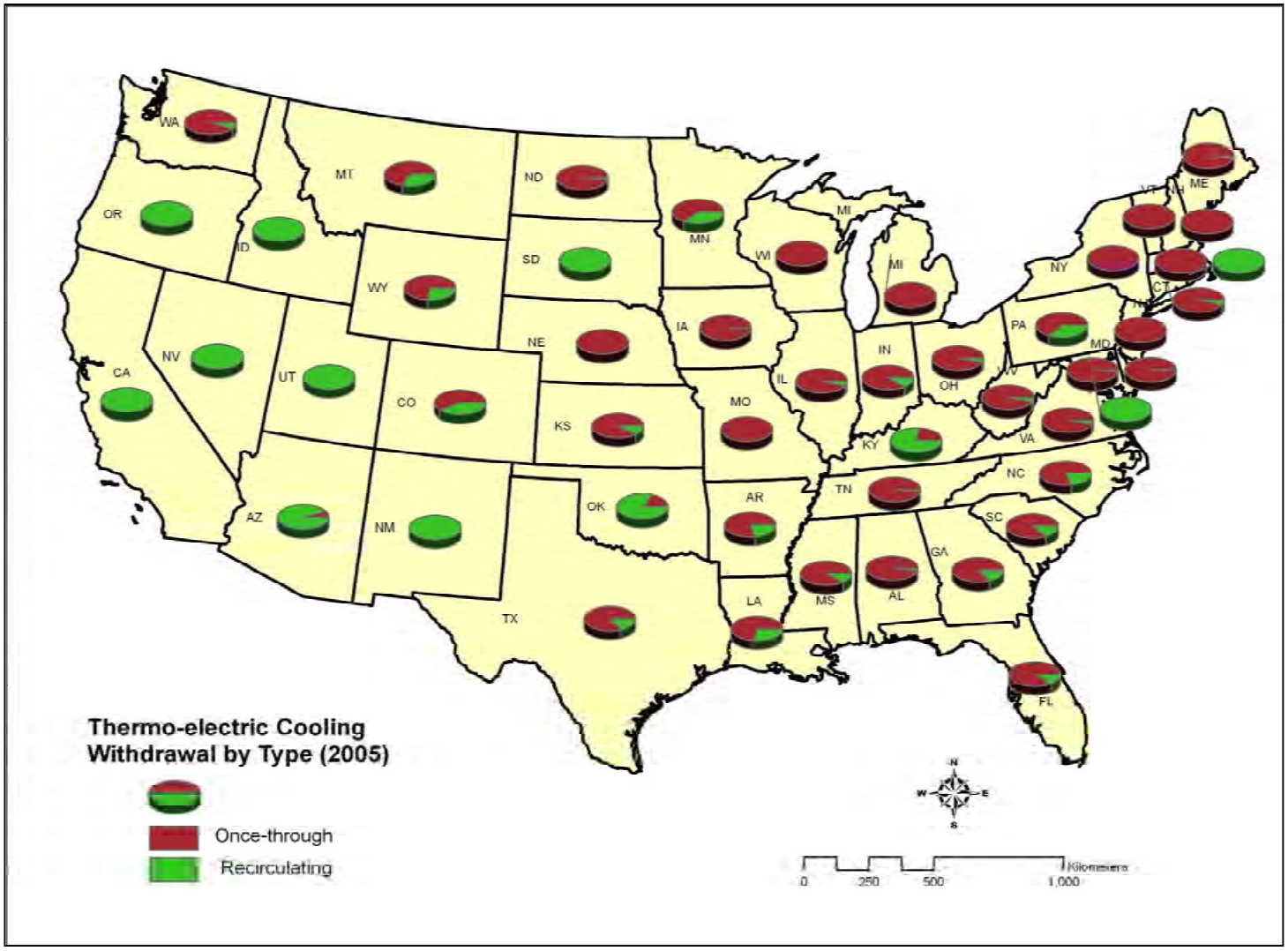


Freshwater Thermoelectric Withdrawal as a Percentage of Total Freshwater Withdrawal (2005)



Relative contribution of thermoelectric withdrawals varies spatially.

Freshwater Thermoelectric Cooling by Type of Cooling System (2005)



Recirculating cooling systems dominate in West.

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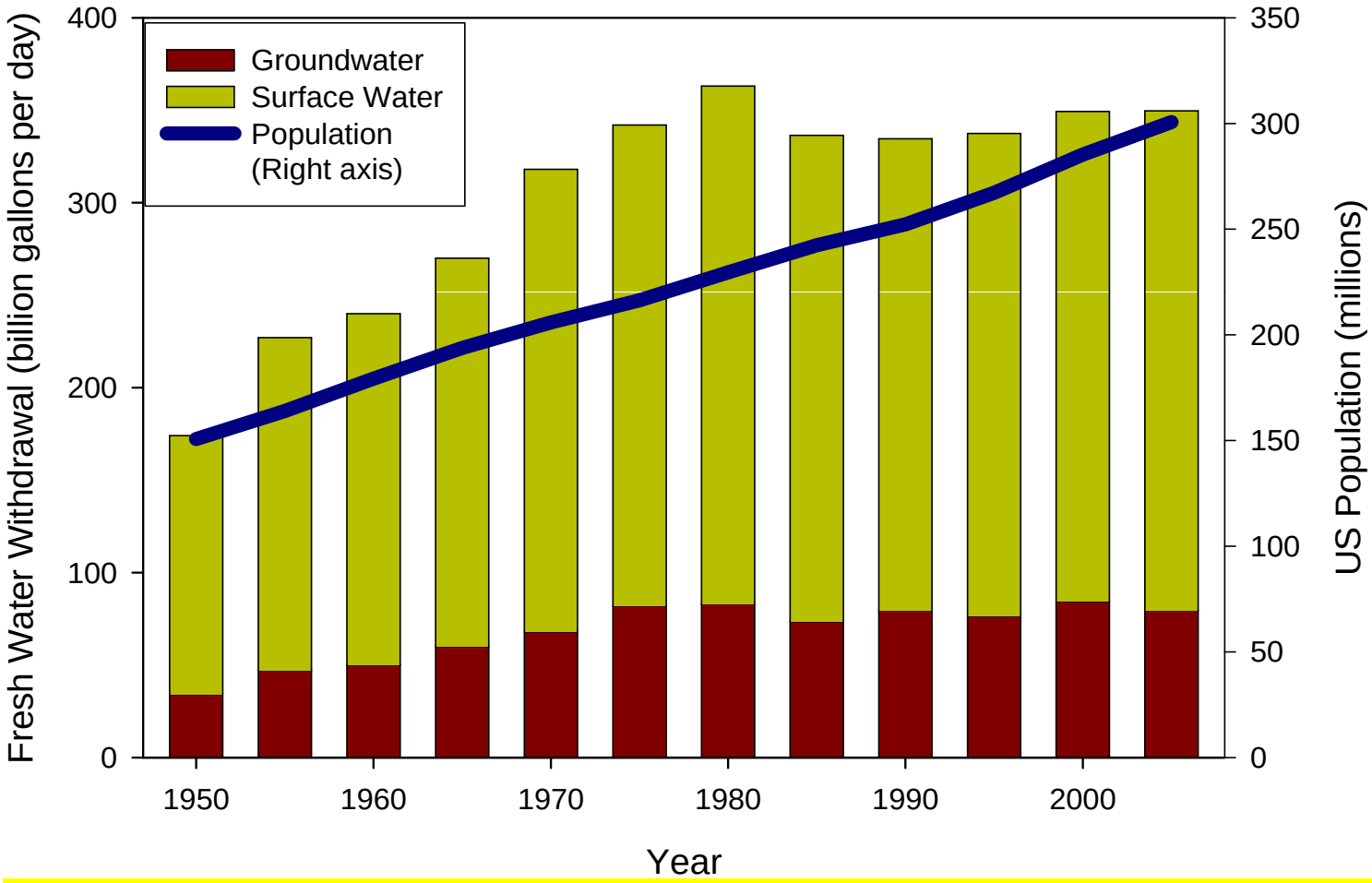
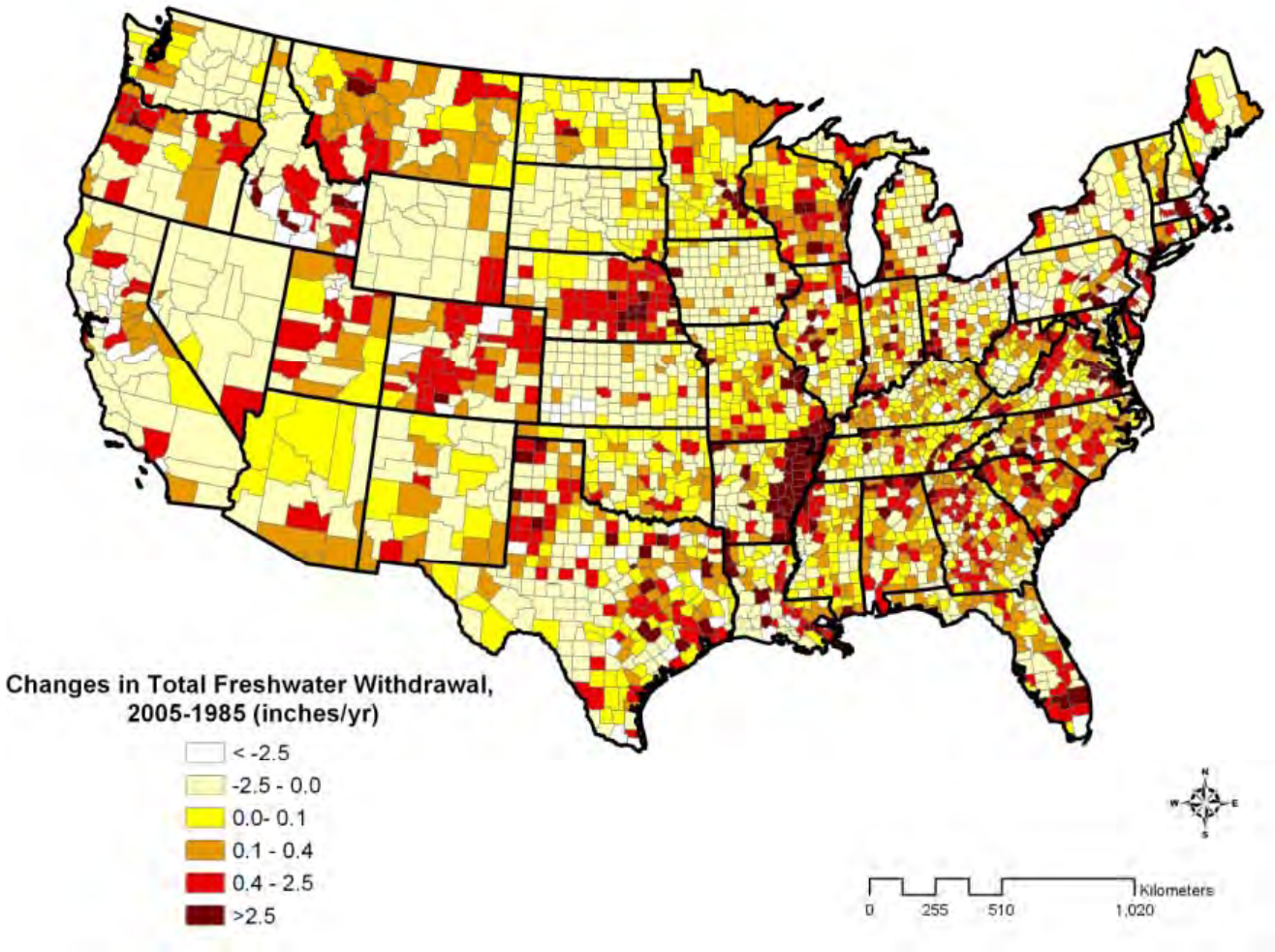
National Freshwater Withdrawals by Year



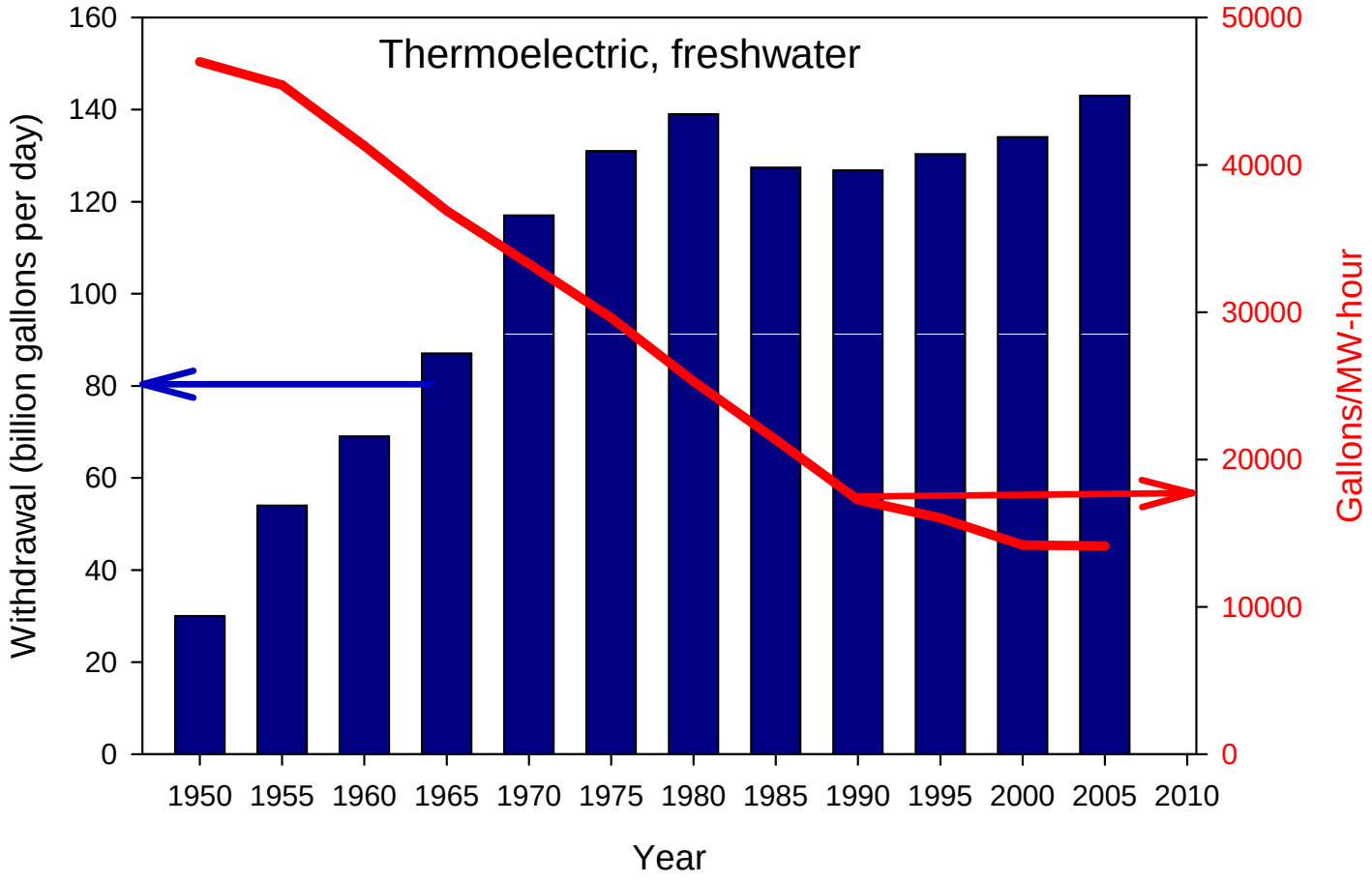
Population increases but total national withdrawal level off after 1985.

Change in Freshwater Withdrawal 2005-1985



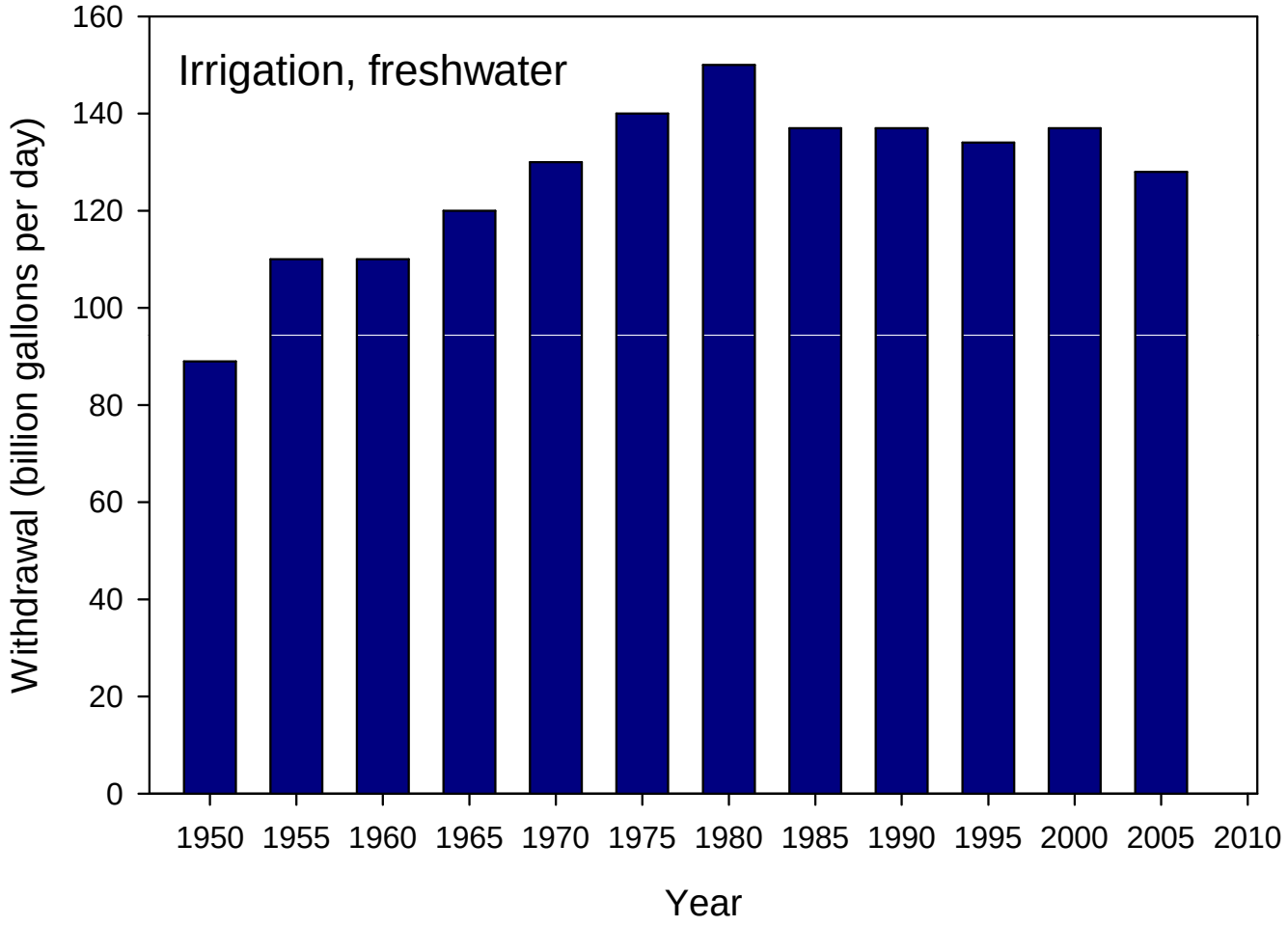
Although total national withdrawal is relatively constant, there are changes in individual localities.

Trend in Thermoelectric Water Withdrawals



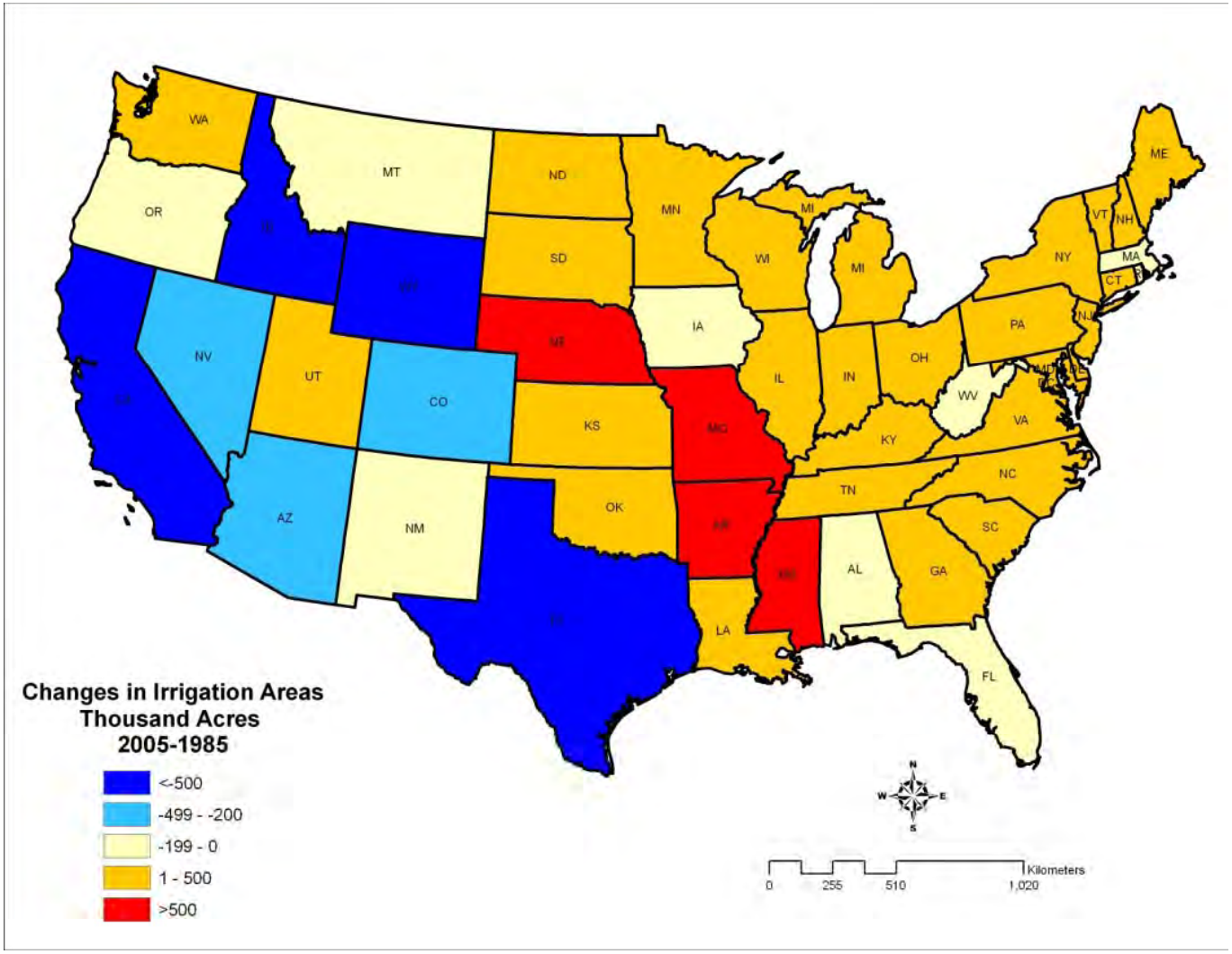
Thermoelectric withdrawals relatively constant after 1980 while withdrawals per unit electric generation decrease from 1950.

Trend in Irrigation Withdrawals



Irrigation withdrawals relatively constant from 1985

Change in Irrigation Area (2005-1985)



Irrigation decreases in West but Increases in East

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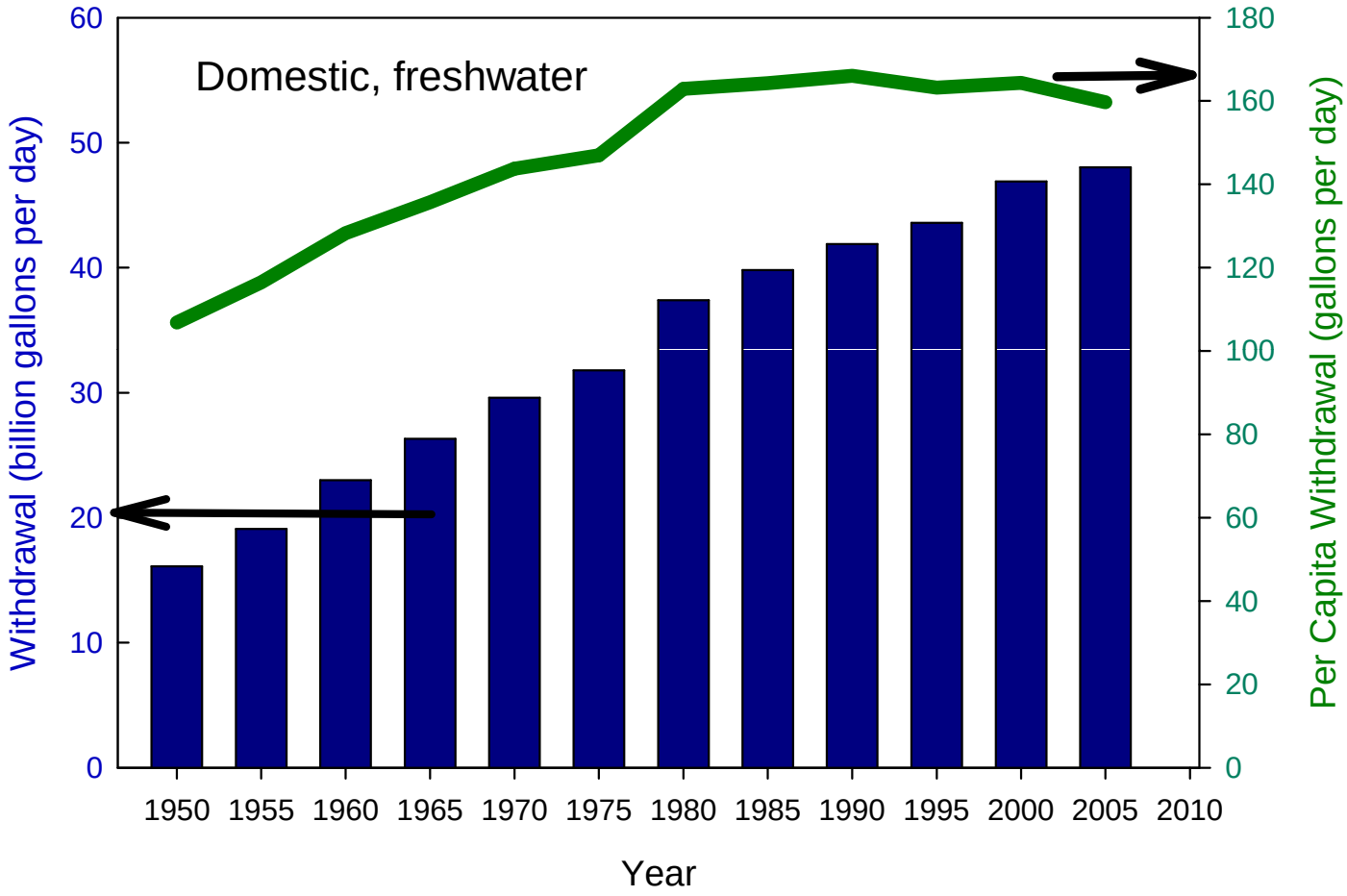
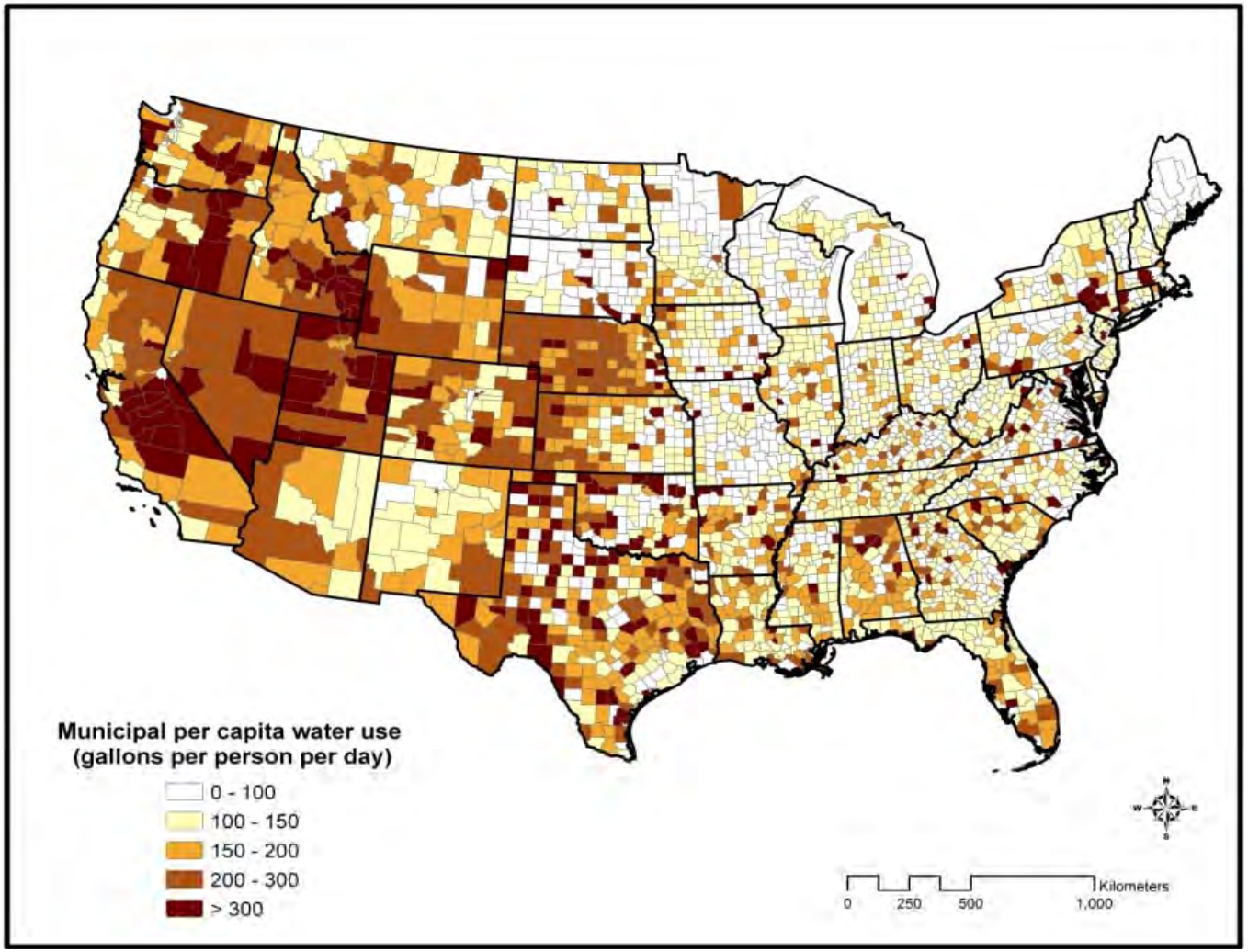
Trend in Domestic Freshwater Withdrawal



Municipal withdrawals increase while per capita withdrawals levels off.

Municipal Per Capita Water Withdrawal (2005)



Per capita withdrawals highest in West. Landscape irrigation dominates municipal consumption.

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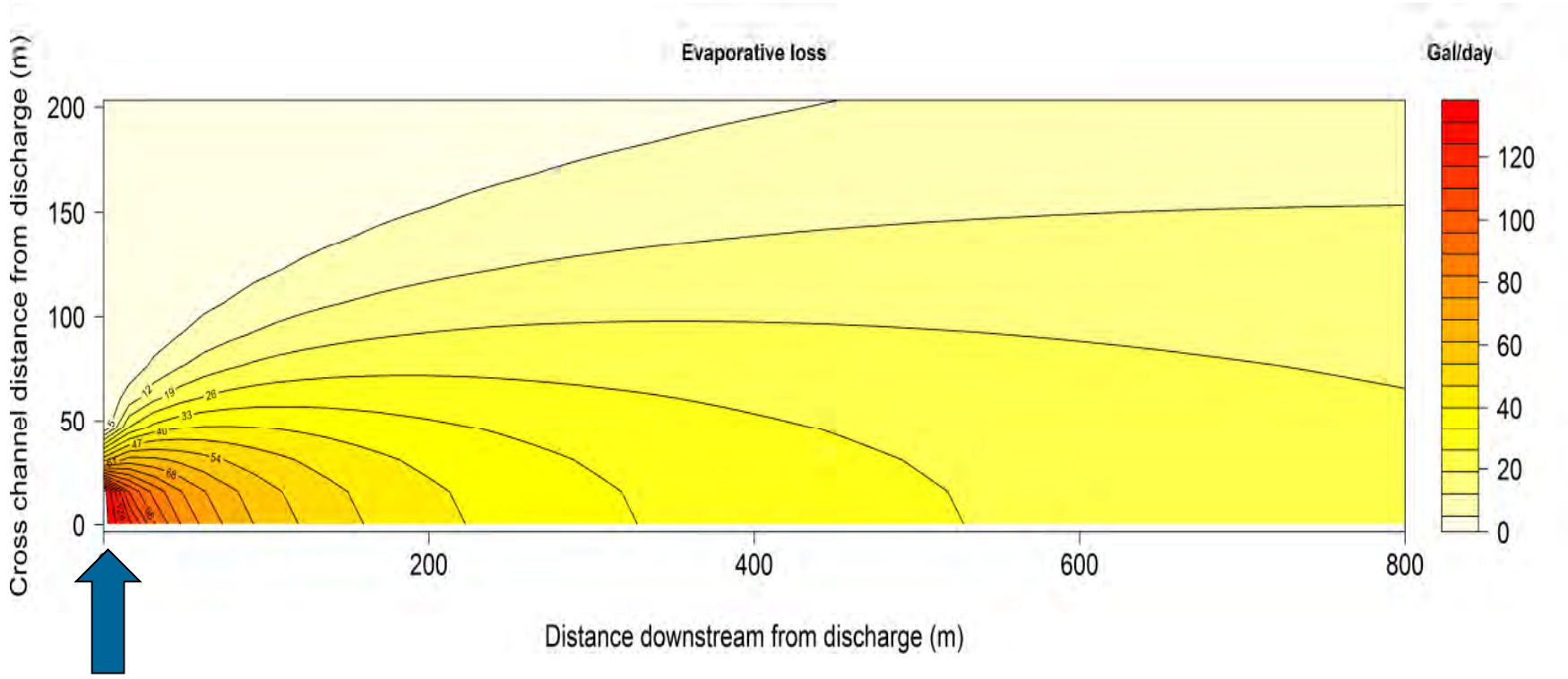
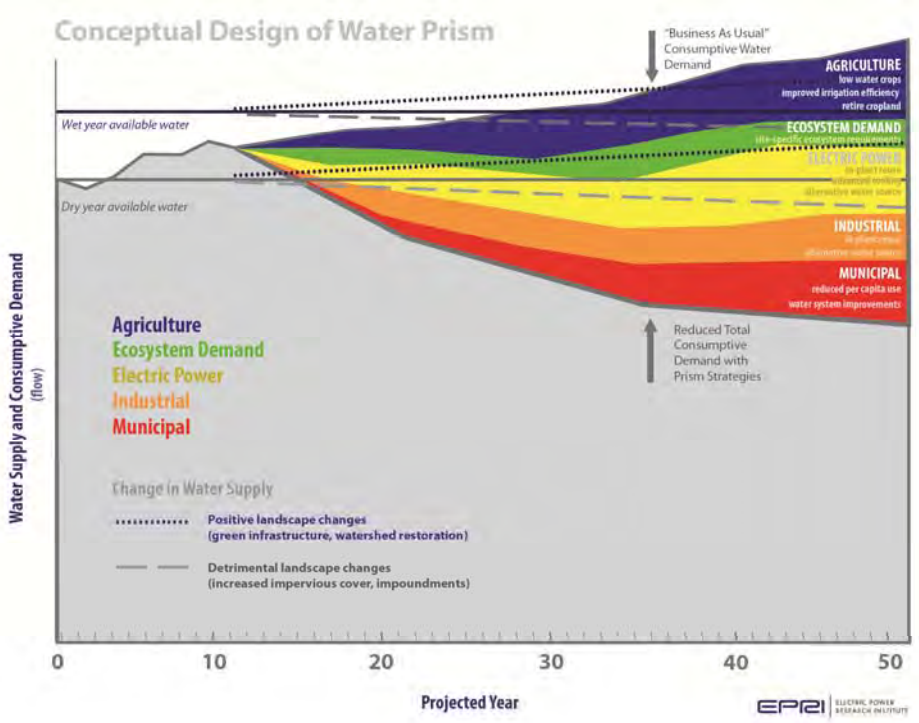
Estimated Evaporative Loss Using 2-D Heat Transport Model



In contrast to cooling tower evaporation, forced evaporation is a diffuse sink.

Water Prism: Conceptual Design

- Compute system water balance on regional scale
  - Available surface water informed by a watershed model
  - Include groundwater sources and uses
- Project consumptive demand for 40 to 50 year horizon
- Explore water saving strategies through scenario analysis
- Give it the "feel" of EPRI's CO_2 Prism – graphical displays



Examine various scenarios to consider water use reductions needed to keep "demand" below "supply"

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Preliminary Water Prism Applications

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Muskingum River Basin

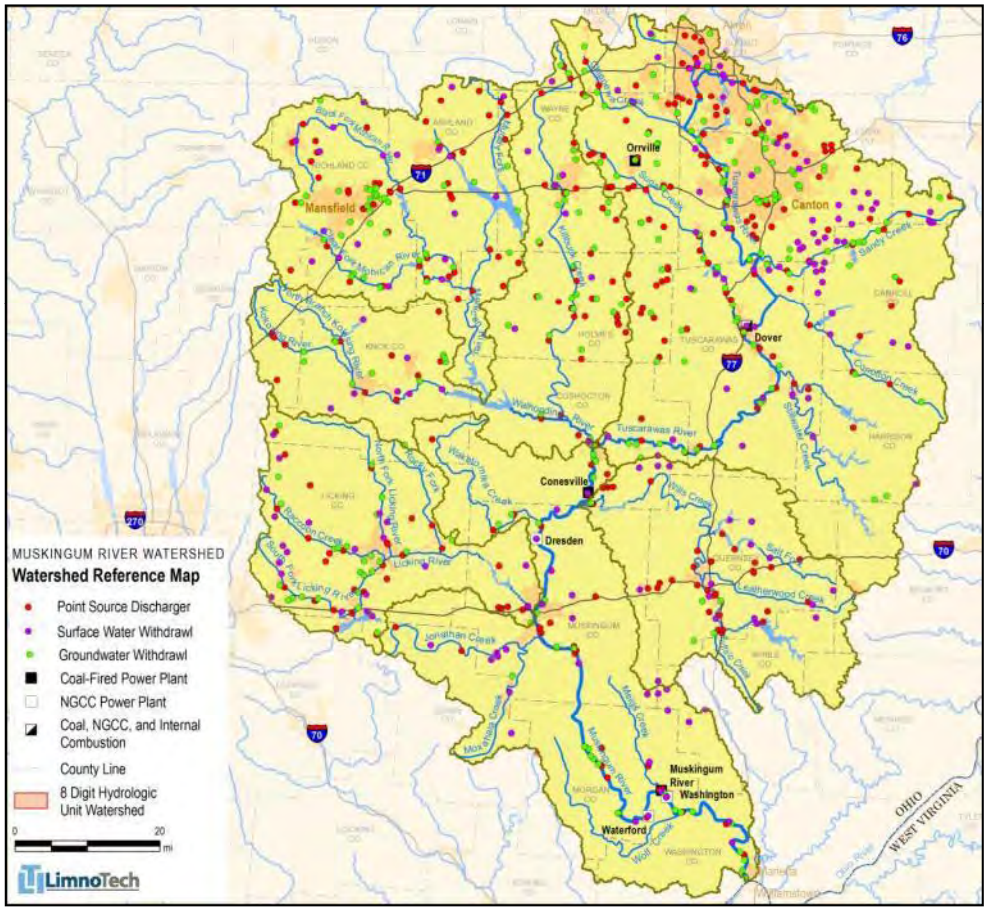
Area: ~8,000 mi^2

Water Use:

- 175 surface water withdrawals
- 329 groundwater withdrawals
- 319 point sources

Power Plants:

- 2 large coal-fired: primarily once-through cooling
- 2 small coal-fired
- 3 NGCC (1 operational in 2012): closed cycle cooling



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Observations for Muskingum River Basin

- Surface water system is generally “gaining” water from the groundwater system; overall low risk for consumptive demand.
- Areas with potential water risk :
  - Consumptive demand in upper tributary reaches during summer months of dry years
  - Withdrawal demand near large once-through cooling plant
  - Potentially unsustainable groundwater system (under conservative aquifer properties)

Water Prism useful to weigh level of risk for each water supply system, water use sector, and region.

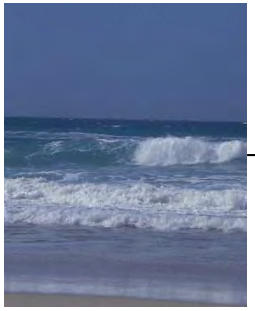
Alternative Water Sources for Electricity Generation

Agricultural drainage

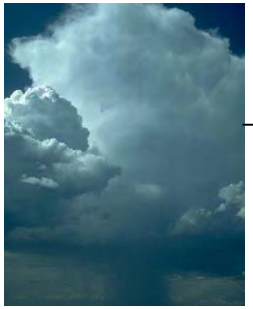
Municipal effluent

Oil and gas produced water

Saline groundwater



Sea water



Storm water

- Availability and quantity
- Water quality and treatment
- Current research
- Case studies

In-plant reuse, recovery, and recycling

- Additional topics:
  - Water transport
  - Acquisition
  - Regulations

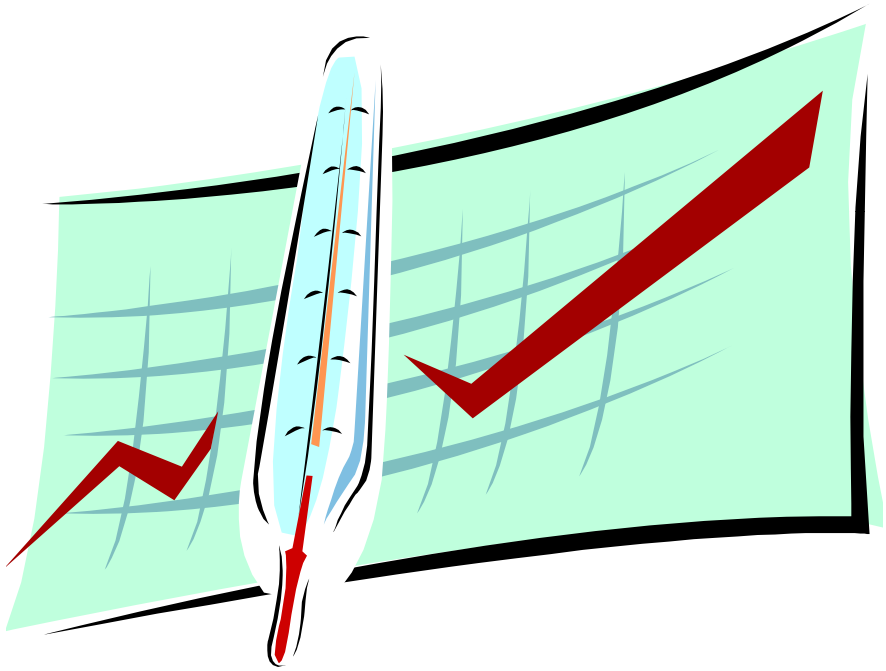
Municipal Effluent

- Used by approximately 60 power plants
- Largest number in FL, CA, TX and AZ
- Amount used varies from 0.1mgd to 55mgd
- Municipal effluent
  - Volume function of population density
  - Quality function of treatment and technologies
- Individual treatment plant information at http://www.epa.gov/enviro/html/pcs/index.html

Alternative Water Source Summary

- Municipal effluent due to its abundance and quality is a viable alternative source for cooling water supply. Potential greatest in regions of high population density.
- Agricultural return flow in terms of quantity is comparable to municipal effluent. However additional treatment may be required depending on site-specific water quality. Potential greatest in western states.
- Oil and gas produced water represents a small quantity of degraded water, often with high TDS concentrations, and is generally not a viable alternative source, although exceptions may exist.
- Saline groundwater due to its large quantity can be a promising alternative source.
- Stormwater can be a meaningful resource for power plant use

Summary of Water Temperature Trends



- No nationwide study of water temperature trends identified
- Most local/regional trend studies based on 20-30 years of data
- Summary of Findings:
  - *Most studies:* increasing temperature trends in streams and lakes
  - *Three studies:* lake surface temps warming faster than observed air temp increases over same period (Great Lakes, CA / NV lakes)
  - Most significant increases noted for post-1970 time periods

NSF-EPRI Power Plant Dry Cooling Science and Technology Innovation Program

Project Title	Orgnization	Funder
Direct Contact Liquid on String Heat Exchangers for Dry Cooling of Power Plants	UCLA	NSF
On-demand Sweating-Boosted Air Cooled Heat-Pipe Condensers for Green Power Plants	U of S Carolina	NSF
Ejector Cooling Systems with Evaporation/Condensation Compact Condensers	Univ of Missouri Columbia/SPX	NSF
Integrated Innovative Heat Pipe Dry Cooling Towers	Univ of Kansas /Univ of Connecticut	NSF
Auto Flutter Enhanced Air Cooled Condensers	GaTech/Johns Hopkins/Southern Company/SPX	NSF-EPRI
Advanced Air Cooled Condensers with Vortex-Generator Arrays between Fins	UIUC	NSF-EPRI
Indirect Dry Cooling Towers with Phase-Change Materials as Intermediate Coolants	Drexel/ACT/Worley Parsons	NSF-EPRI
Novel Heat-driven Microemulsion-based Adsorption Green Chillers for Steam Condensation	UMD/Worley Parsons	EPRI
Nanostructure Enhanced Air-Cooled Steam Condensers	MIT/HTRI	EPRI
Porous Structures With 3D Manifolds For Ultra-Compact Air Side Dry Cooling	Stanford	EPRI

Concluding Thoughts

- Water resources and human use are varying temporally and spatially.
- Thermoelectric plant cooling is about 5% of the national freshwater consumption budget, compared to about 40% of withdrawal budget.
- Largest source of uncertainty in consumption budget is crop irrigation water conveyance.
- Most municipal consumption is associated with landscape irrigation.
- Nontraditional water sources, with appropriate treatment, are viable alternatives to freshwater sources for power plants.
- Need localized, fine resolution decision support tools to manage community water resources.
- Growing national and local concerns create need for increased research on water resource management tools and new water saving technologies.

John Steinbeck

"And it never failed that during the dry years the people forgot about the rich years, and during the wet years they lost all memory of the dry years. It was always that way."
– John Steinbeck, East of Eden.