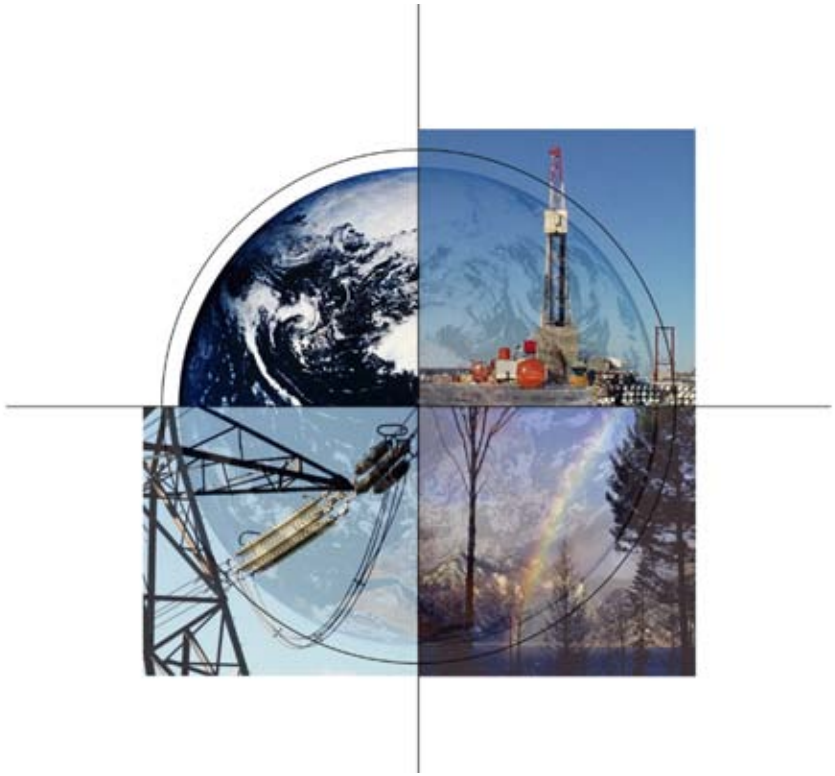
Estimating Freshwater Needs for Thermoelectric Power Plants Through 2030



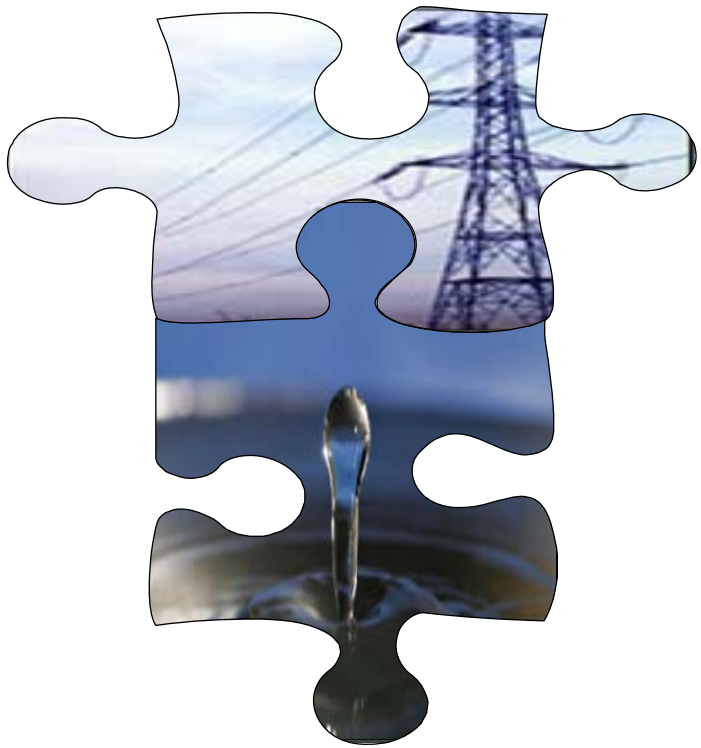
A Water Constrained Future – How Power Producers Can Minimize the Impact in the West

May 1 - 2, 2007
San Diego, CA

Andrea McNemar
National Energy Technology Laboratory

Outline

- Background on issue
- Thermoelectric withdrawal and consumption projections
- NETL's R&D program
- Estimated benefits of R&D
- Summary



National Energy Technology Laboratory

- **Only DOE national lab dedicated to fossil energy**
  - Fossil fuels provide 85% of U.S. energy supply
- **One lab, five locations, one management structure**
- **1,200 Federal and support-contractor employees**
- **Research spans fundamental science to technology demonstrations**

Alaska

Oklahoma

Oregon

Pennsylvania

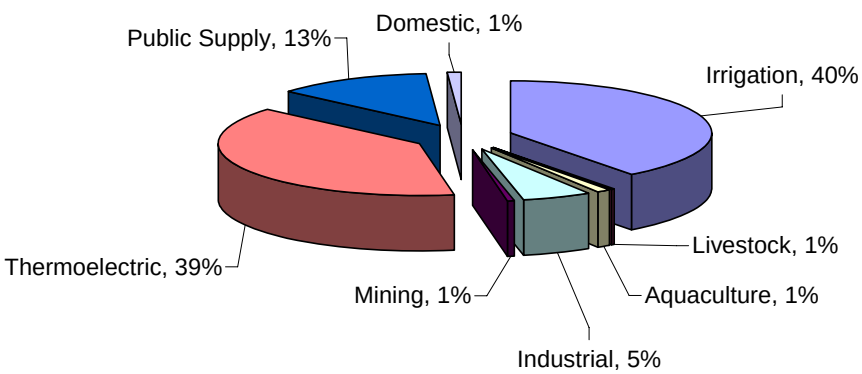
West Virginia

NETL Mission

Implement research, development, and demonstration programs to resolve the environmental, supply, and reliability constraints of producing and using fossil resources

The Issues: Competing Freshwater Uses

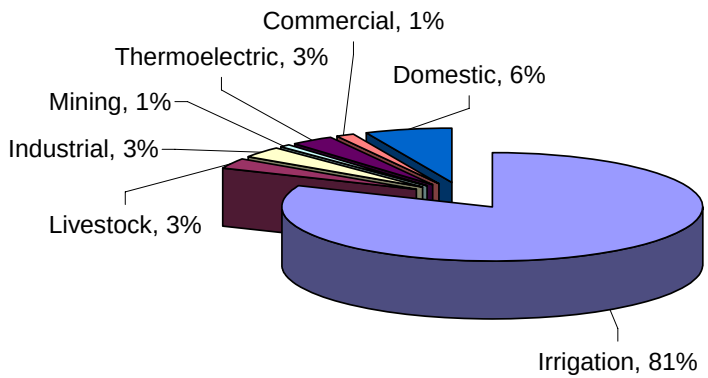
U.S. Freshwater Withdrawal (2000)



- **2000 thermoelectric water requirements:**
  - **Withdrawal: ~ 136 BGD**
  - **Consumption: ~ 3 BGD**

- **Thermoelectric competes with other users, including in-stream use.**
- **Which is more important: drinking and personal use, growing food, or energy production?**

U.S. Freshwater Consumption (1995)



Sources: USGS, Estimated Use of Water in the United States in 2000, USGS Circular 1268, March 2004
USGS, Estimated Use of Water in the United States in 1995, USGS Circular 1200, 1998

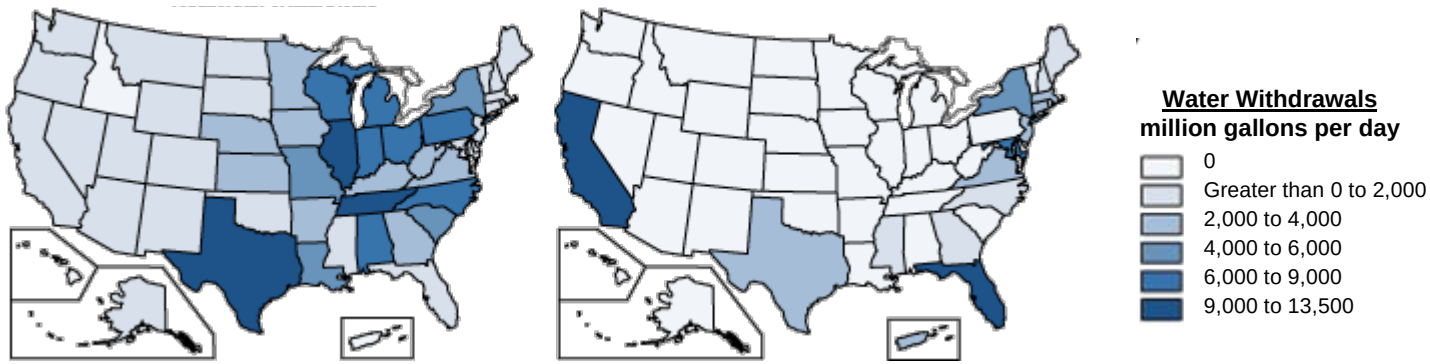
Saline Water Use Not Addressed in this NETL Analysis

However:

- In 2000, thermoelectric plants withdrew 59 BGD of saline water ≈ 30% of total thermo withdraw
- In California, 97% of thermoelectric withdraw was saline
- 316(b) and related regulation impacts – likely to decrease saline use

Freshwater Withdrawals, 2000

Saline Water Withdrawals, 2000



Source: USGS, Estimated Use of Water in the United States in 2000, USGS Circular 1268, March 2004

Recent Articles on Water-Related Impacts on Power Plant Siting and Operation

May 2006 Issue of Power Magazine

Idaho May Adopt Moratorium on Coal Power Due to Water Issues
- *Reuters, March* 2006

California's Efforts to End Use of Sea Water to Cool Plants Could Jeopardize 24 GW
- *POWERnews*, October 2006

Energy Project Could Threaten Water Supply in Salina, Kansas
- *McClatchy-Tribune Business News,* November 2006

Desert Rock Water Agreement Passes Navajo National Committee
- *The Daily Times,* February 2006

Southern Drought Leads to Shutdown of Hydro, Forcing Utilities to Buy from Market
- *POWERnews*, October 2006

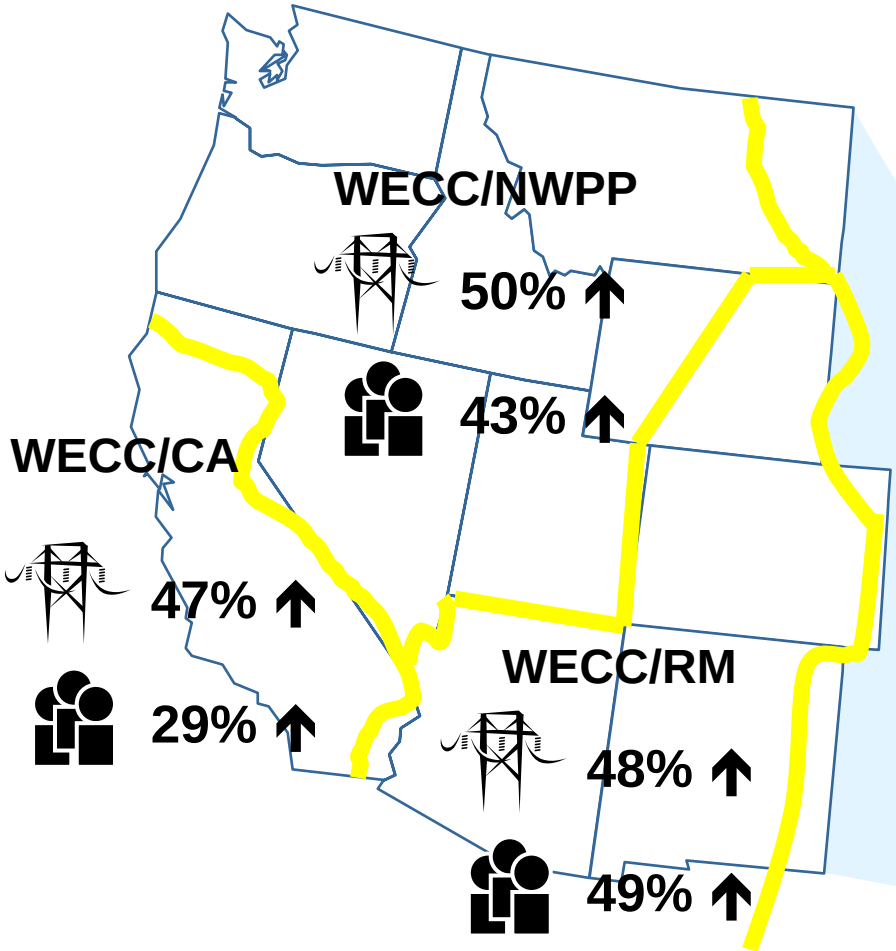
Summary of Generation Capacity Impacted by Water-Related Issues

Plant Generation Type	Generation Affected by Availability Issues (MW)	Generation Affected by Environmental Issues (MW)	Total Affected Generation (MW)
Pulverized Coal	17151	1200	18351
Hydro	8040	0	8040
Nuclear	4113	985	5098
Natural Gas/NGCC	1225	2887	4112
Total	30529	5072	35601

- New plants face difficulties in obtaining water withdrawal permits
- Existing plants face reduced generation

Source: DOE/NETL, *Review of Public Media Sources Identifying Energy-Water Related Issues between 2002 and 2007,* NETL Energy-Water R&D Program Internal Analysis, 2007

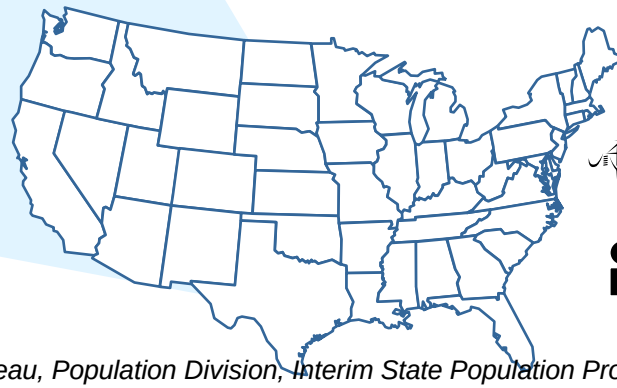
Projected Thermoelectric Capacity & Population Increases from 2005 to 2030



Regional Population and Thermoelectric Capacity Projected to Rise Significantly in the Future

Demands on our Limited Water Resources Expected to Constrain Regional Development

Sustainable Energy-Water Resource Strategies are Needed!



U.S. Total

24%

23%

Source: U.S. Census Bureau, Population Division, Interim State Population Projections, 2005. Energy Information Agency, Annual Energy Outlook 2006, Regional Tables, 2007.

Thermoelectric Power Freshwater Withdrawal and Consumption Projections

Data Resources

Resource	Type of Data
AEO 2006	• Projections of thermoelectric capacity and generation by NERC region • Coal capacity, generation, and capacity factor breakdown by four categories: existing unscrubbed, existing scrubbed, new PC (scrubbed), and IGCC
NETL 2005 Coal Power Plant Database – Including data from 2003 EIA-767	• Plant generation • Average water withdrawal and consumption • Cooling water source • Type of cooling water system • Type of boiler • Type of FGD system
EIA-860	• Plant location by NERC region • Plant summer capacity
CMU – Integrated Environmental Control Model (IECM)	• Water use factors for wet FGD and dry FGD
Parsons - Power Plant Water Consumption Study, August 2005	• Water use factors for boiler make-up • Water use factors for IGCC plants
NETL IEP Descriptions for Water-Related Projects	• Reductions in water withdrawal and consumption factors

National Average W&C Factors for Model Coal Plants

Generation Type	Cooling Water System Type	Boiler Type	Type of FGD	Withdrawal Factor (gal/kWh)	Consumption Factor (gal/kWh)
Coal	Once-Through	Subcritical	Wet	27.113	0.138
			Dry	27.088	0.113
			None	27.046	0.071
		Supercritical	Wet	22.611	0.124
			Dry	22.590	0.103
			None	22.551	0.064
	Wet Cooling Tower	Subcritical	Wet	0.531	0.462
			Dry	0.506	0.437
			None	0.463	0.394
		Supercritical	Wet	0.669	0.518
			Dry	0.648	0.496
			None	0.609	0.458
	Cooling Pond	Subcritical	Wet	17.927	0.804
			Dry	17.902	0.779
			None	17.859	0.737
		Supercritical	Wet	15.057	0.064
			Dry	15.035	0.042
			None	14.996	0.004

National Average W&C Factors for Model Non-coal Plants

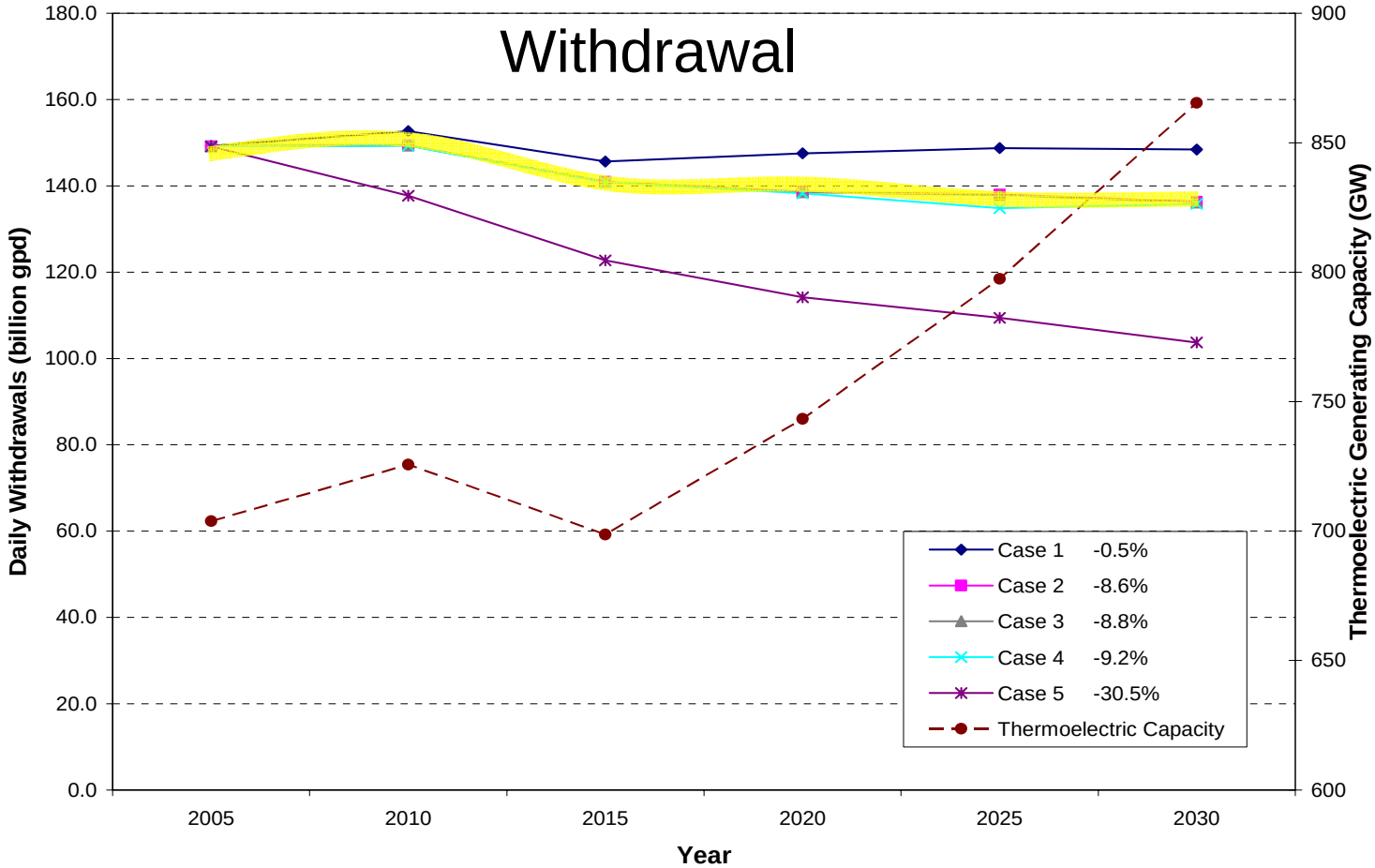
Generation Type	Cooling Water System Type	Boiler Type	Type of FGD	Withdrawal Factor (gal/kWh)	Consumption Factor (gal/kWh)
Nuclear	Once-Through	NA	NA	31.497	0.137
	Wet Cooling Tower	NA	NA	1.101	0.624
Oil & NG	Once-Through	NA	NA	22.74	0.09
	Wet Cooling Tower	NA	NA	0.25	0.16
	Cooling Pond	NA	NA	7.89	0.11
NGCC	Once-Through	NA	NA	9.01	0.002
	Wet Cooling Tower	NA	NA	0.15	0.13
	Cooling Pond	NA	NA	5.95	0.24
	Air Cooled	NA	NA	0.004	0.004
IGCC	Wet Cooling Tower	NA	NA	0.226	0.173

NG = Natural Gas
NGCC = Natural Gas Combined Cycle
IGCC = Integrated Gasification Combined Cycle

Water Use Projection Cases

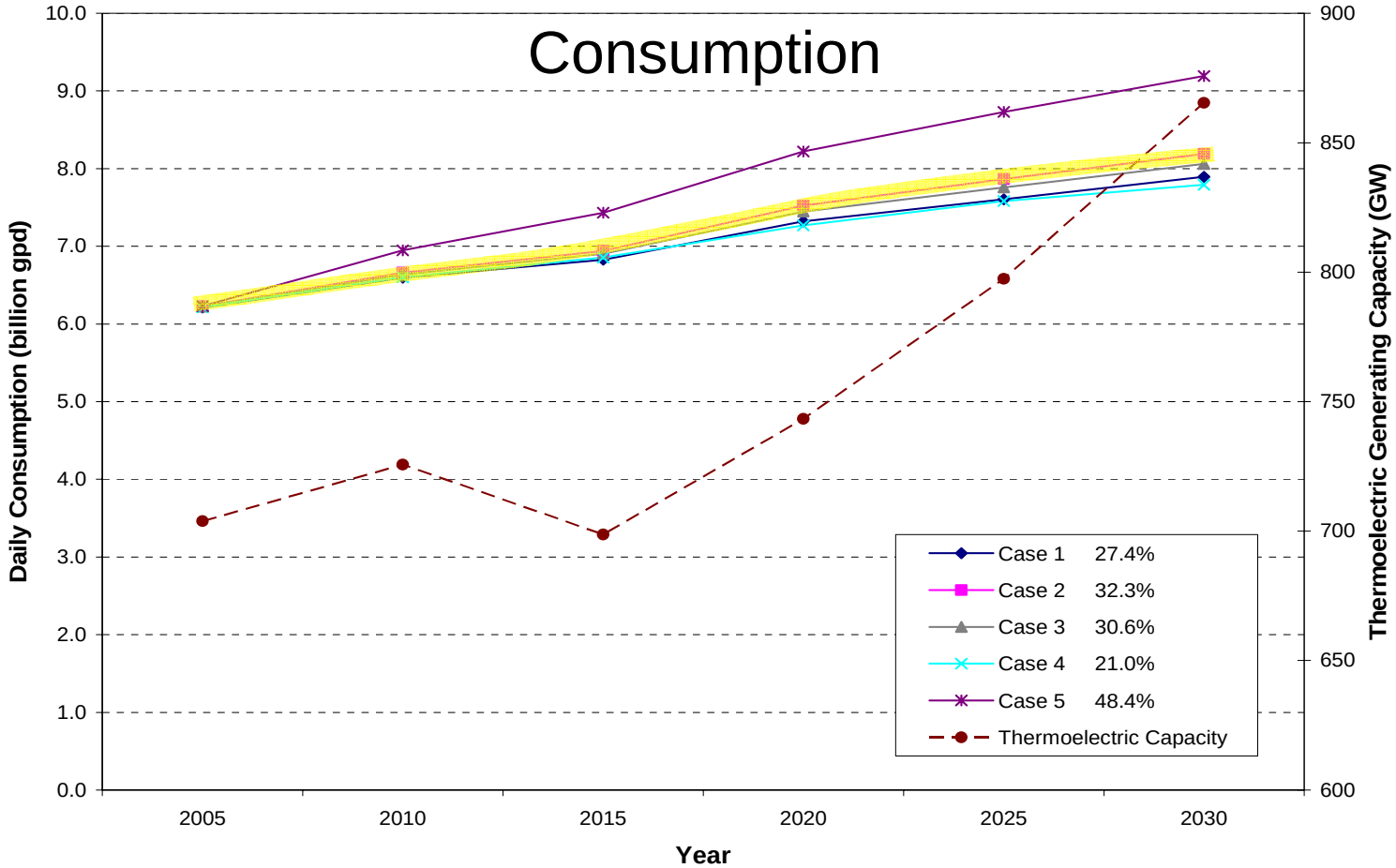
- **Case 1 (Status Quo)** – Additions and retirements are proportional to current water source and type of cooling.
- **Case 2 (Regulatory Driven) – All additions use freshwater and wet re-circulating cooling (WRC), while retirements are proportional to current water source and type of cooling.**
- **Case 3 (Regulatory Light)** – 90% of additions use freshwater and WRC, and 10% of additions use saline water and once-through cooling, while retirements are proportional to current water source and type of cooling.
- **Case 4 (Dry Cooling)** – 25% of additions use dry cooling and 75% of additions use freshwater and WRC, while retirements are proportional to current water source and type of cooling.
- **Case 5 (Conversion)** – Additions use freshwater and WRC, while retirements are proportional to current water source and type of cooling. 5% of existing freshwater once-through cooling capacity is retrofitted with WRC every five years starting in 2010.

Projected Changes in U.S. Thermoelectric Sector Freshwater Withdrawal and Consumption



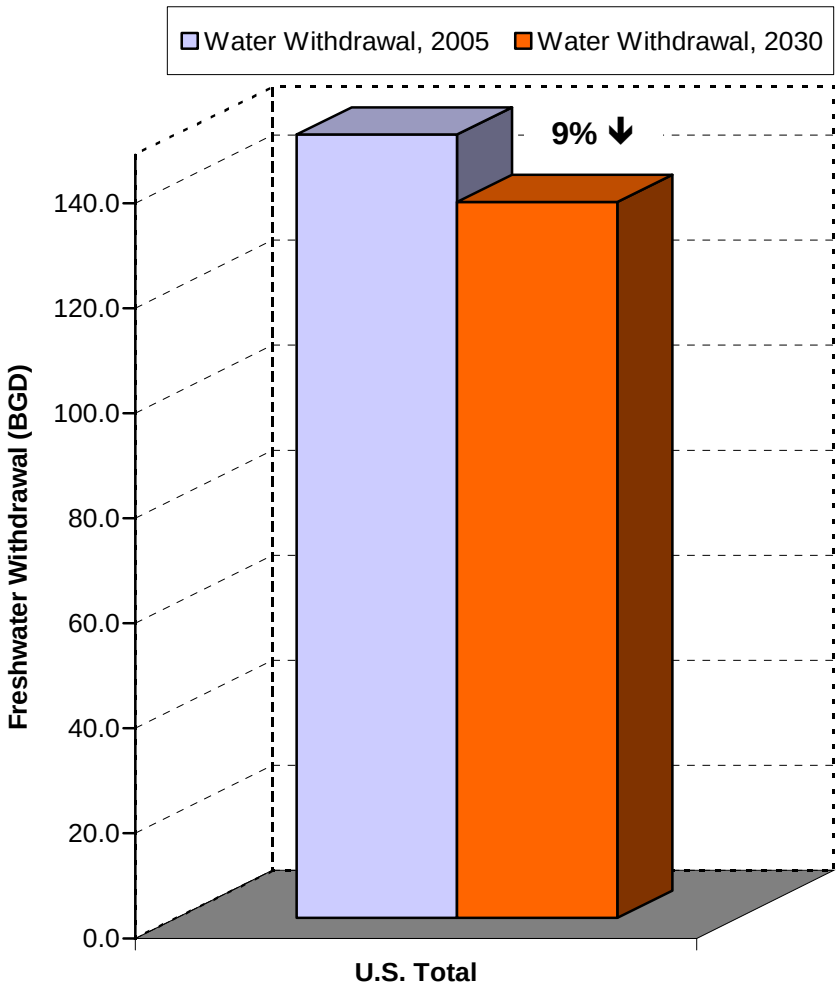
DOE/NETL, ***"Estimating Freshwater Needs to Meet Future Thermoelectric Generation Requirements***," August, 2006 http://www.netl.doe.gov/technologies/coalpower/ewr/pubs/WaterNeedsAnalysisPhaseI1006.pdf

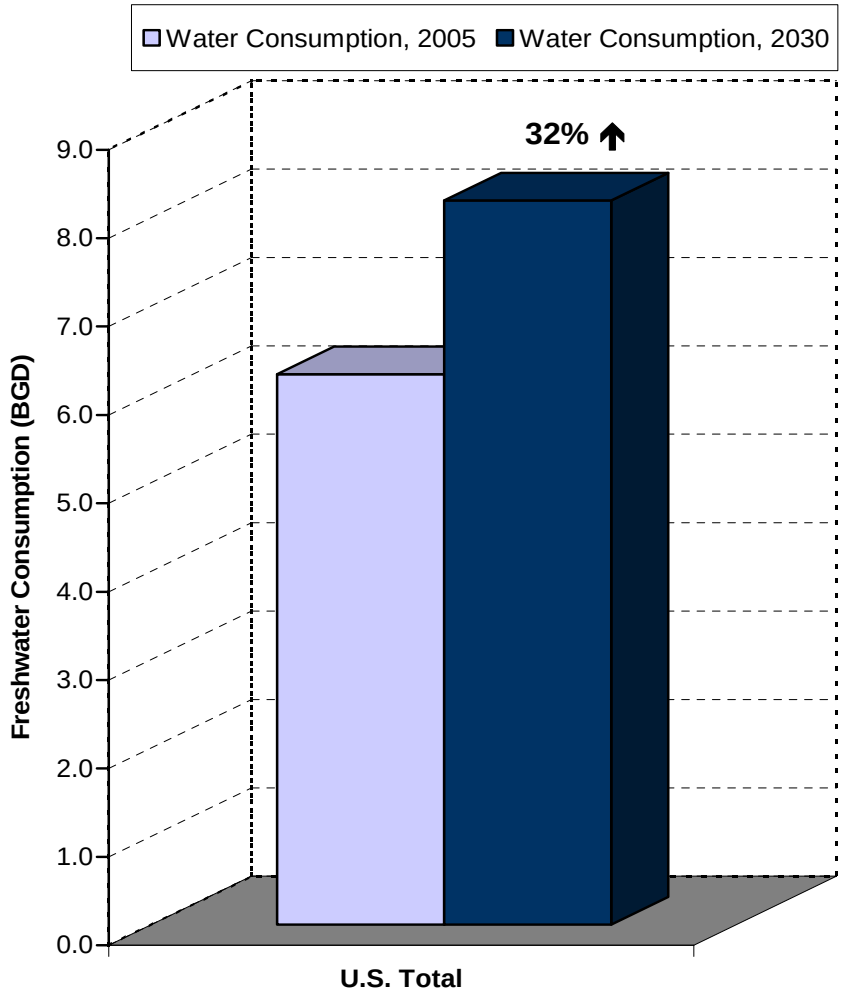
Projected Changes in U.S. Thermoelectric Sector Freshwater Withdrawal and Consumption



DOE/NETL, ***"Estimating Freshwater Needs to Meet Future Thermoelectric Generation Requirements***," August, 2006 http://www.netl.doe.gov/technologies/coalpower/ewr/pubs/WaterNeedsAnalysisPhaseI1006.pdf

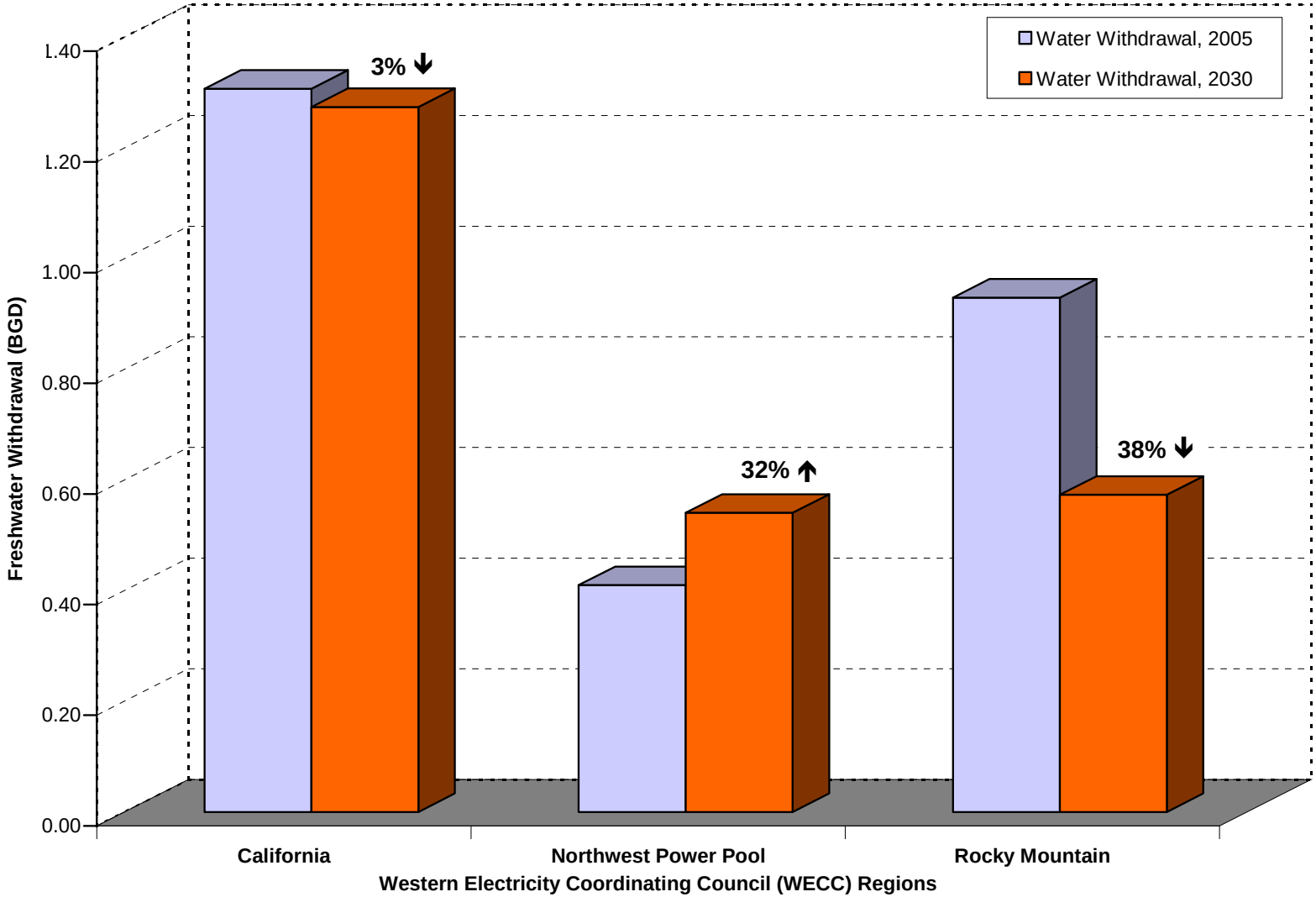
Projected Change in U.S. Thermoelectric Sector Freshwater Withdrawal and Consumption (Case 2)





DOE/NETL, ***"Estimating Freshwater Needs to Meet Future Thermoelectric Generation Requirements***," August, 2006 http://www.netl.doe.gov/technologies/coalpower/ewr/pubs/WaterNeedsAnalysisPhaseI1006.pdf

Regional Thermoelectric Withdrawal Results (Case 2)



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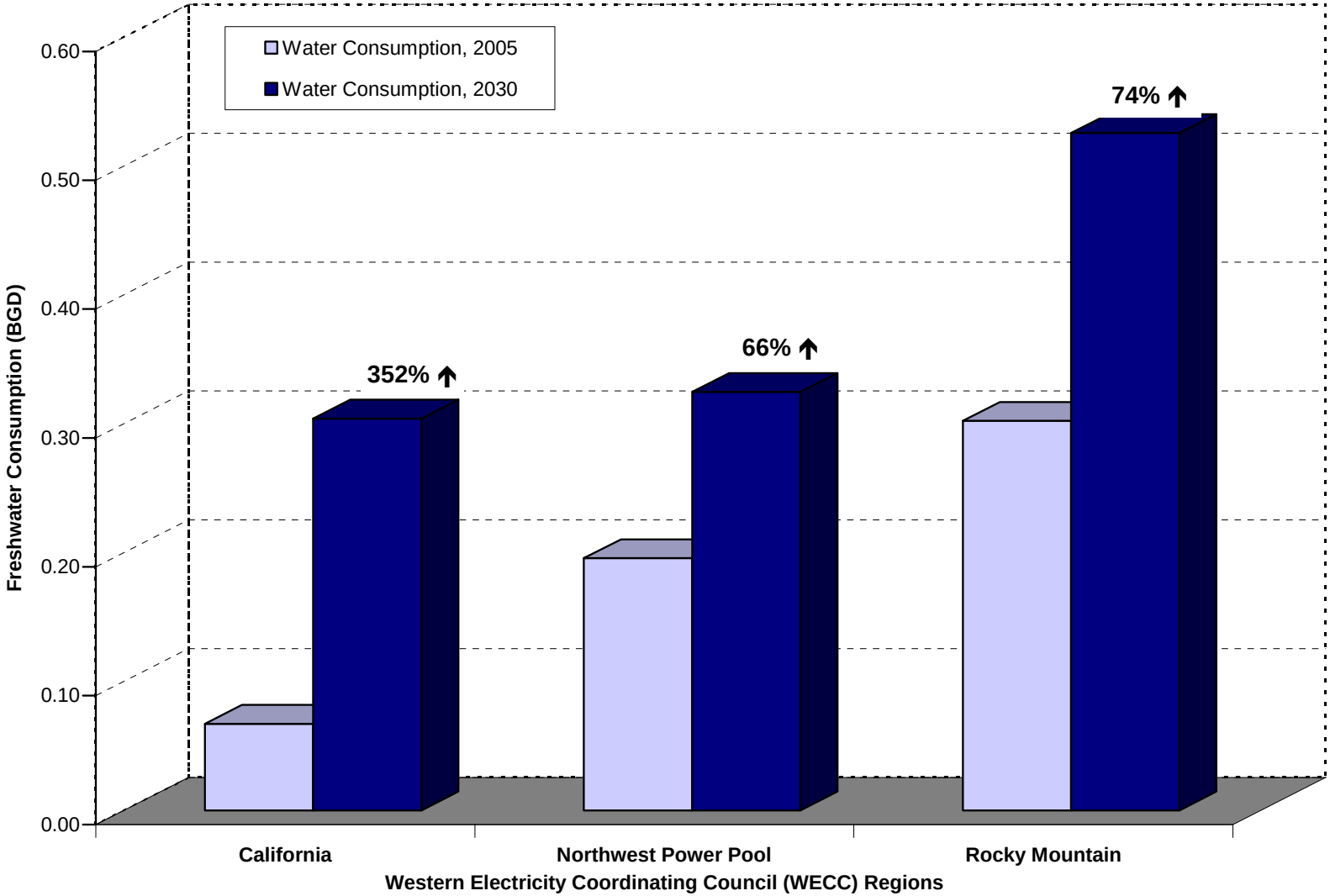
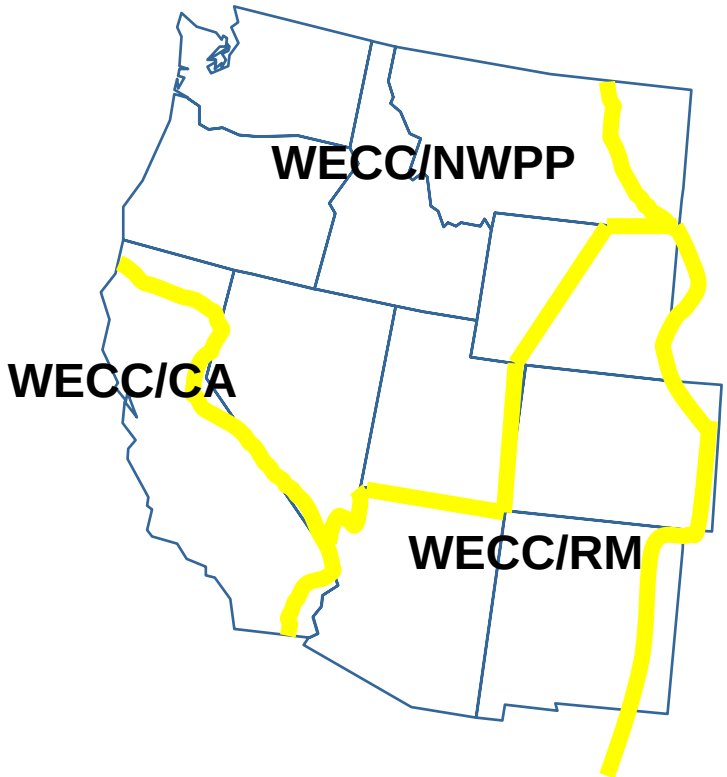
Regional Thermoelectric Consumption Results (Case 2)



DOE/NETL, ***"Estimating Freshwater Needs to Meet Future Thermoelectric Generation Requirements***," August, 2006 http://www.netl.doe.gov/technologies/coalpower/ewr/pubs/WaterNeedsAnalysisPhaseI1006.pdf

Overview of Regional Results: Case 2 (2005 – 2030)
by Western Electricity Coordinating Council (WECC)

- **EIA thermoelectric capacity projections:**
  - 24% increase in U.S., Total
  - 47% increase in California
  - 50% increase in Northwest Power Pool
  - 48% increase in Rocky Mountains
- **Case 2 withdrawal projections:**
  - 9% decrease in U.S., Total
  - 3% decrease in California
  - 32% increase in Northwest Power Pool
  - 38% decrease in Rocky Mountains
- **Case 2 consumption projections:**
  - 32% increase in U.S., Total
  - 352% increase in California
  - 66% increase in Northwest Power Pool
  - 74% increase in Rocky Mountains



WECC U.S. Regions

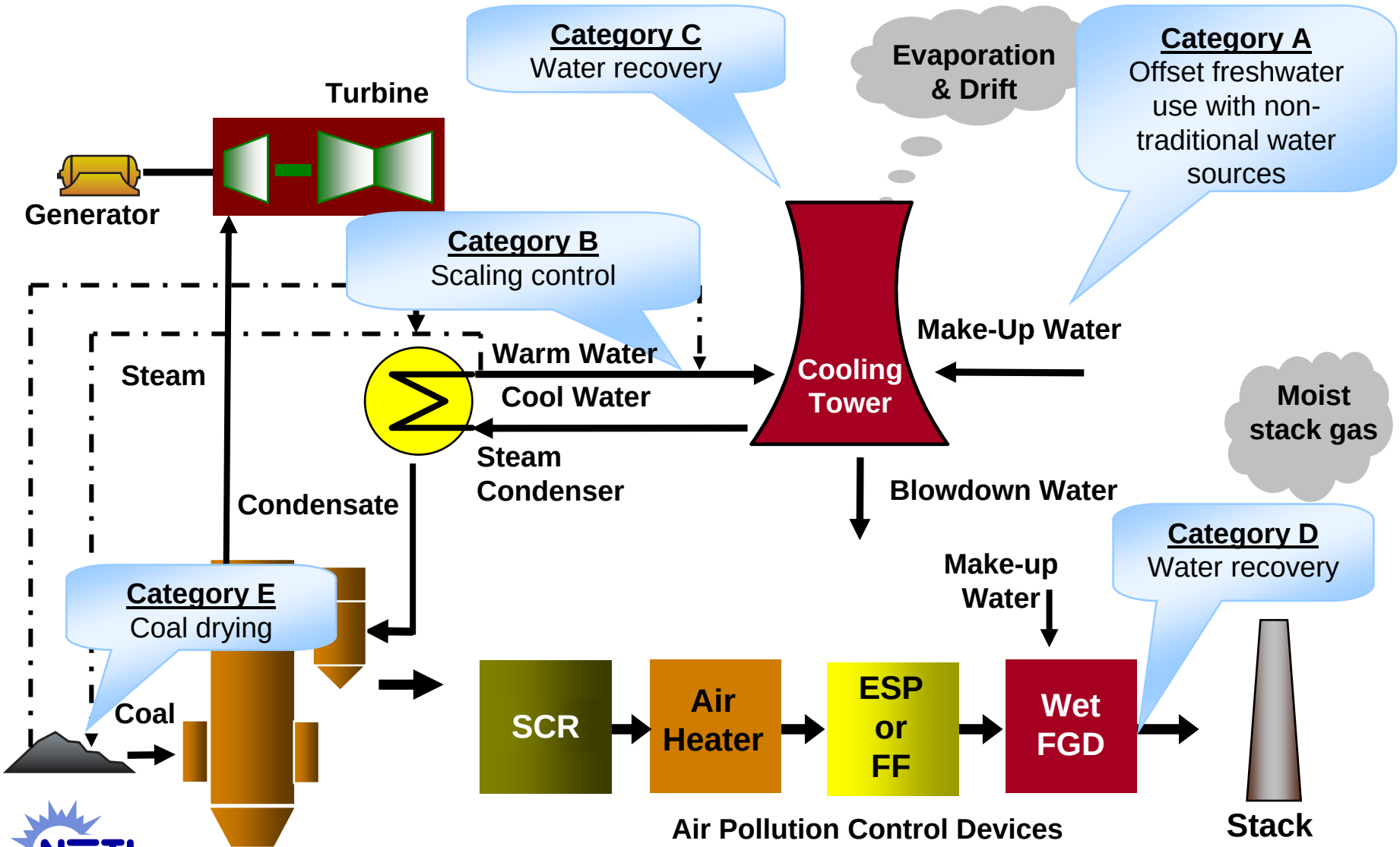
DOE/NETL's R&D Program

Technical & Cost Goals

- **Short Term – Have technologies ready for commercial demonstration by 2015 that, when used alone or in combination, can reduce freshwater withdrawal and consumption by 50% or greater for thermoelectric power plants equipped with wet recirculating cooling technology at levelized cost of less than $2.40 per 1000 gallons freshwater conserved.**

- **Long Term – Have technologies ready for commercial demonstration by 2020 that when used in combination can reduce freshwater withdrawal and consumption by 70% or greater at levelized cost of less than $1.60 per 1000 gallons freshwater conserved.**

FE/NETL IEP Water Technology Categories

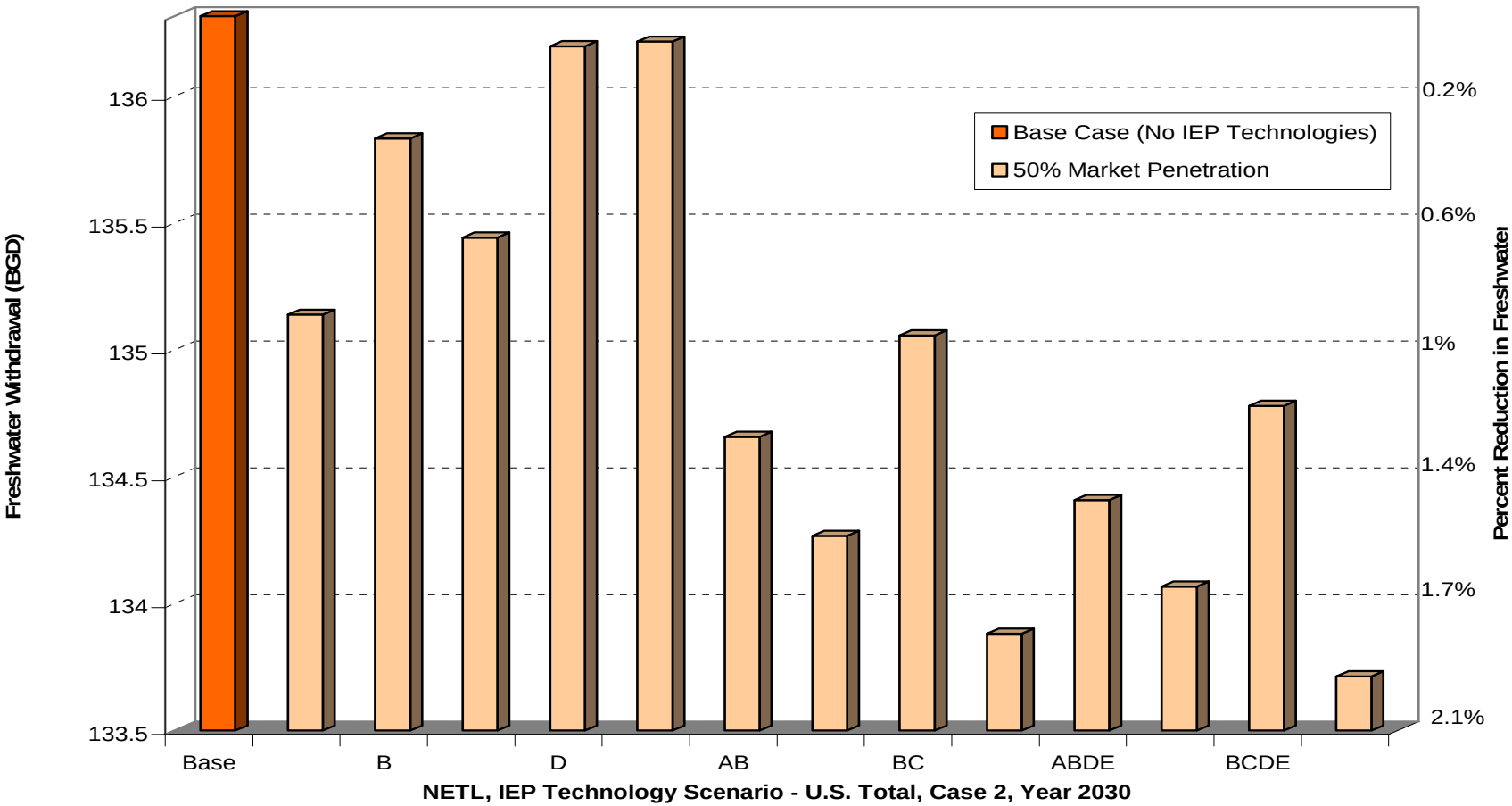


IEP Energy-Water Technology Categories & Current Projects

Description
Category A - Provide Alternate Source of Cooling Water Make-up • Use of Produced Water in Recirculated Cooling Systems at Power Generation Facilities & Development of an Impaired Water Cooling System - *EPRI* • Development and Demonstration of a Modeling Framework for Assessing the Efficacy of Using Mine Water for Thermoelectric Power Generation – *West Virginia University* • Reuse of Treated Internal or External Wastewaters in the Cooling Systems of Coal-Based Thermoelectric Power Plants – *University of Pittsburgh*
Category B - Increase Cycles of Concentration for Wet Recirculating Systems, thereby Decreasing Wet Cooling Tower Blowdown Requirements • A Synergistic Combination of Advanced Separation and Chemical Scale Inhibitor Technologies for Efficient Use of Impaired Water as Cooling Water in Coal-Based Power Plants – *Nalco Company* • Application of Pulsed Electrical Fields for Advanced Cooling in Coal-Fired Power Plants – *Drexel University*
Category C - Advanced Cooling Technology • Use of Air2Air™ Technology to Recover Fresh-Water from the Normal Evaporative Cooling Loss at Coal-Based Thermoelectric Power Plants – *SPX Cooling Systems*
Category D - Reclaim Water from Combustion Flue Gas for Use as Cooling Water Make-up • Water Extraction from Coal-Fired Power Plant Flue Gas – *University of North Dakota, UNDEERC* • Recovery of Water from Boiler Flue Gas – *Lehigh University* • Reduction of Water Use in Wet FGD System – *URS Group, Inc.*
Category E - Reduce Cooling Tower Evaporative Losses via Coal Drying • Use of Coal Drying to Reduce Water Consumed in Pulverized Coal Power Plants – *Lehigh University*

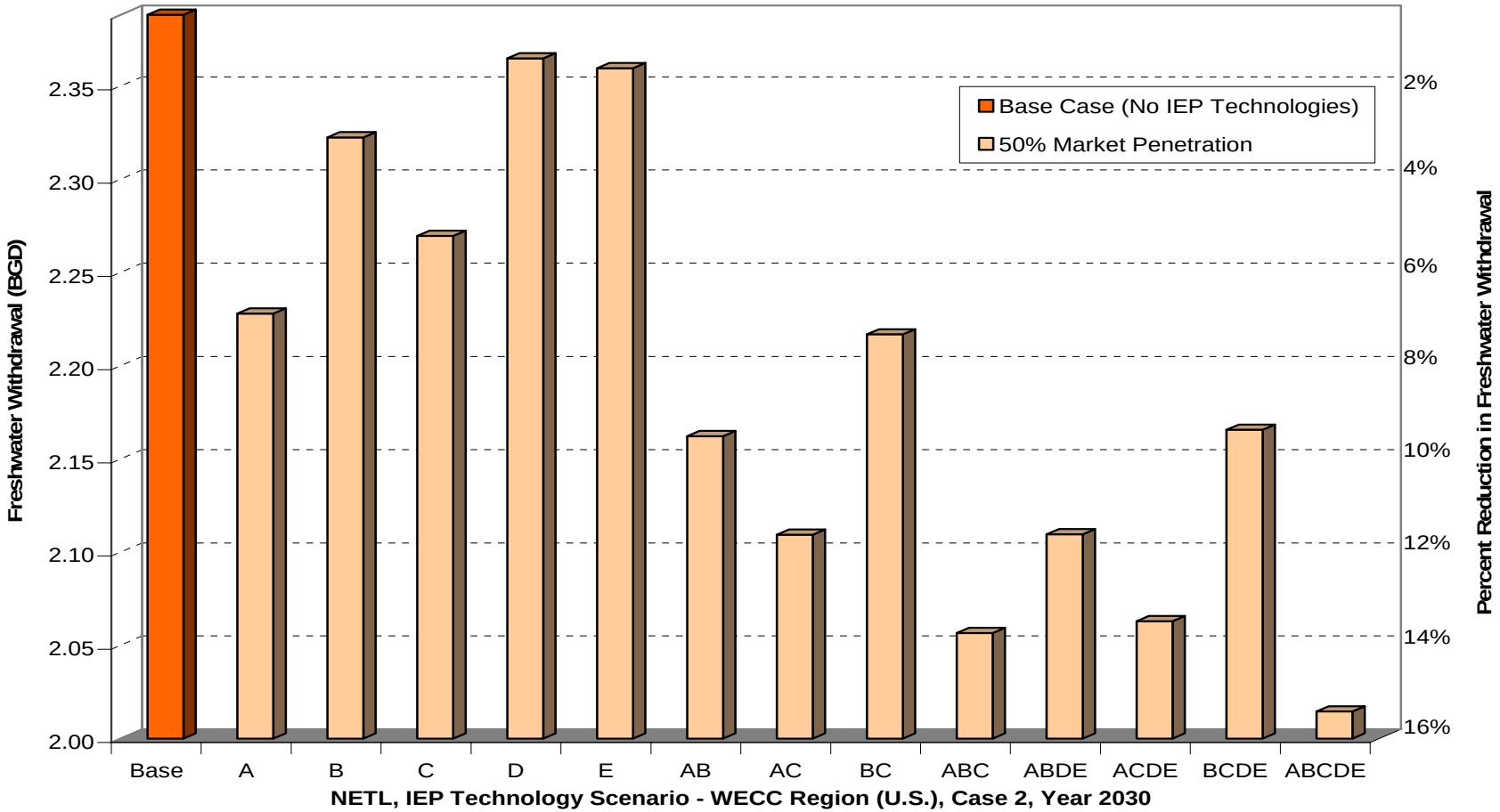
Estimated Benefits of R&D

U.S. Total Water Withdrawal with IEP Program Technologies

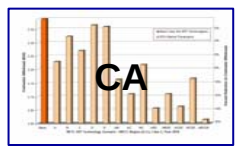


Results by Region:

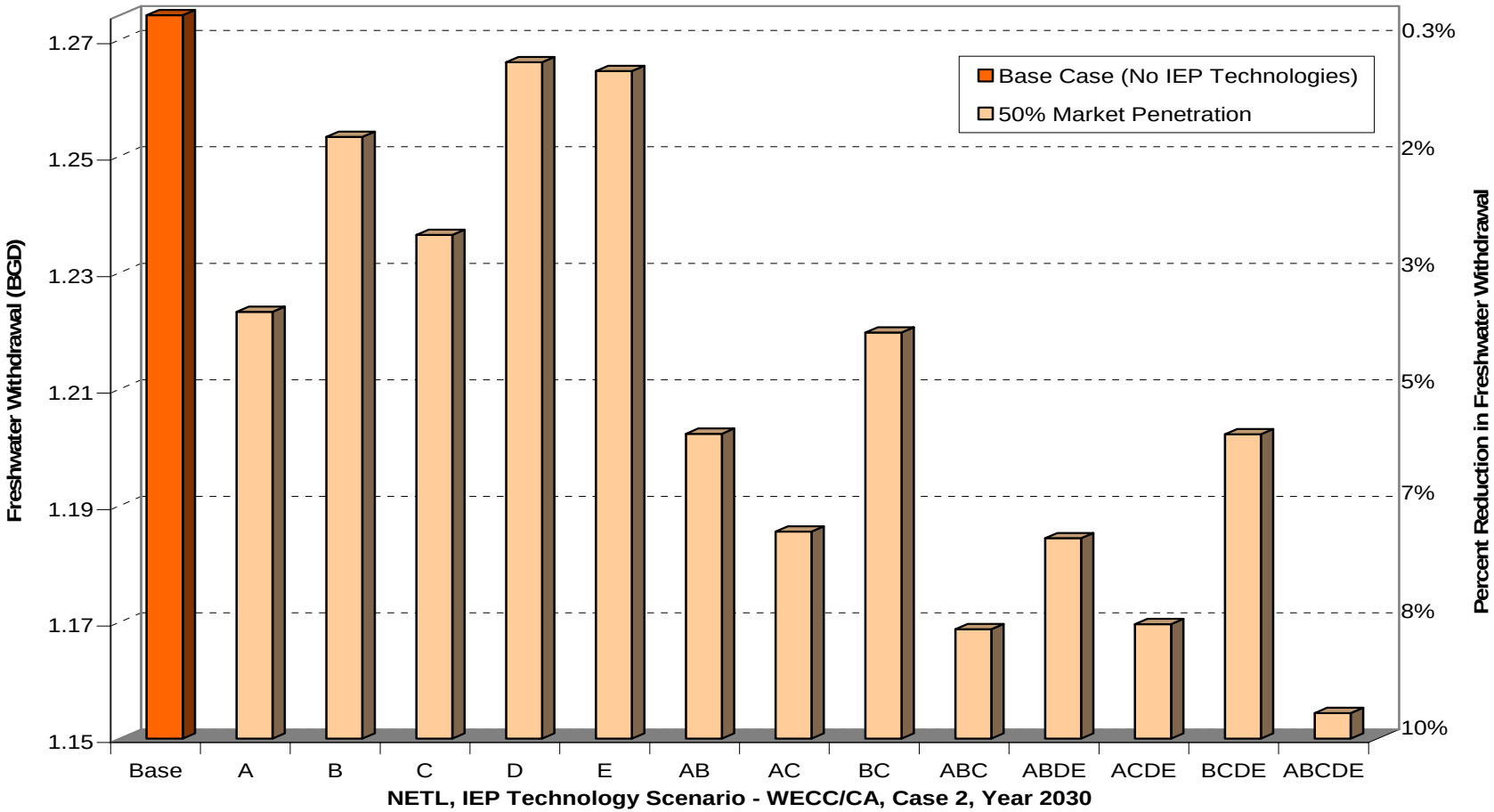
WECC Region (U.S.) Water Withdrawal with IEP Program Technologies



Results by Region:

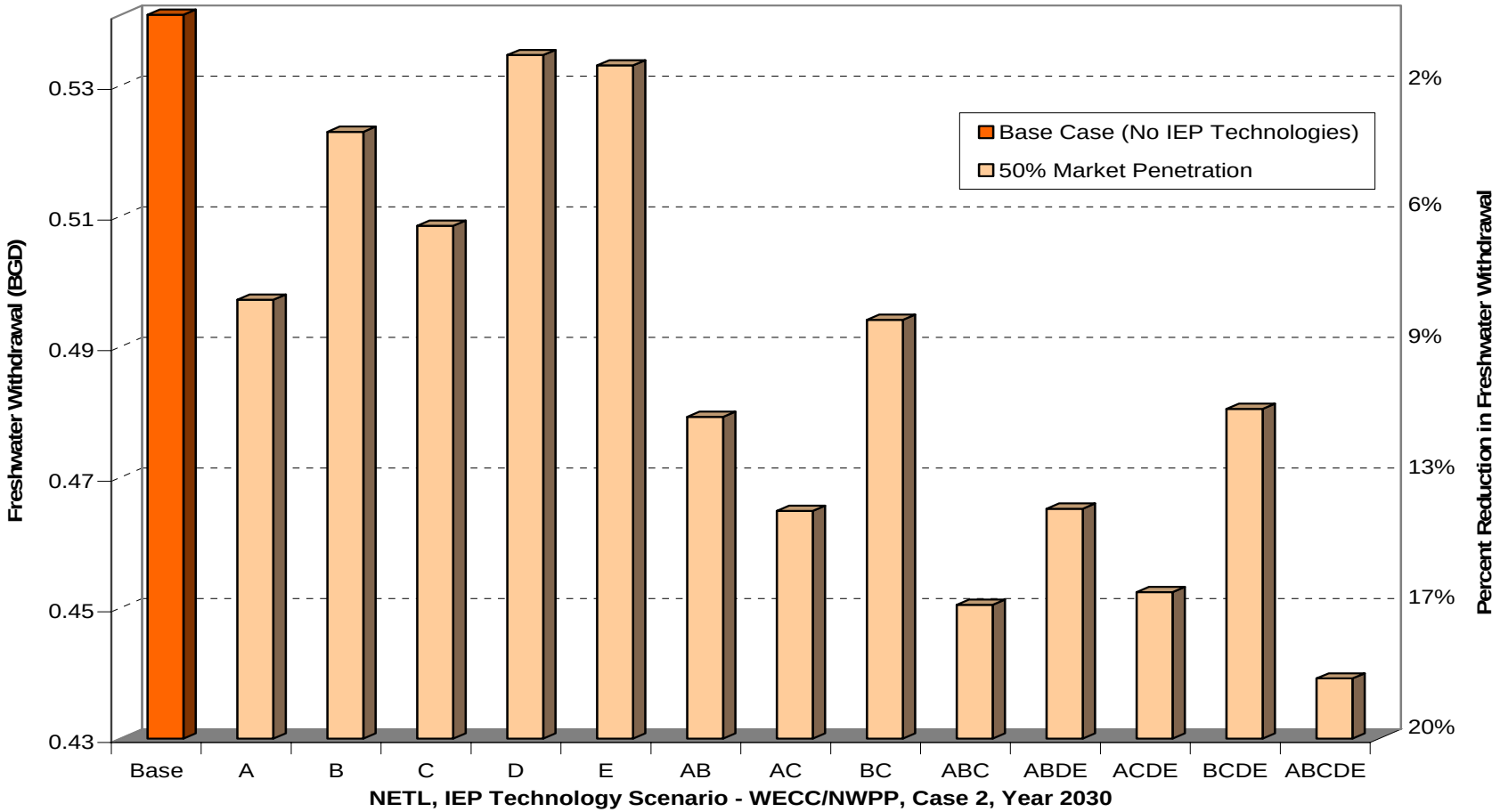


WECC/California Water Withdrawal with IEP Program Technologies

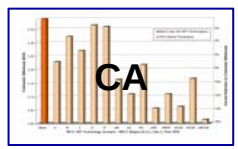


Results by Region:

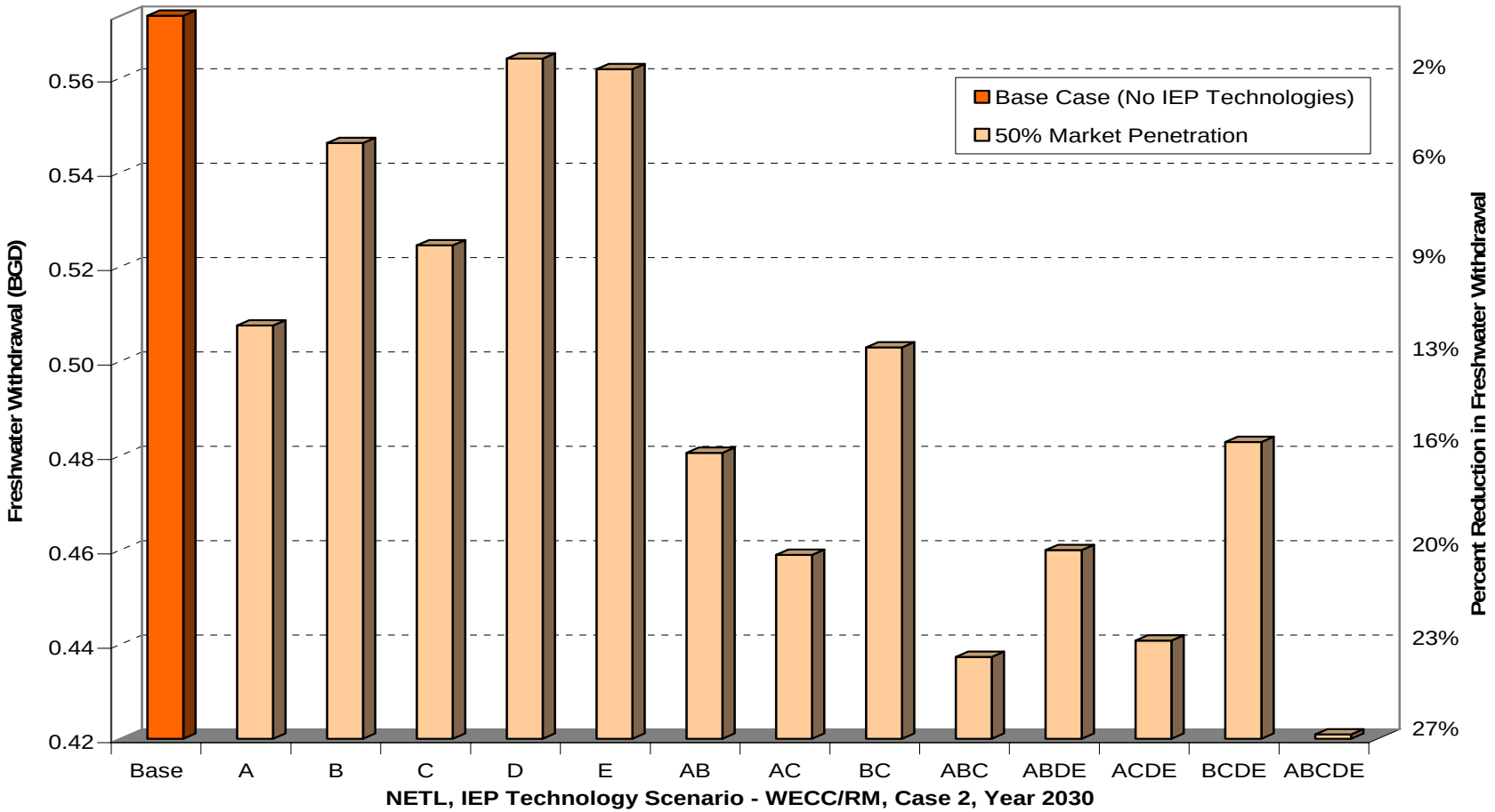
WECC/Northwest Power Pool Water Withdrawal with IEP Program Technologies



Results by Region:

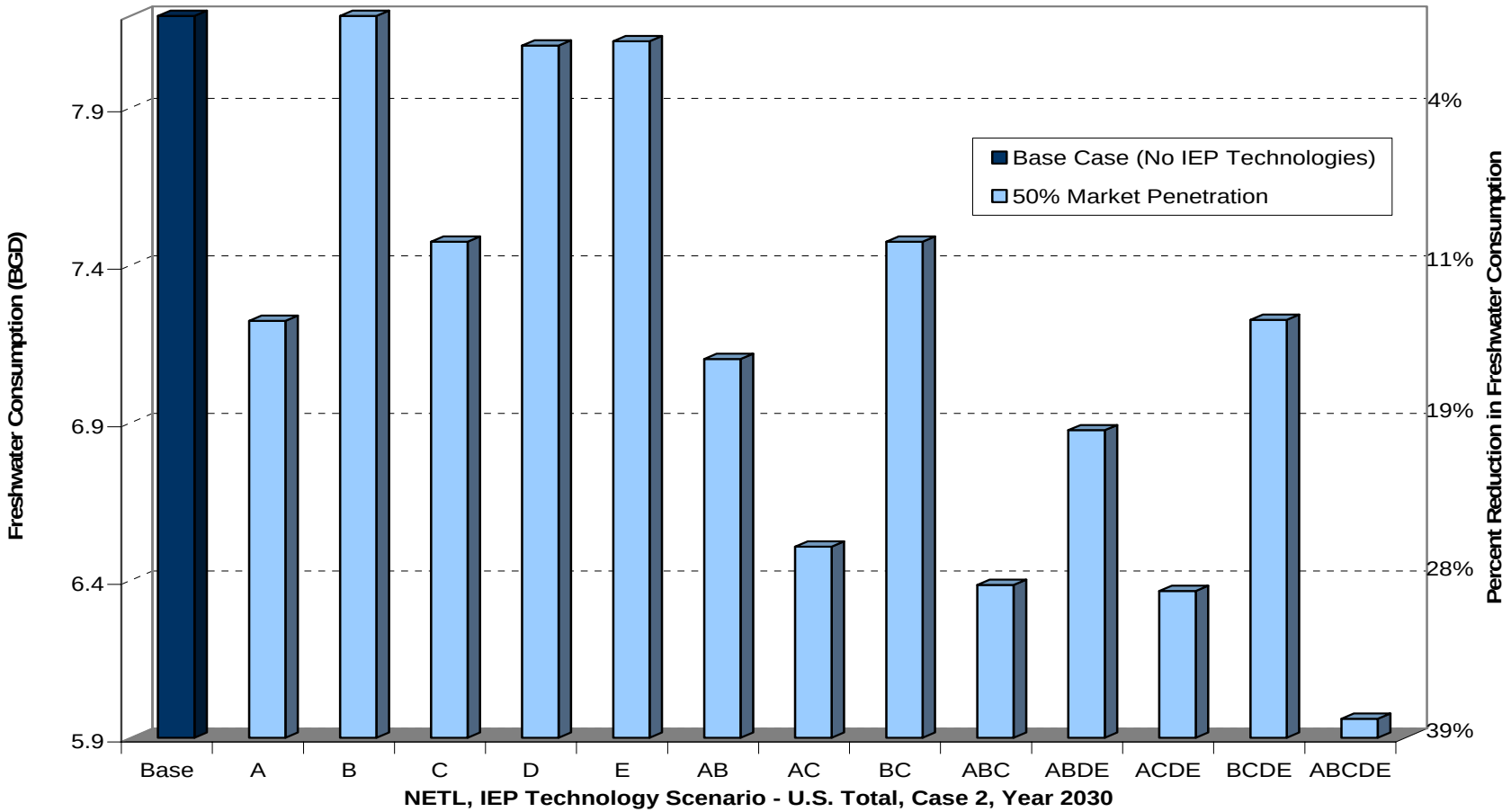


WECC/Rocky Mountain Water Withdrawal with IEP Program Technologies



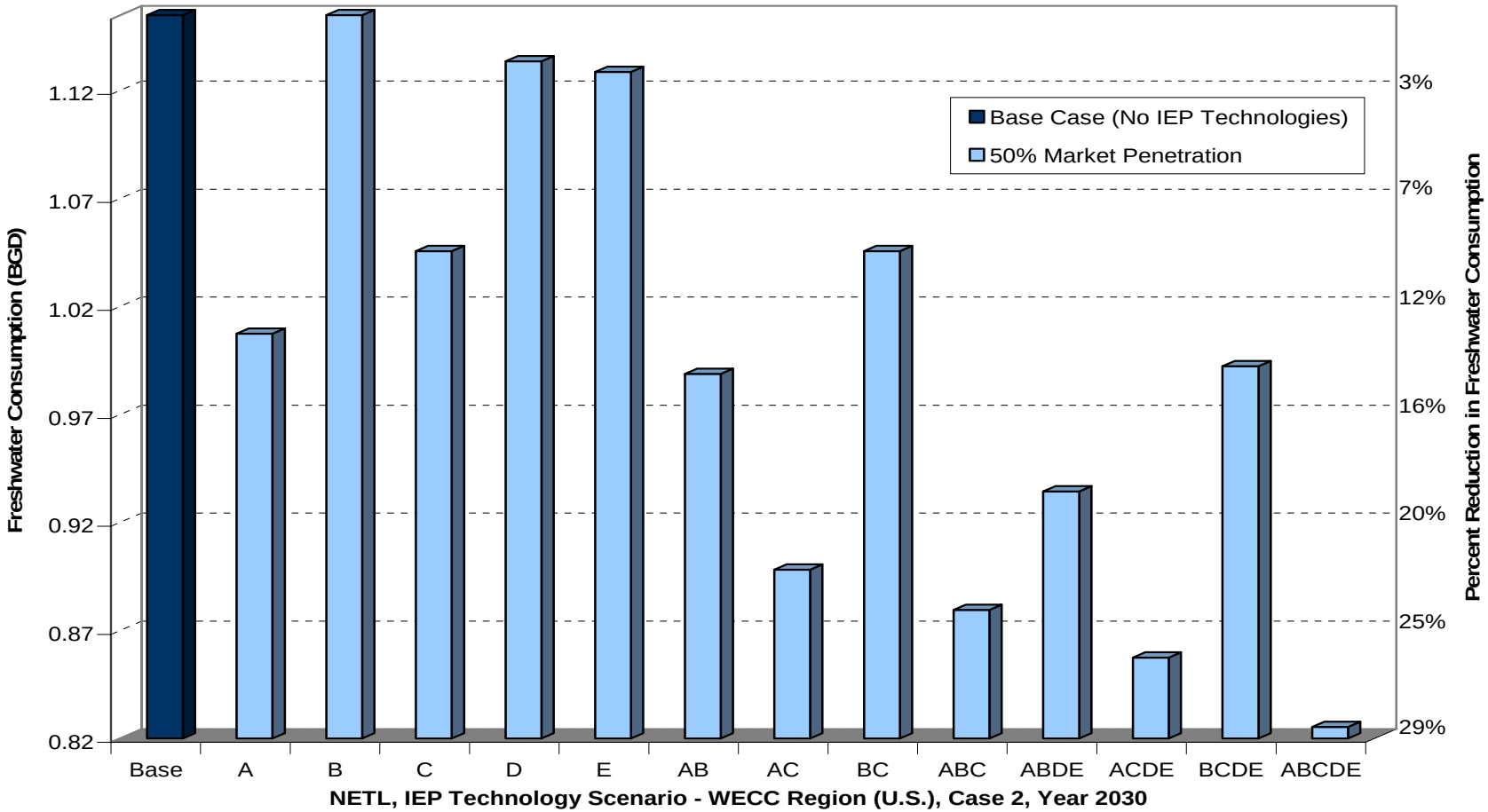
Results by Region:

U.S. Total Water Consumption with IEP Program Technologies



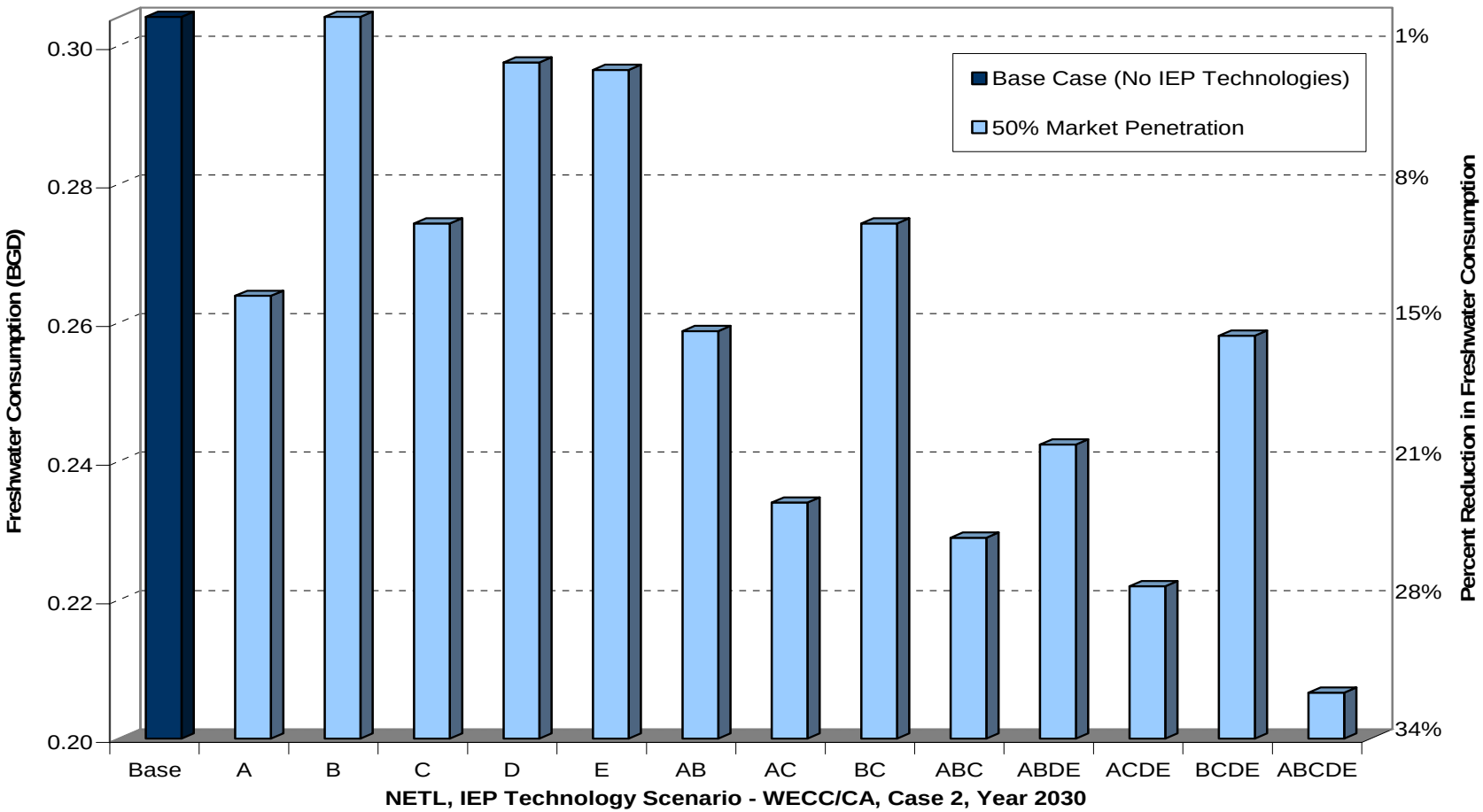
Results by Region:

WECC Region (U.S.) Water Consumption with IEP Program Technologies

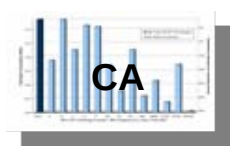


Results by Region:

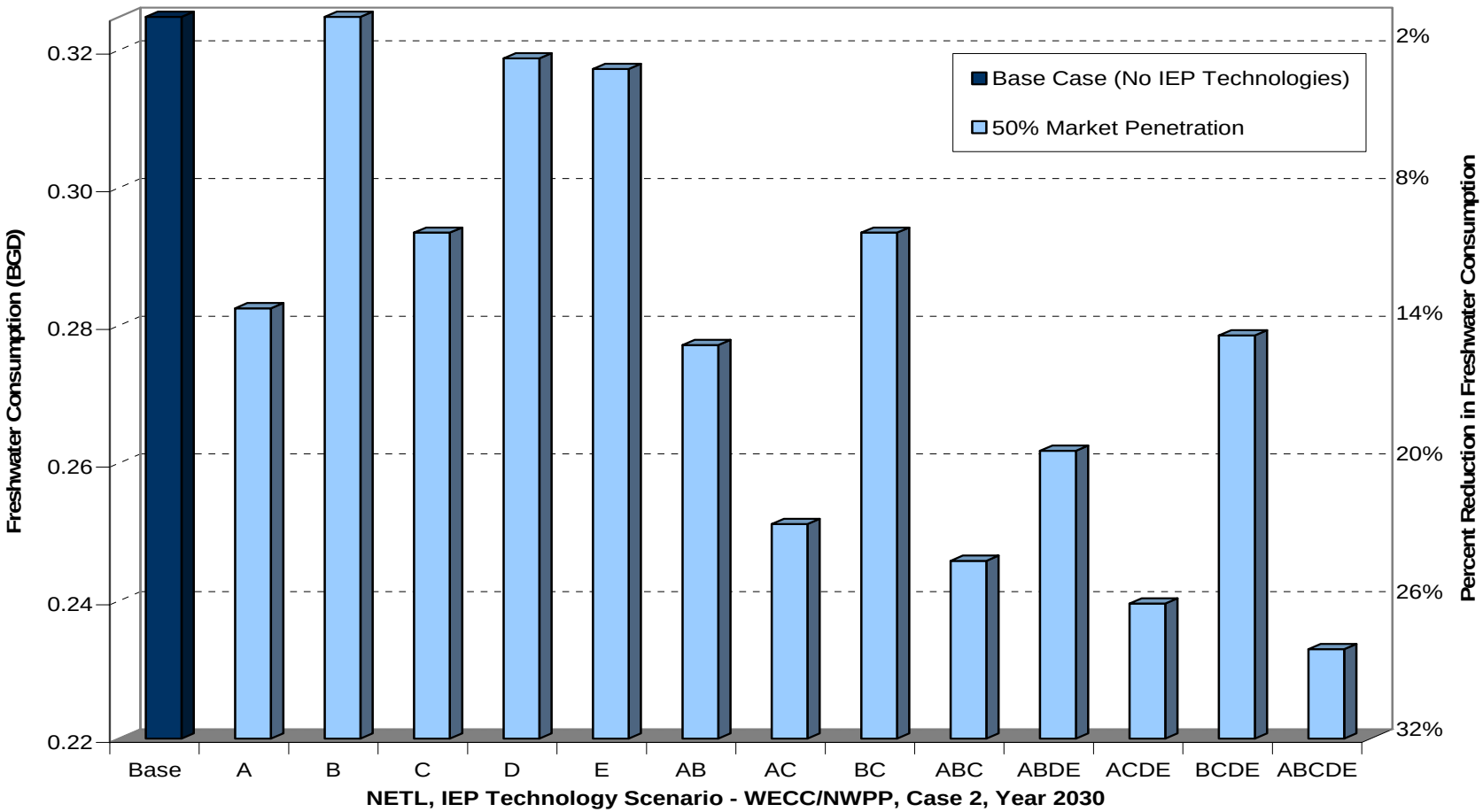
WECC/California Water Consumption with IEP Program Technologies



Results by Region:

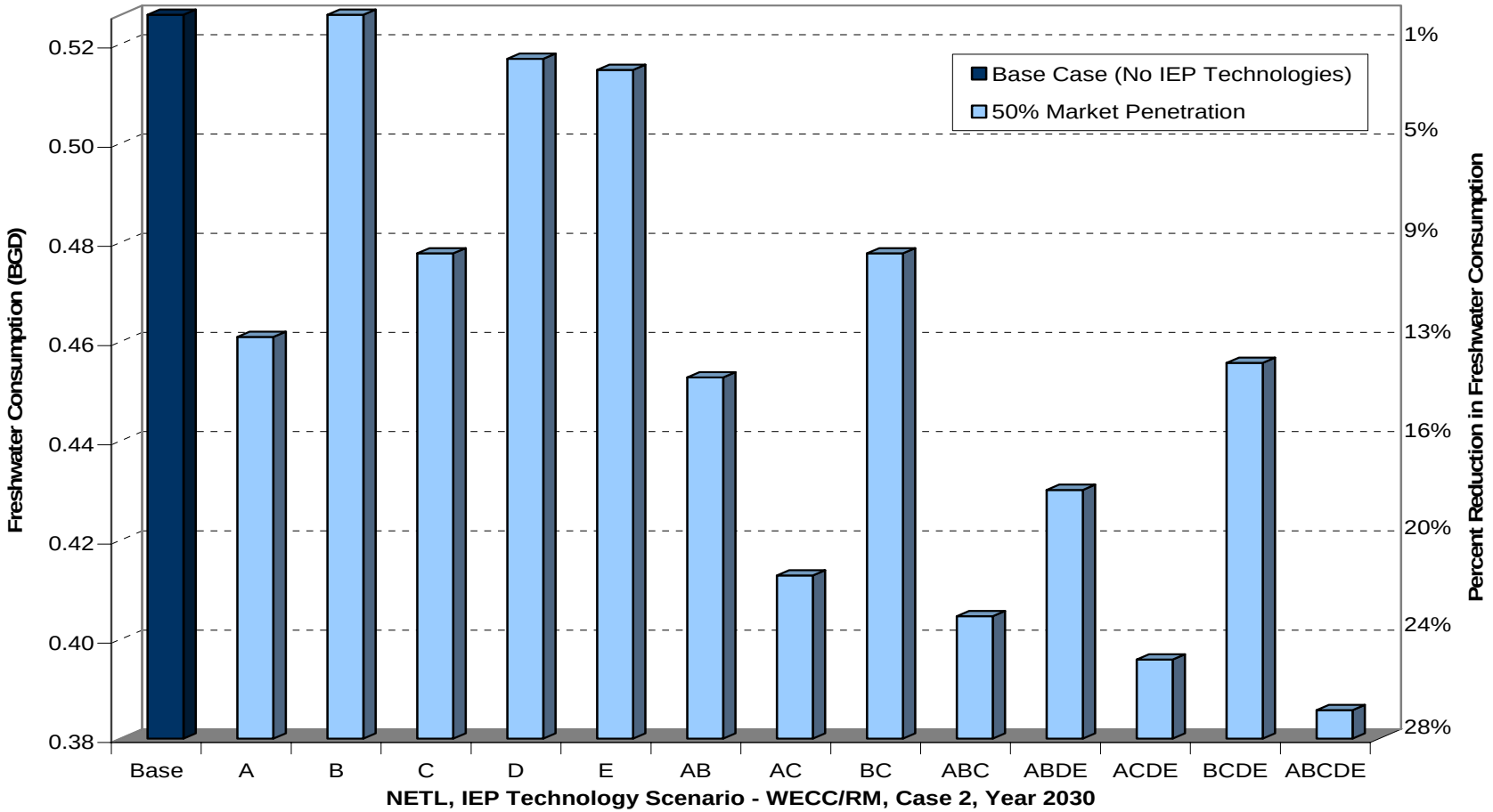


WECC/Northwest Power Pool Water Consumption with IEP Program Technologies



Results by Region:

WECC/Rocky Mountain Water Consumption with IEP Program Technologies



Results by Region:

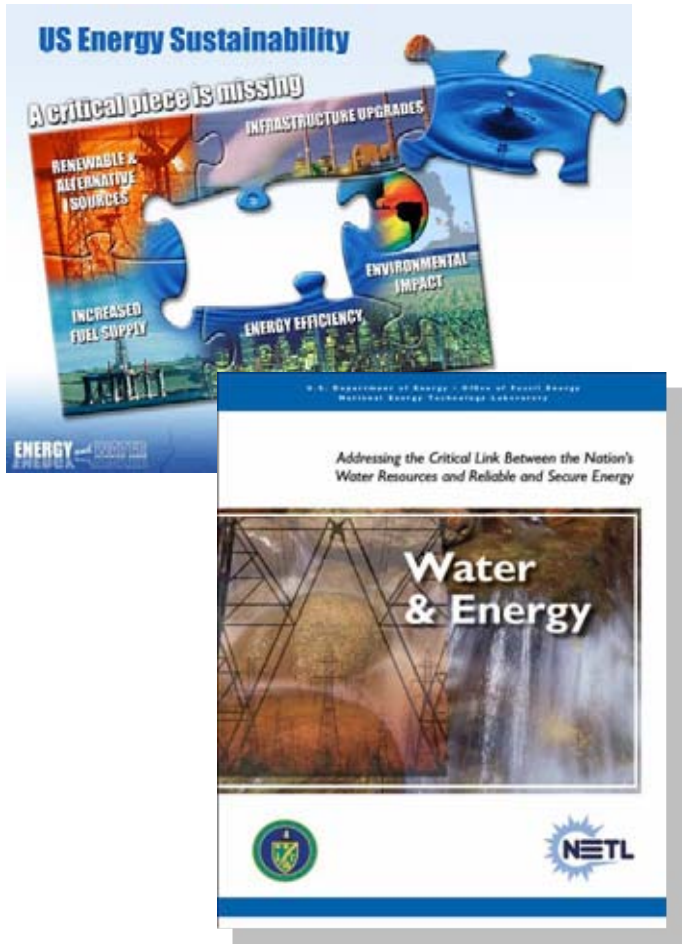
Summary of Potential IEP Energy-Water Technology Benefits to WECC Region

- **U.S. Total**
  - Withdrawal: 1.9% decrease (2.91 million a-f/yr)
  - Consumption: 27.2% decrease (2.50 million a-f/yr)
- **WECC Region**
  - Withdrawal: 15.7% decrease (0.42 million a-f/yr)
  - Consumption: 28.5% decrease (0.37 million a-f/yr)
- **WECC/California**
  - Withdrawal: 9.4% decrease (0.13 million a-f/yr)
  - Consumption: 32.1% decrease (0.11 million a-f/yr)
- **WECC/Northwest Power Pool**
  - Withdrawal: 18.8% decrease (0.11 million a-f/yr)
  - Consumption: 28.3% decrease (0.10 million a-f/yr)
- **WECC/Rocky Mountain**
  - Withdrawal: 26.6% decrease (0.17 million a-f/yr)
  - Consumption: 26.7% decrease (0.16 million a-f/yr)

Projected benefits for Case 2, Year 2030, with a 50% Market Penetration.
Values represent the maximum potential from the array of technology scenarios.
[a-f/yr = acre-feet per year]

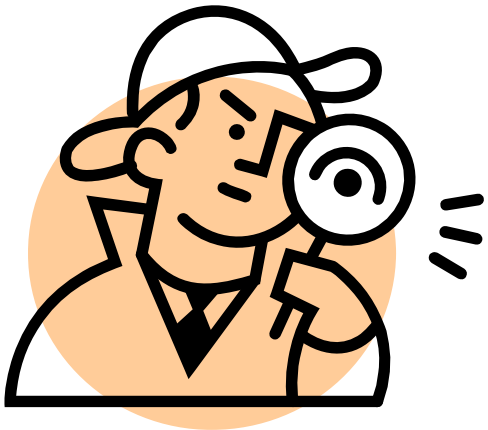
Summary

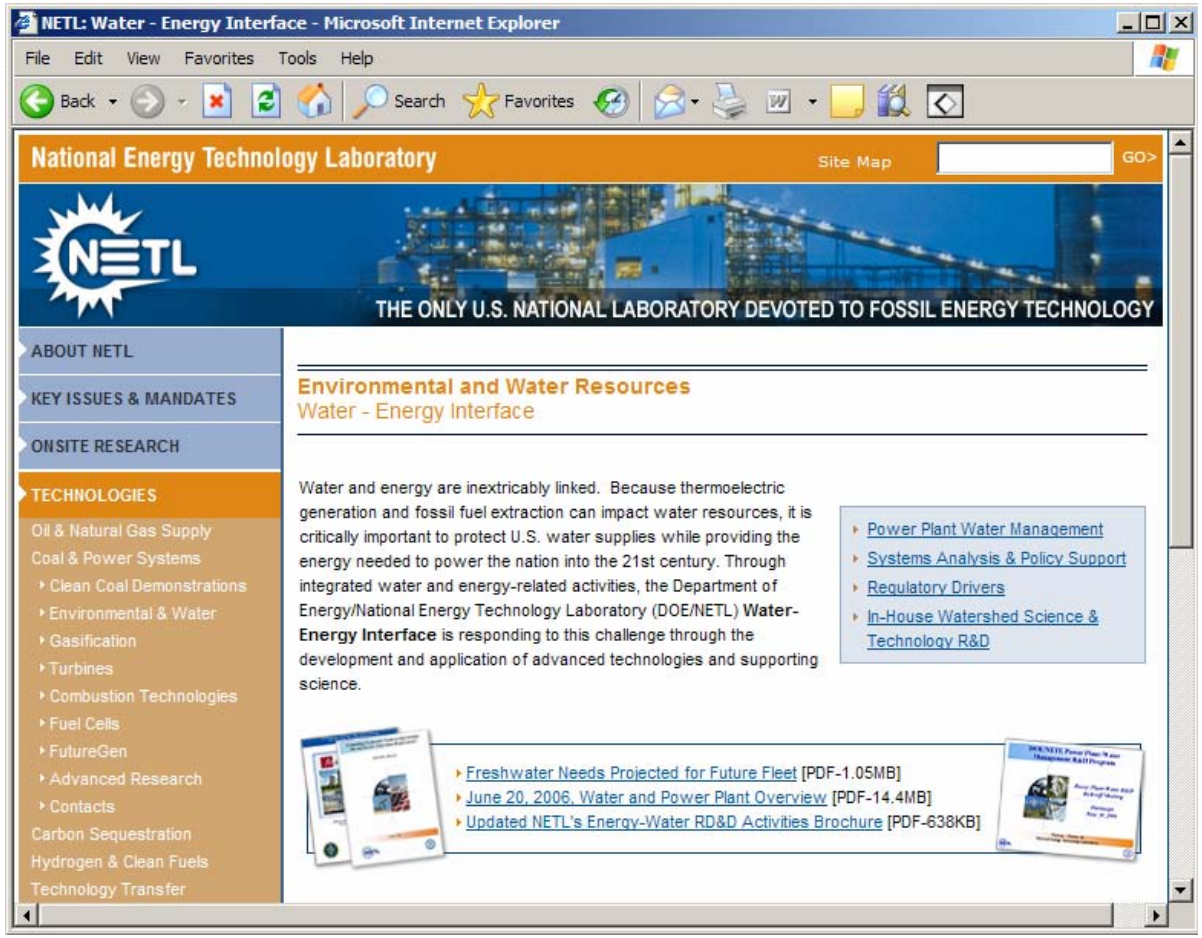
- **Water-related issues will continue to challenge siting of new and/or operation of existing thermoelectric power plants**
- **These issues <u>may</u> become more critical in future due to competing demands, population growth, and increased energy demands**
- **In response, NETL will:**
  - Update our analyses of water needs related to thermoelectric generation and coal, oil and natural gas production
  - Continue research and development of advanced water management technologies and concepts
  - Continue to work with/support Energy-Water Nexus team



FE/NETL Energy-Water Program Plan

To Find Out More About NETL's Energy-Water R&D





http://www.netl.doe.gov/technologies/coalpower/ewr/water/index.html

Questions?