Energy and Water Resources National Perspectives

National Water Conference
USDA-CSREES
Sparks, NV

February 3-7, 2008

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U.S. Department of Energy

National Energy Technology Laboratory

Outline

- Energy, Water
- Electricity Generation
  - Cooling Water
- DOE Research Initiative
- Future Concerns
- Extraction of Fossil Fuels

Background image by JRDuda

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Fossil Energy Will Continue to Dominate

Energy Demand Today

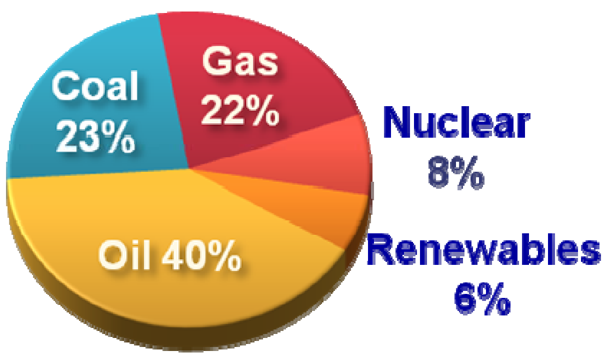
+24%

Energy Demand 2030

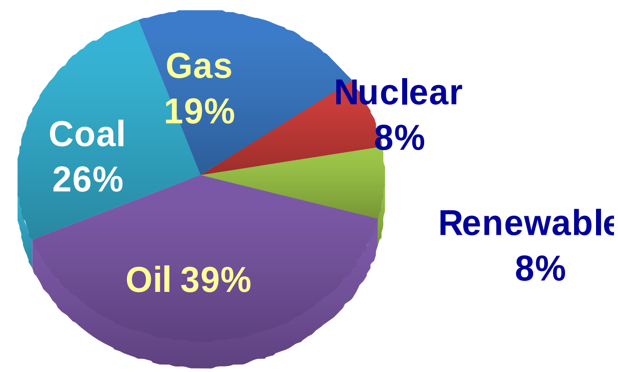
101 QBtu/Year
85% Fossil Energy

124 QBtu/Year
84% Fossil Energy

United States



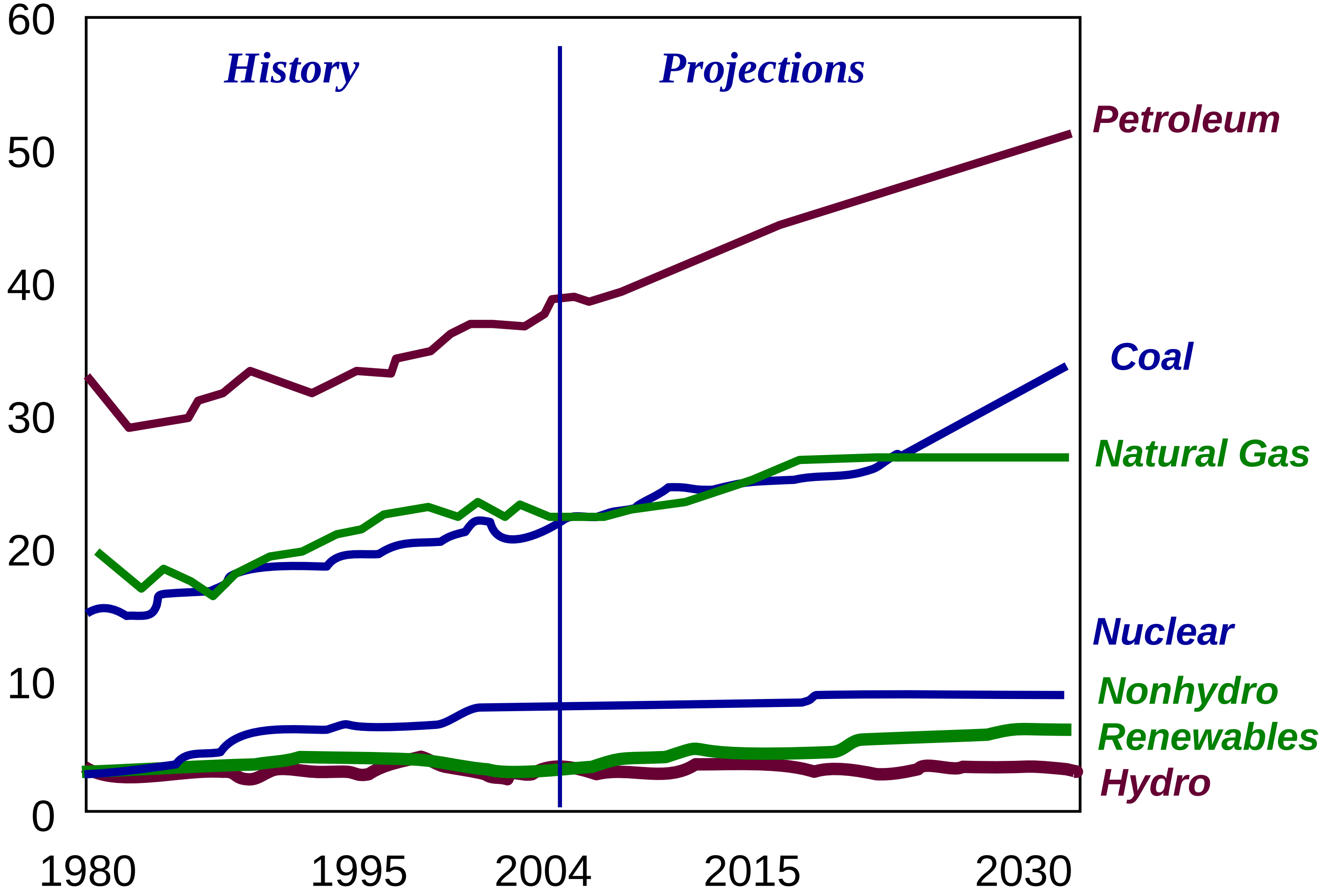
United States



U.S. data from EIA, Annual Energy Outlook 2008 Early Release, years 2006 and 2030; world data from IEA, World Energy Outlook 2007, years 2005 and 2030

U.S. Energy Demand to Increase Water Requirements to "*Track Btu's*" ?

Energy Consumption by Fuel, 1980-2030
(quadrillion Btu)



AEO2006

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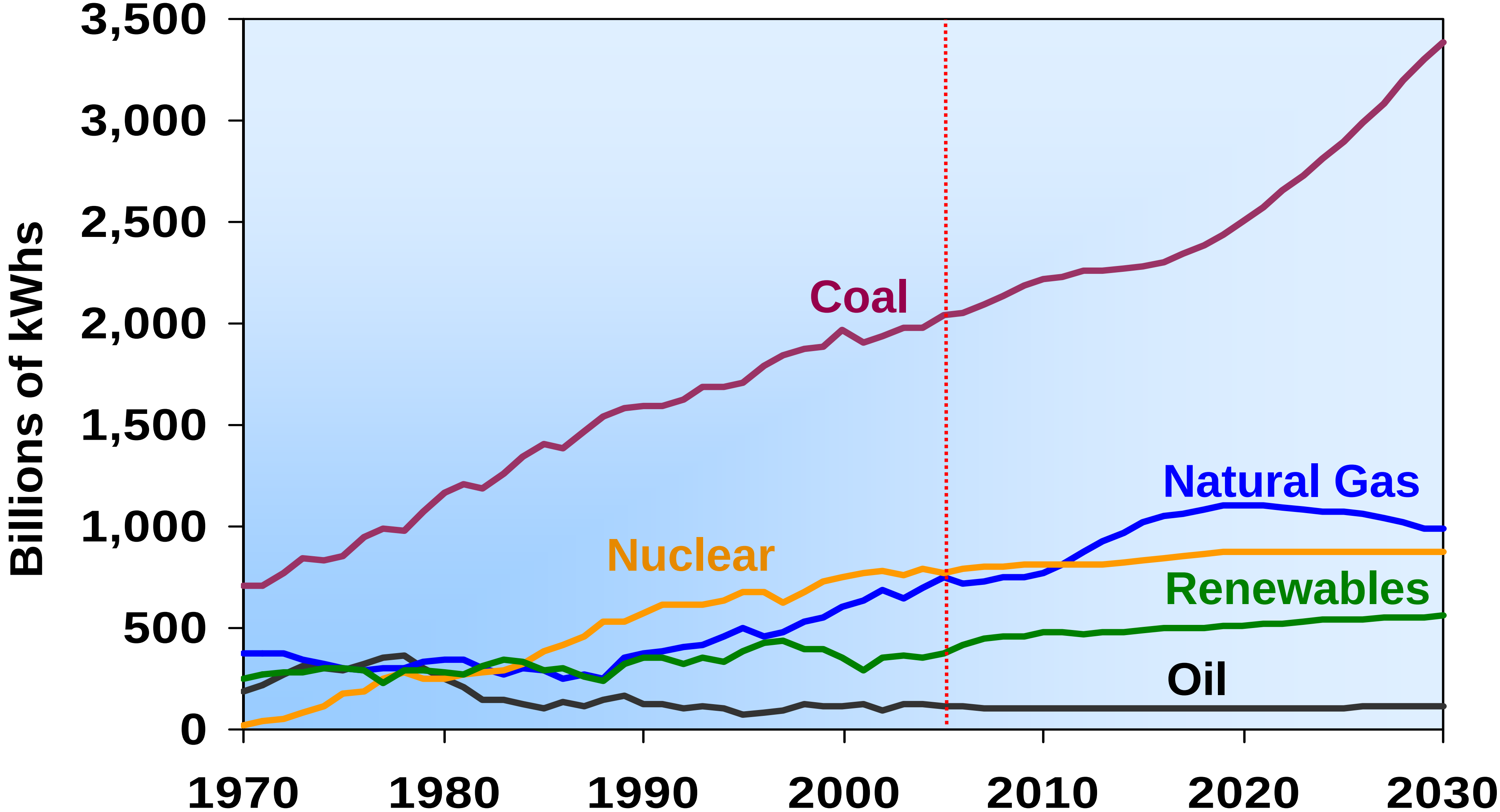
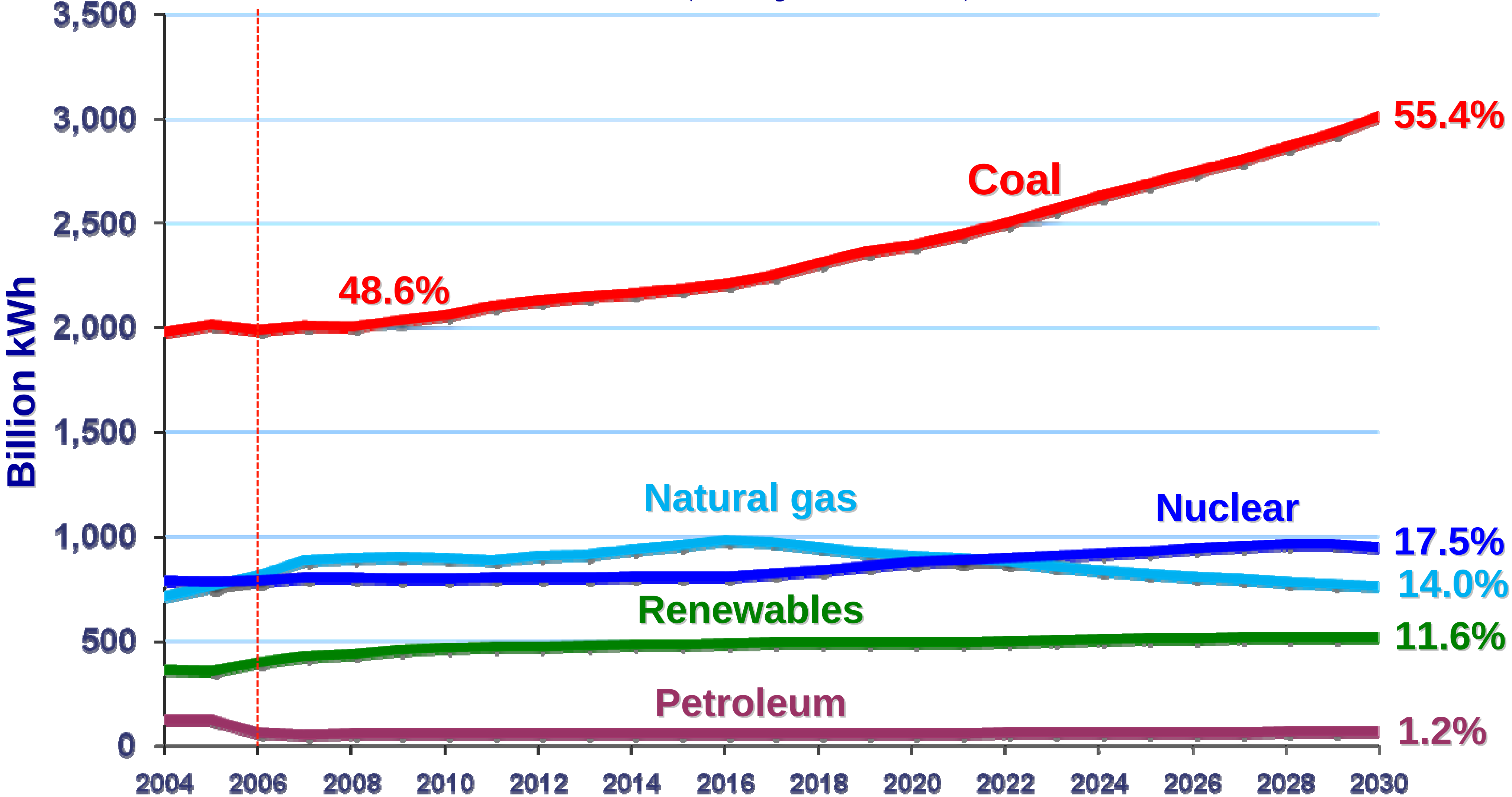
Electric Energy Demand Forecast for 2030



Annual Energy Outlook 2006

Domestic Electricity Generation Forecast

AEO'08 (early release)



Significant growth in share of electricity generated by coal

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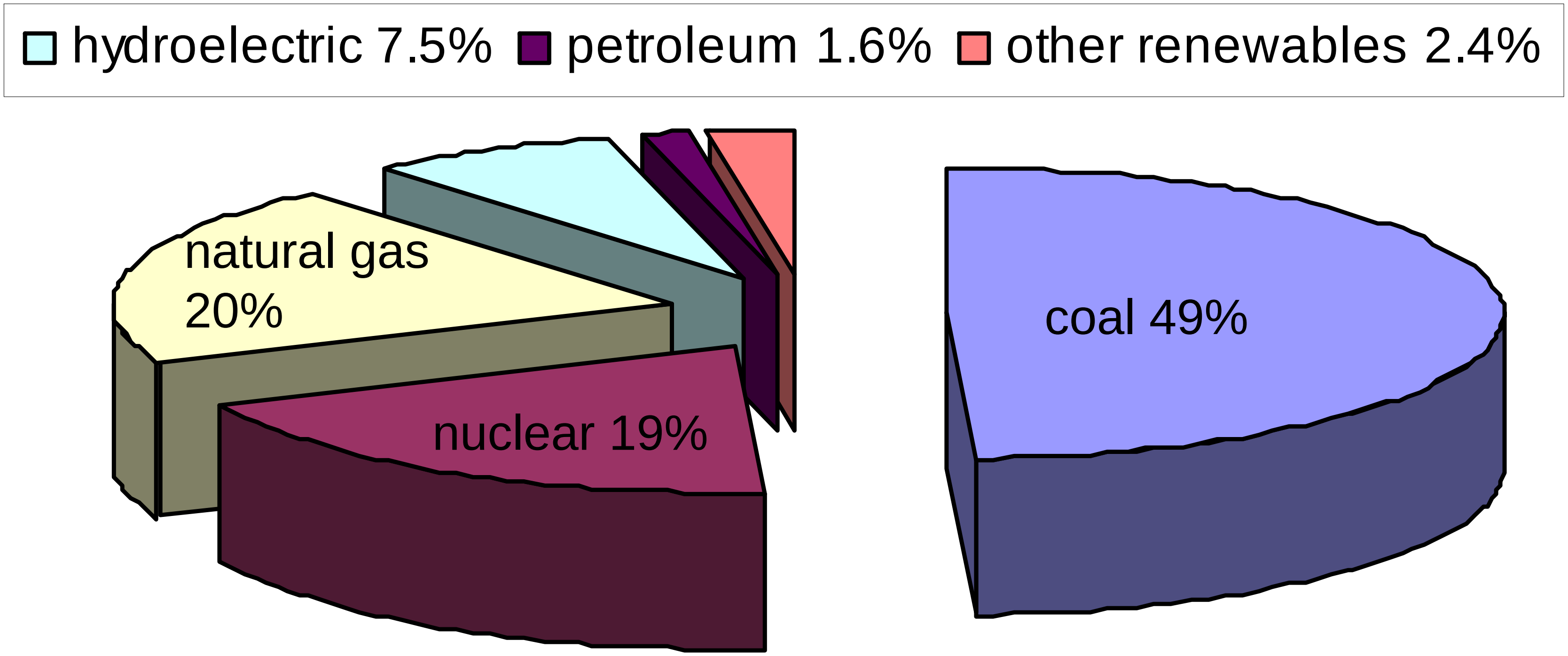
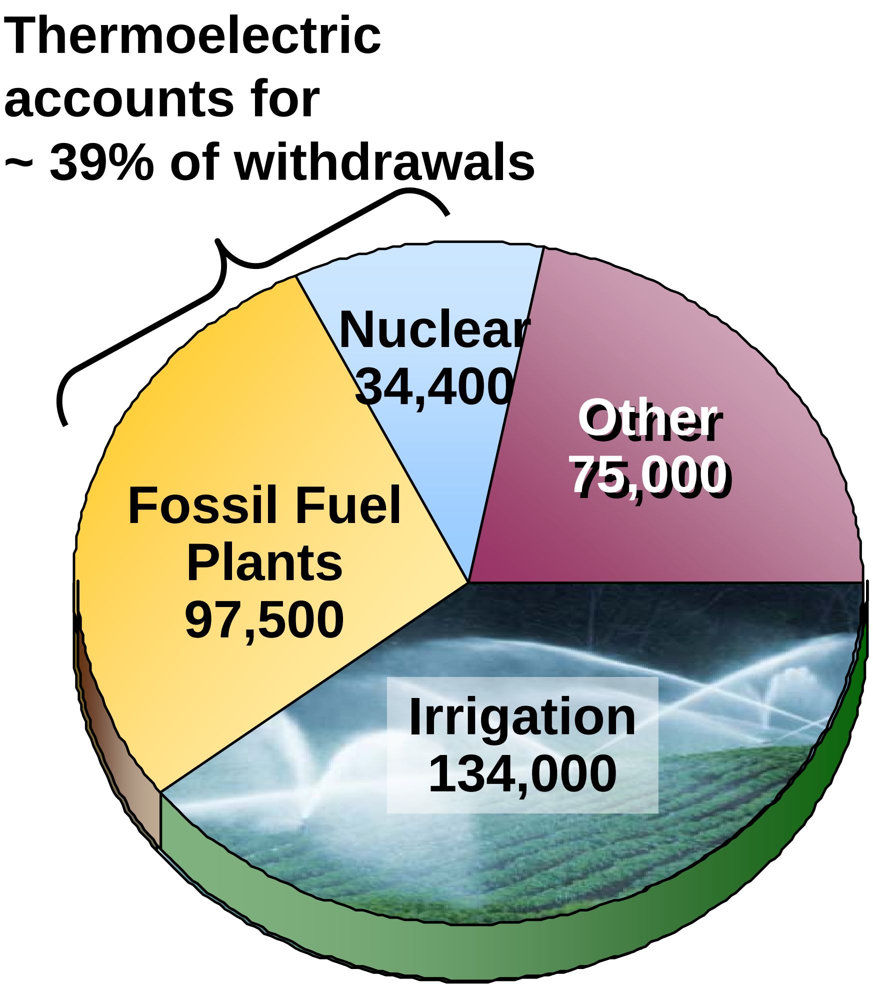
Annual Energy Outlook 2008 early release, December 11, 2007

Electical Generation in US 2006

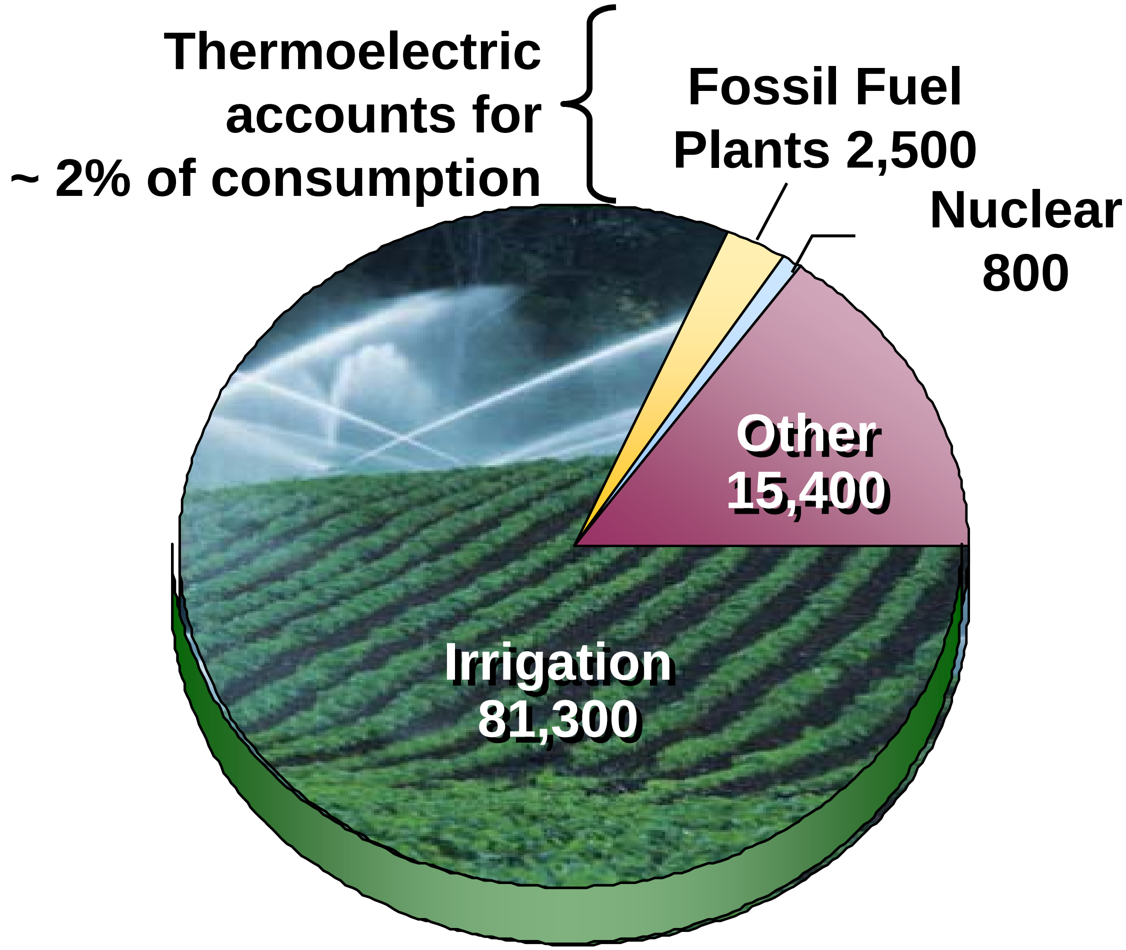


Freshwater Withdrawals and Consumption

Mgal/Day



Withdrawals

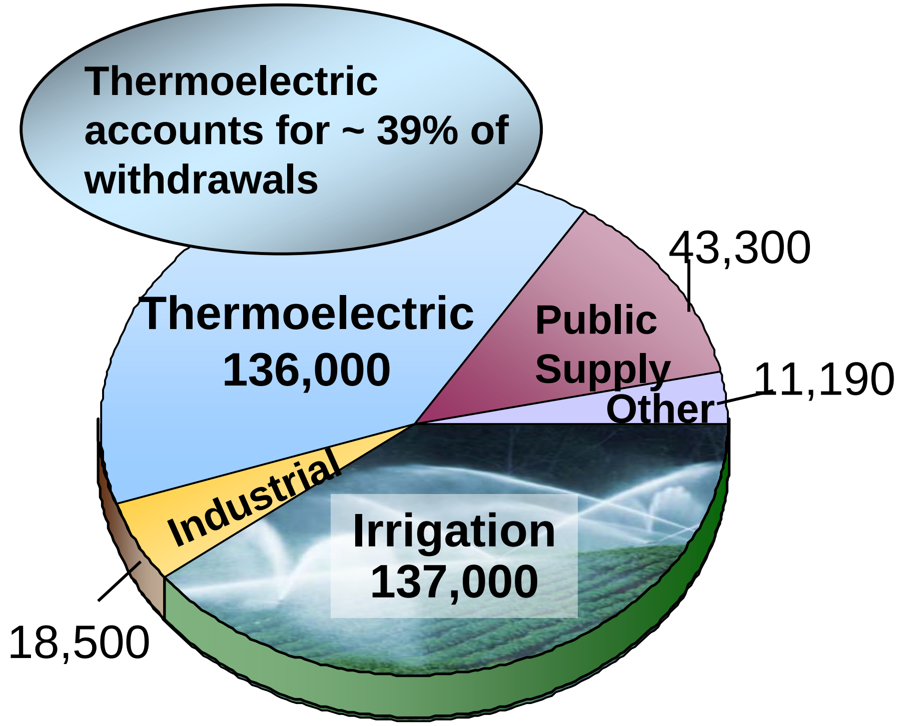


Consumption

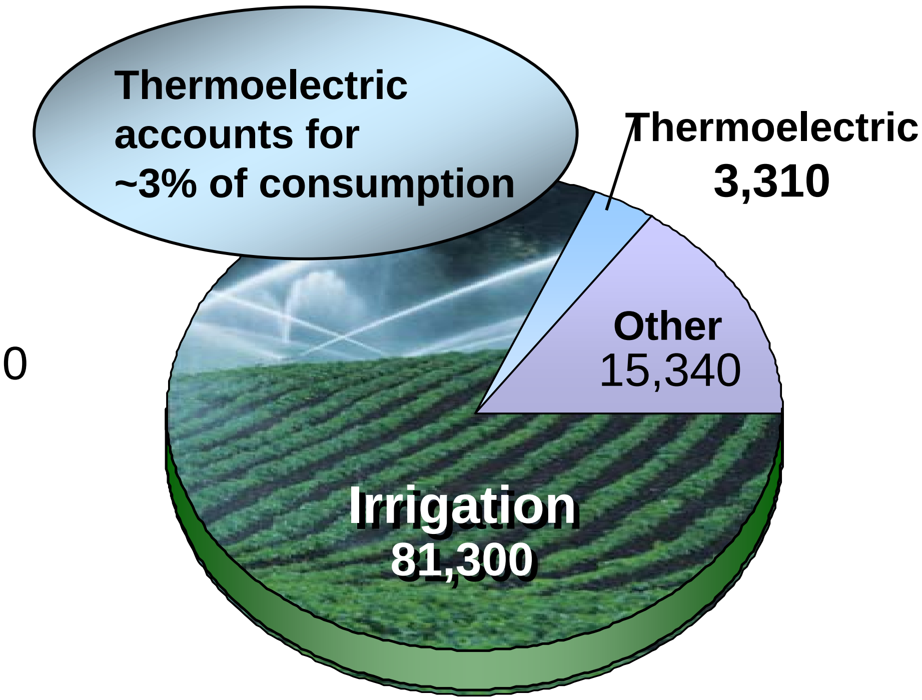
Source: "Estimated Use of Water in the United States in 1995," USGS Circular 1200, 1998

Freshwater Withdrawals and Consumption

Mgal / Day



Withdrawal



Consumption

Water is essential in generation of thermoelectric power!

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

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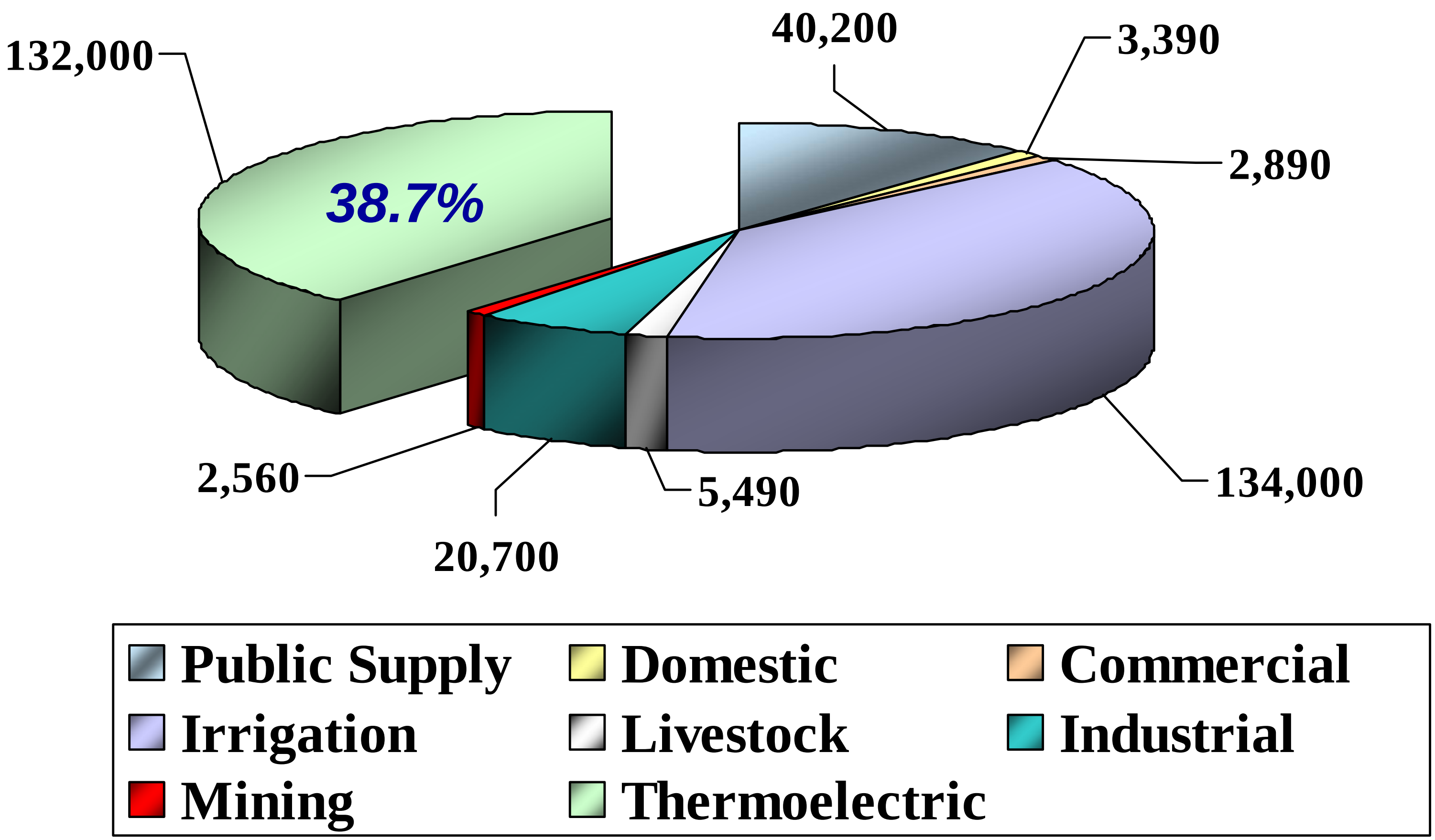
U.S. Fresh Water Withdrawals (MGD)

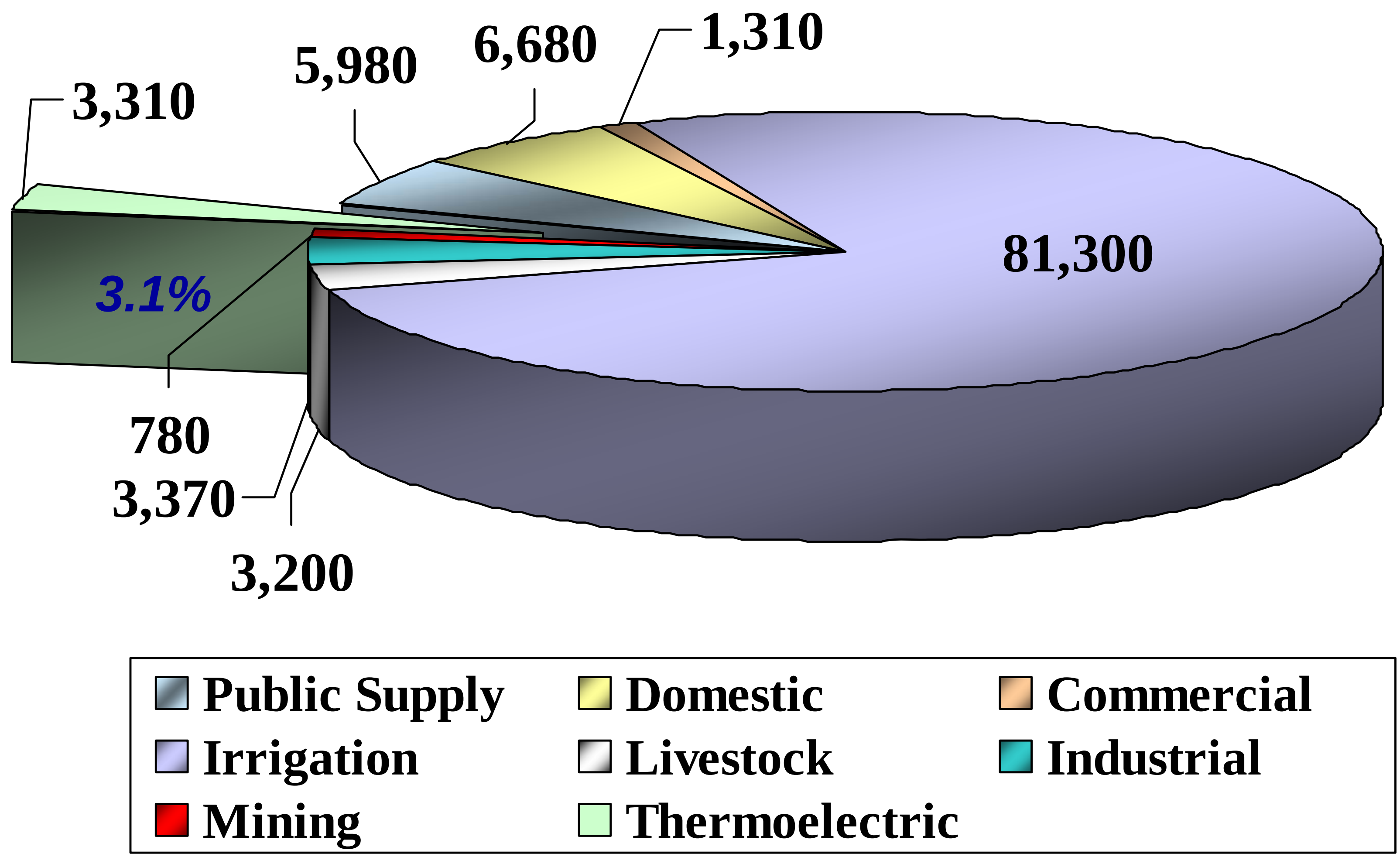
Total Withdrawals: 341,000 MGD



Source: USGS Circular 1200, Estimated Use of Water in the United States in 1995

U.S. Fresh Water Consumption (MGD)

Total Consumption: 105,930 MGD



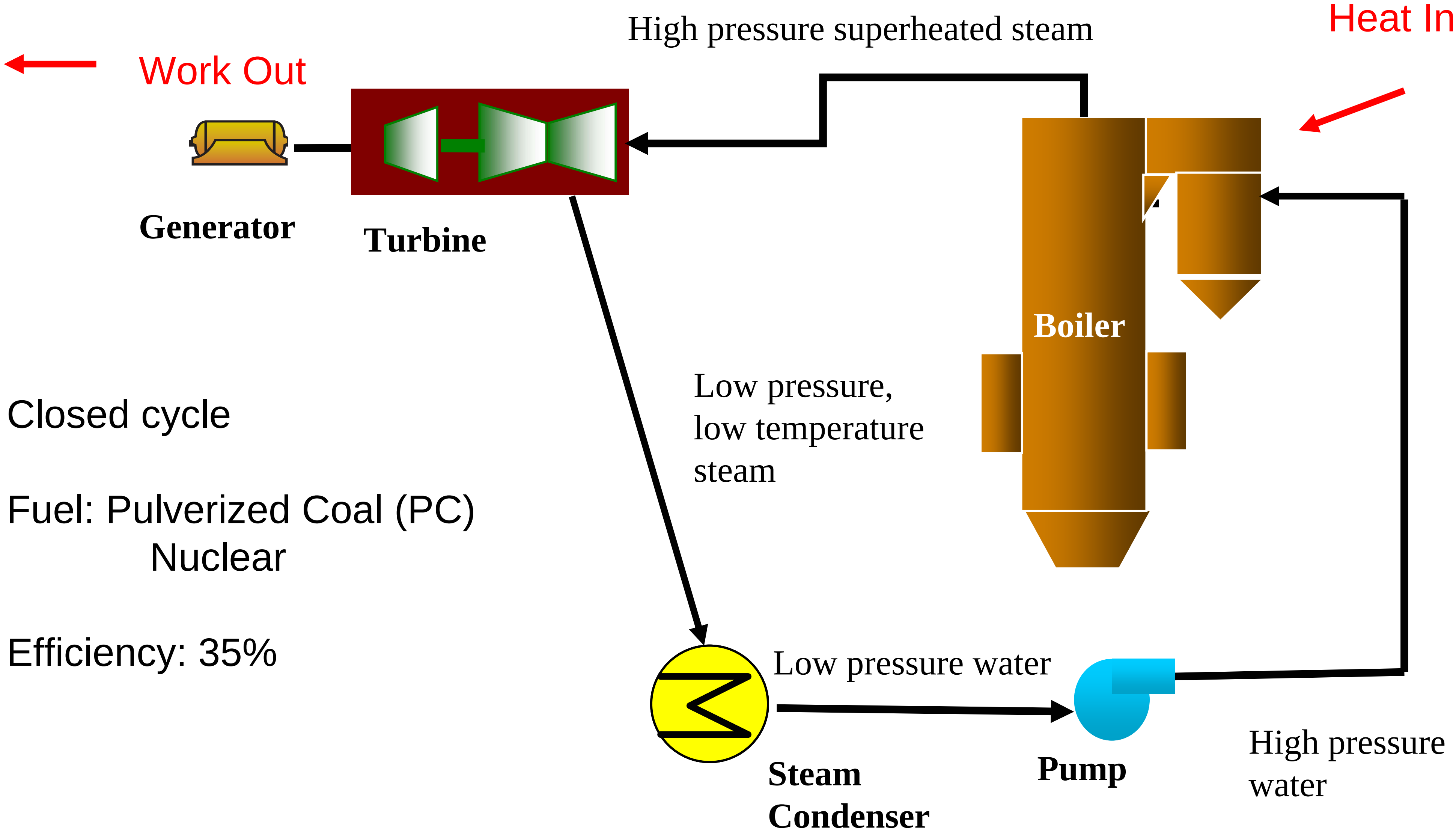
Source: USGS Circular 1200, Estimated Use of Water in the United States in 1995

The "Big Hitter"
Thermo-electric Power Generation

What *is* Thermo-Electric Power Generation?

- **Converting thermal energy to electrical energy**
- **Convert heat to mechanical energy**
- **By using hot fluid to SPIN a TURBINE**
- **Turbine spins a generator-makes electricity**
- **Chemical-to-Mechanical-to-Electrical energy**

Rankine (Steam) Cycle

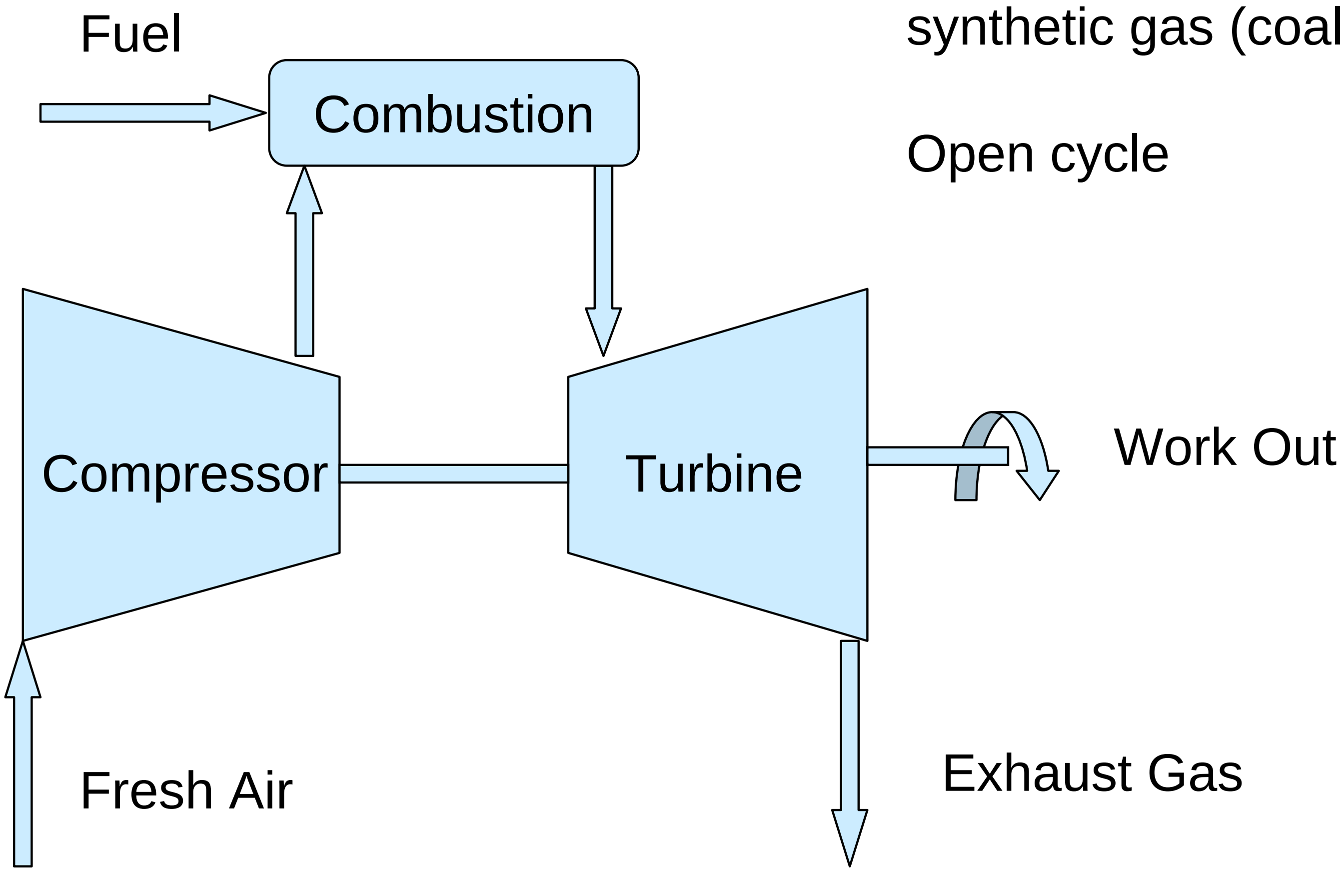


Closed cycle

Fuel: Pulverized Coal (PC)
Nuclear

Efficiency: 35%

Brayton (Joule) Cycle-Gas Turbine



Fuel: natural gas or
synthetic gas (coal gasification)

Open cycle

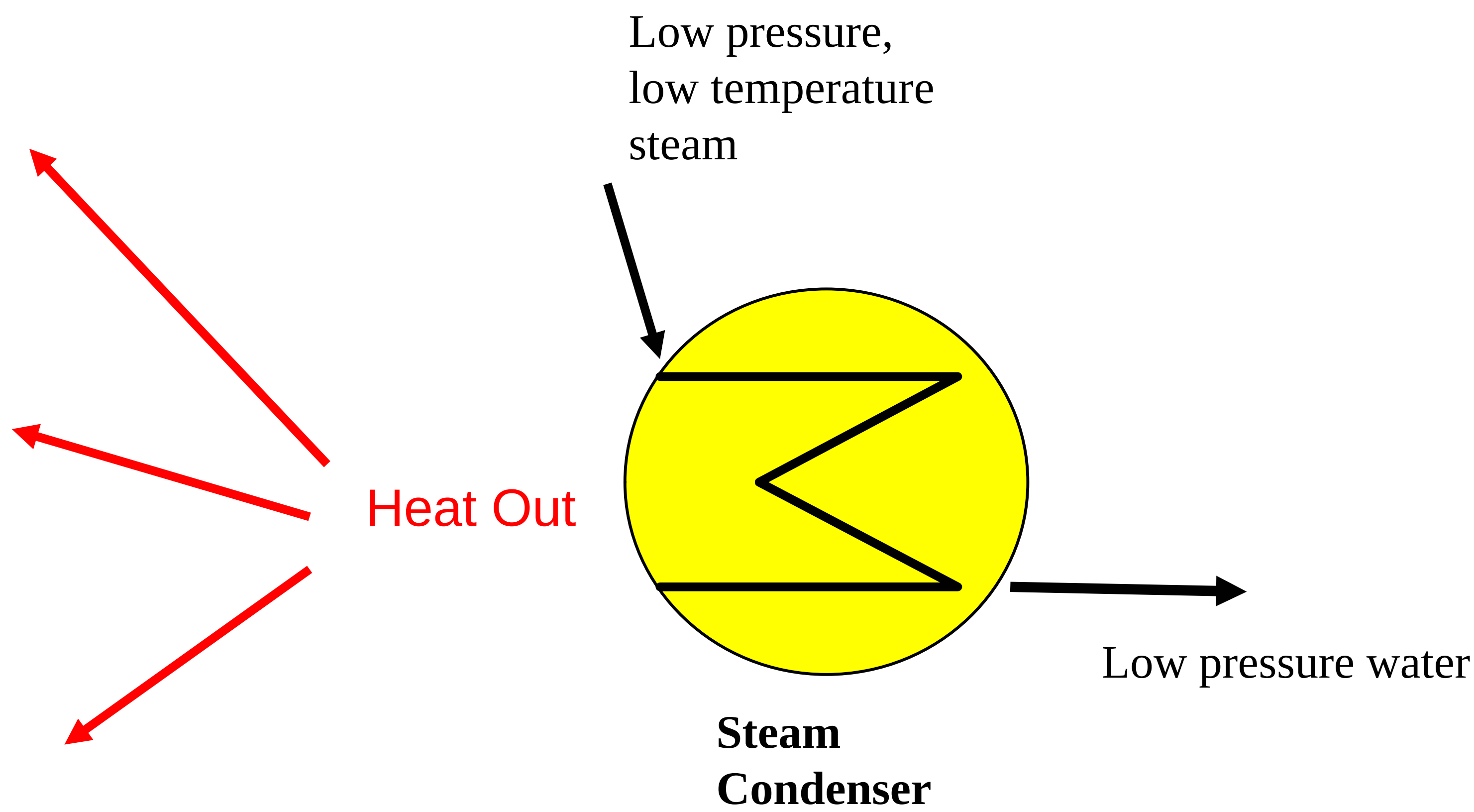
To Steam Cycle for Combined Cycle (59% efficient)

Water usually gets rid of Waste Heat

Once-through
High use,
low consumption

Recirculating
Natural draft or
Forced air (fan)
Lower use,
high consumption

Dry cooling
High capital cost,
high backpressure
(energy penalty)



Power Plant Water Usage, 500 MW

		gal/kWh	gal/min	gal/hour	MGD
Once Through	PC	38	317,000	19,000,000	456
Wet Cooling Tower	PC	1.1	9,200	550,000	13
	IGCC	0.8	6,700	400,000	10
	NGCC	0.5	4,100	250,000	6

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Once-through Cooling

- Traditional approach, locate power plant on a river or bay/ocean
- Inexpensive
- Low parasitic power
- Good efficiency on power generation

- No longer any sites left
- Sometimes loose permit and have to retrofit to cooling tower

Cooling Water Intake Structures
Clean Water Act 316(b)

- ….. the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact.

- Entrainment, Impingement

- Consent Decree, October 1995

Adverse Environmental Impacts

- **Steam Electric Plants (NPDES permits)**
  - 3-4 billion larvae/post larvae per year
  - 23 tons fish/shellfish per year
  - 1 million fish/ 3 week study
- **Hudson River Study**
  - 6 species, 4-79% reduction
- **Cape Fear Estuarine System Modeling**
  - 6 species, 4-79% reduction
- **Brayton Point (Mt Hope Bay, RI)**
  - Unit 4 closed cycle to once-through in 1985, 45% more flow, finfish decline 87%, 4.9 billion tautog eggs, 0.86 billion windowpane eggs, 0.89 billion winter flounder larvae
- **San Onofre Nuclear Generating Station (S. Calif.)**
    - 350,000 juvenile white croaker killed
    - 33,000 adults killed
    - 3.5 tons killed

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Cooling Water Intake Structures 316(b) Regulations

- Phase I – New Facilities
- Phase II – Large Existing Electric Generating Plants
- Phase III – Existing Facilities-Small and Non Power Producers

- Reduce impingement mortality by 80-95%
- Reduce entrainment by 60-90 %
- Through-screen velocity of 0.5 feet per second (ft/s) or less

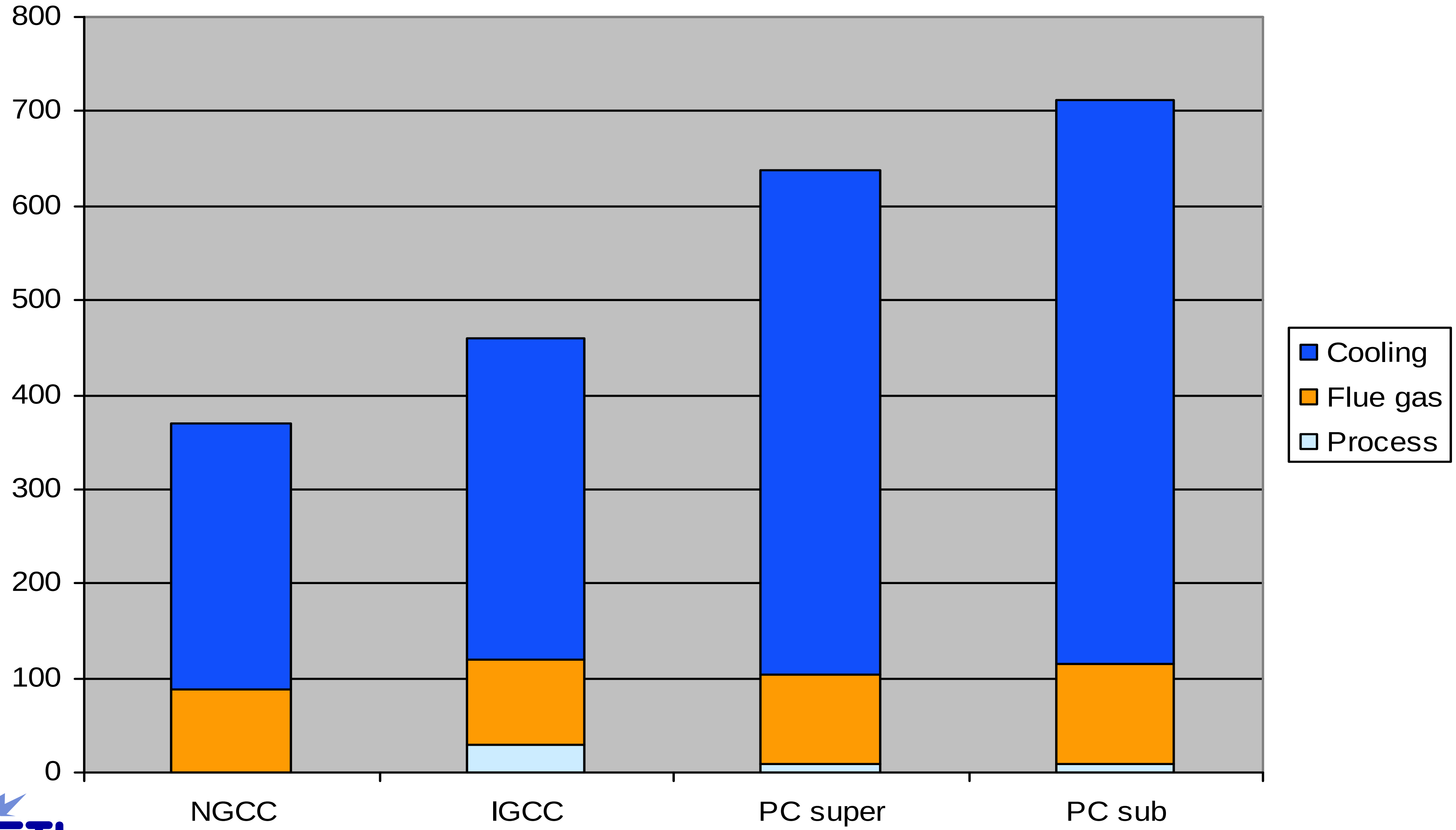
Clean Water Act 316(a)

- Thermal pollution
- Can cause dissolved oxygen problems
- Tampa Bay project—bubble air into outflow
  -expensive and not feasible

Recirculating Cooling Towers

- Take warm water from the condenser, flow into a tower to evaporate some of the water to cool the rest
- Requires tower and pumps (maybe fan)
- Blowdown returns saltier water back to the river
- Pure water is lost to atmosphere (consumed)

Water Loss (Gal/MWhr)



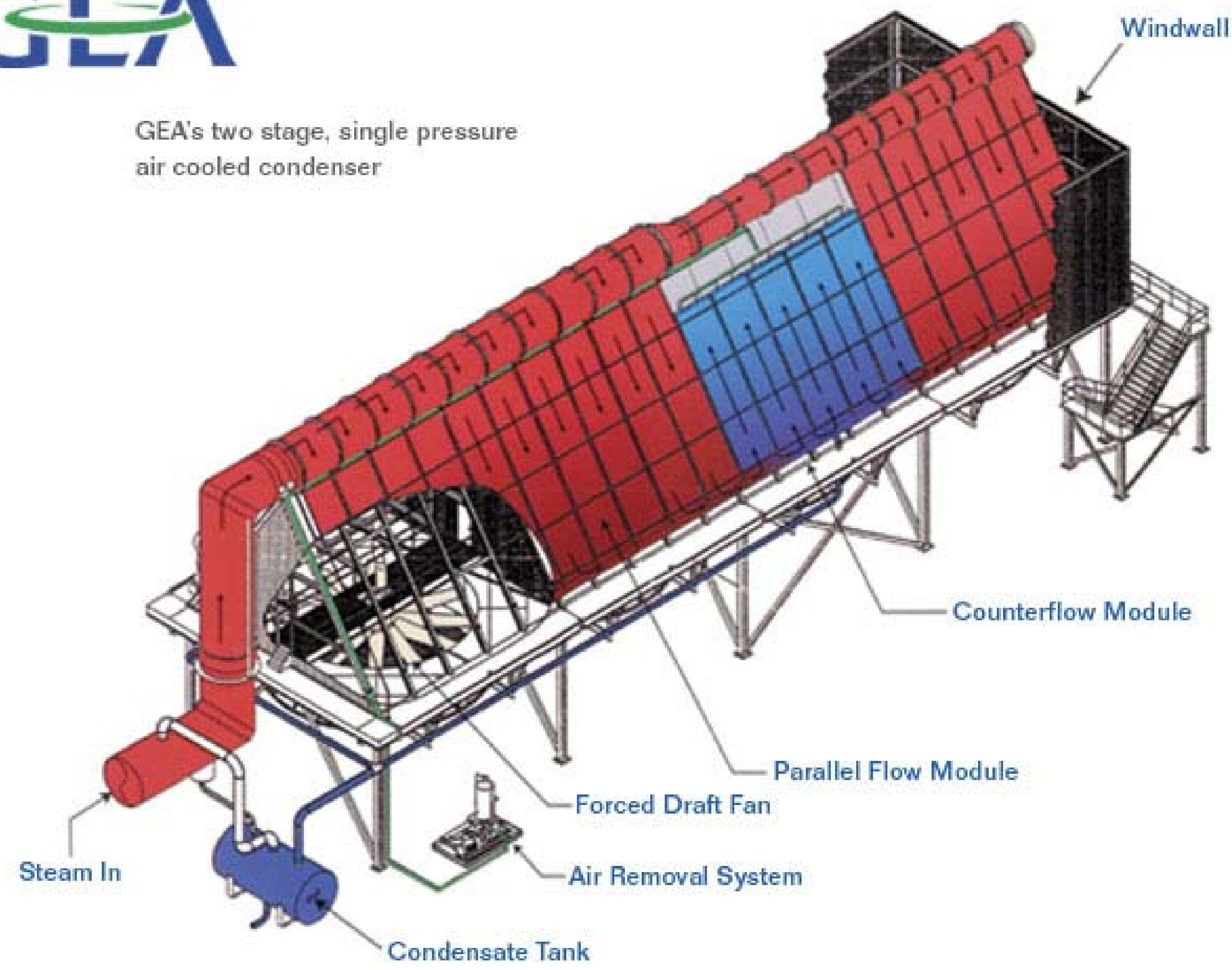
Limerick Nuclear Power Plant

Natural Draft Cooling Tower

Dry Cooling

- **Largest capital expense**
- **Energy penalty on hot days due to higher backpressure on the turbine**
- **Can cool steam directly or use water to cool steam and cool the water without evaporating (indirect dry)**
- **Currently <5% of cooling**

Dry Cooling A-frame—Mechanical Draft



Dry Cooling-Mechanical Draft

FERRERA, Italy — ACC for 2x380 MW, 1x280 MW Combined Cycle Power Plant.

From: SPX Cooling Technologies

Dry Cooling-Natural Draft

The world's largest Natural Draft Dry Cooling System
6 x 690 MW Kendal Power Station, South Africa

From: SPX Cooling Technologies

Dry Cooling Systems Can Have Substantial Cost and Performance Penalties

	E-Gas	Shell	GE	Subcritical PC	Supercritical PC
Dry Cooling Tower Capital Cost, $x1000	$32,000 - $56,000	$38,000 - $66,000	$41,000 - $71,000	$59,000 - $103,000	$52,000 - $90,000
Average Capital Cost, $/kW	$87	$100	$101	$168	$149
Comparison with Wet Cooling Tower					
Percentage Reduction in Total Water Consumption	90%	93%	94%	94%	94%
Average Capital Premium of Dry Cooling, $x1000	$36,000	$44,000	$46,000	$65,000	$55,000
Energy Penalty of Dry Cooling, MW	8 - 24	8 - 26	9 - 29	18 - 59	18 - 60
Average COE Increase, mills/kWh	1.4	1.7	1.7	2.8	2.4

Note: Cost and performance impacts based on nominal 500 MW net output baseline plant with mechanical draft wet cooling towers

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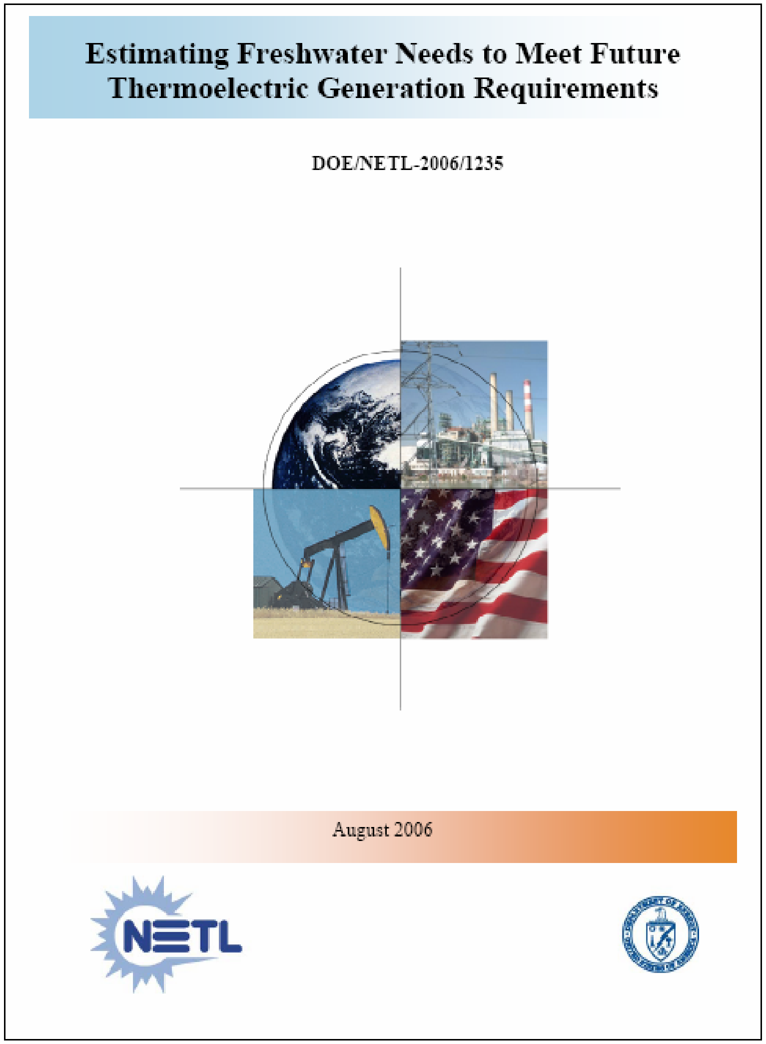
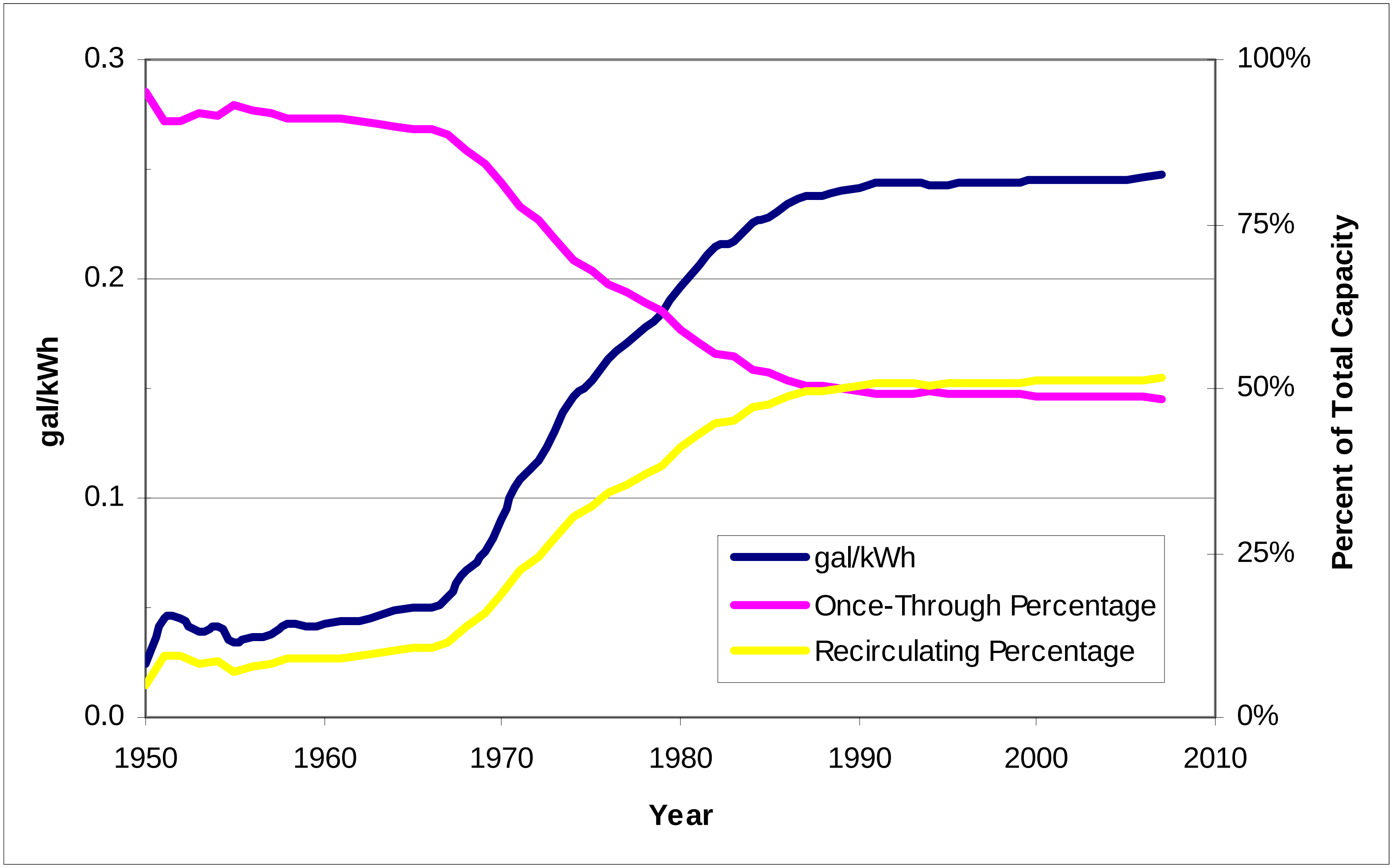
Source: DOE/NETL Calculations

Freshwater Withdrawal and Consumption Projected Through 2030



http://www.netl.doe.gov/technologies/coalpower/ewr/pubs/WaterNeedsAnalysisPhaseI1006.pdf

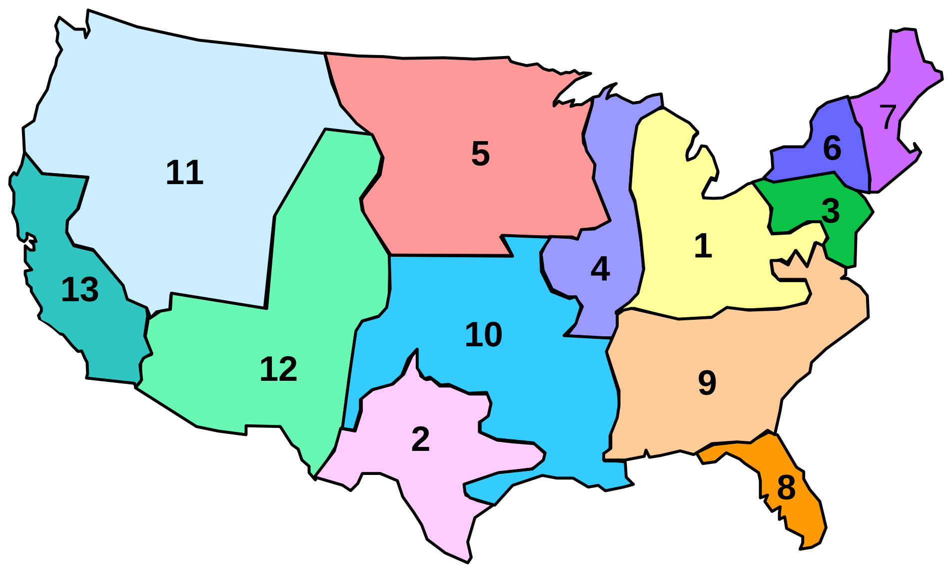
Freshwater Consumption Increases for Coal Fueled Generation



Source: Platts UDI World Electric Power Plants Data Base

Thermoelectric Power Plant Water W&C: NERC Sub-Regions

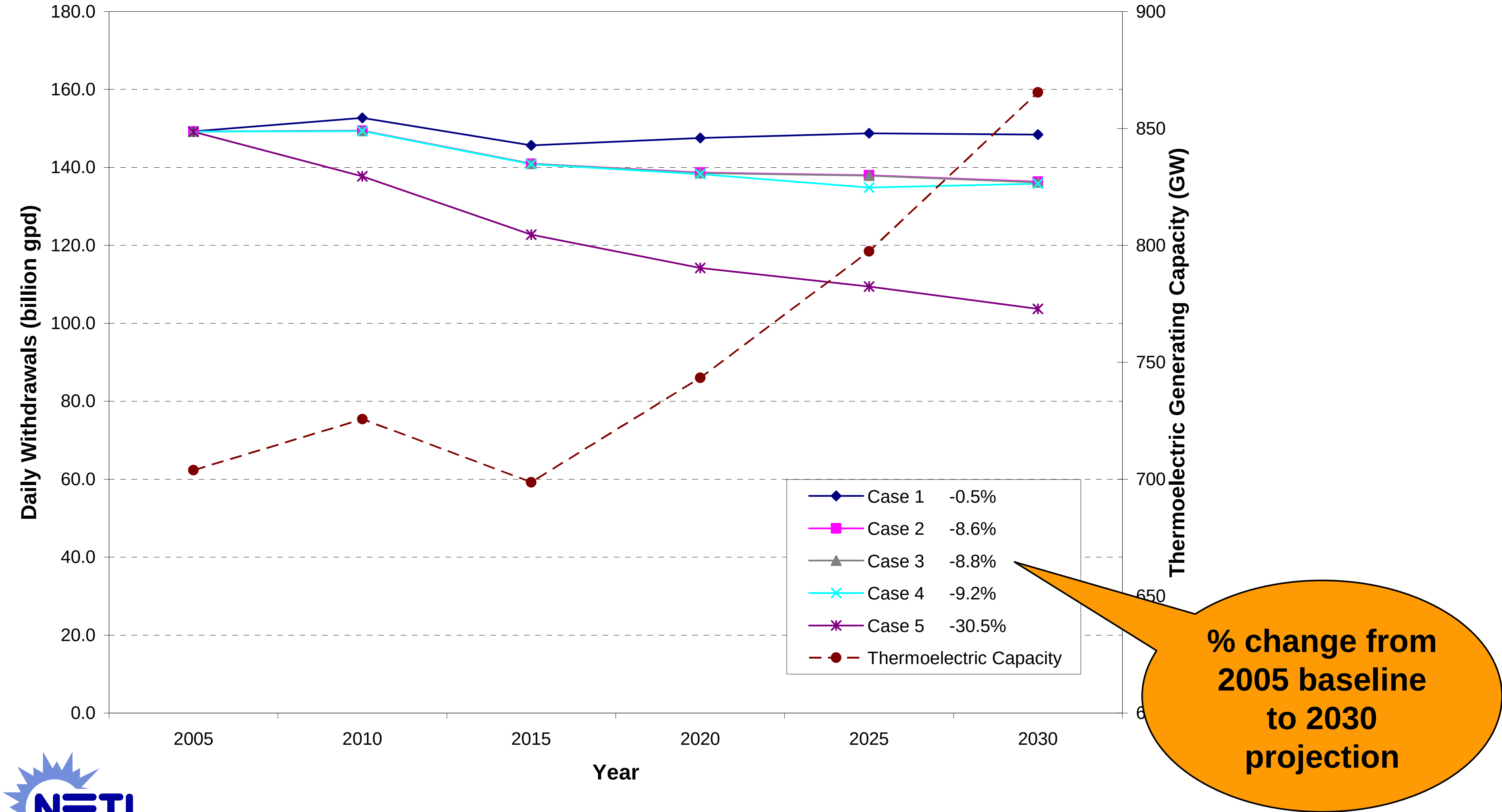
Region Number	Abbreviation	Region
1	ECAR	East Central Area Reliability Coordination Agreement
2	ERCOT	Electric Reliability Council of Texas
3	MAAC	Mid-Atlantic Area Council
4	MAIN	Mid-America Interconnected Network
5	MAPP	Mid-Continent Area Power Pool
6	NPCC/NY	Northeast Power Coordinating Council / New York
7	NPCC/NE	Northeast Power Coordinating Council / New England
8	FRCC	Florida Reliability Coordinating Council
9	SERC	Southeastern Electric Reliability Council
10	SPP	Southwest Power Pool
11	WECC / NWCC	Western Electricity Coordinating Council/Northwest Power Pool
12	WECC/RM	Western Electricity Coordinating Council / Rocky Mountains, AZ, NM, southern NV
13	WECC/CA	Western Electricity Coordinating Council / California



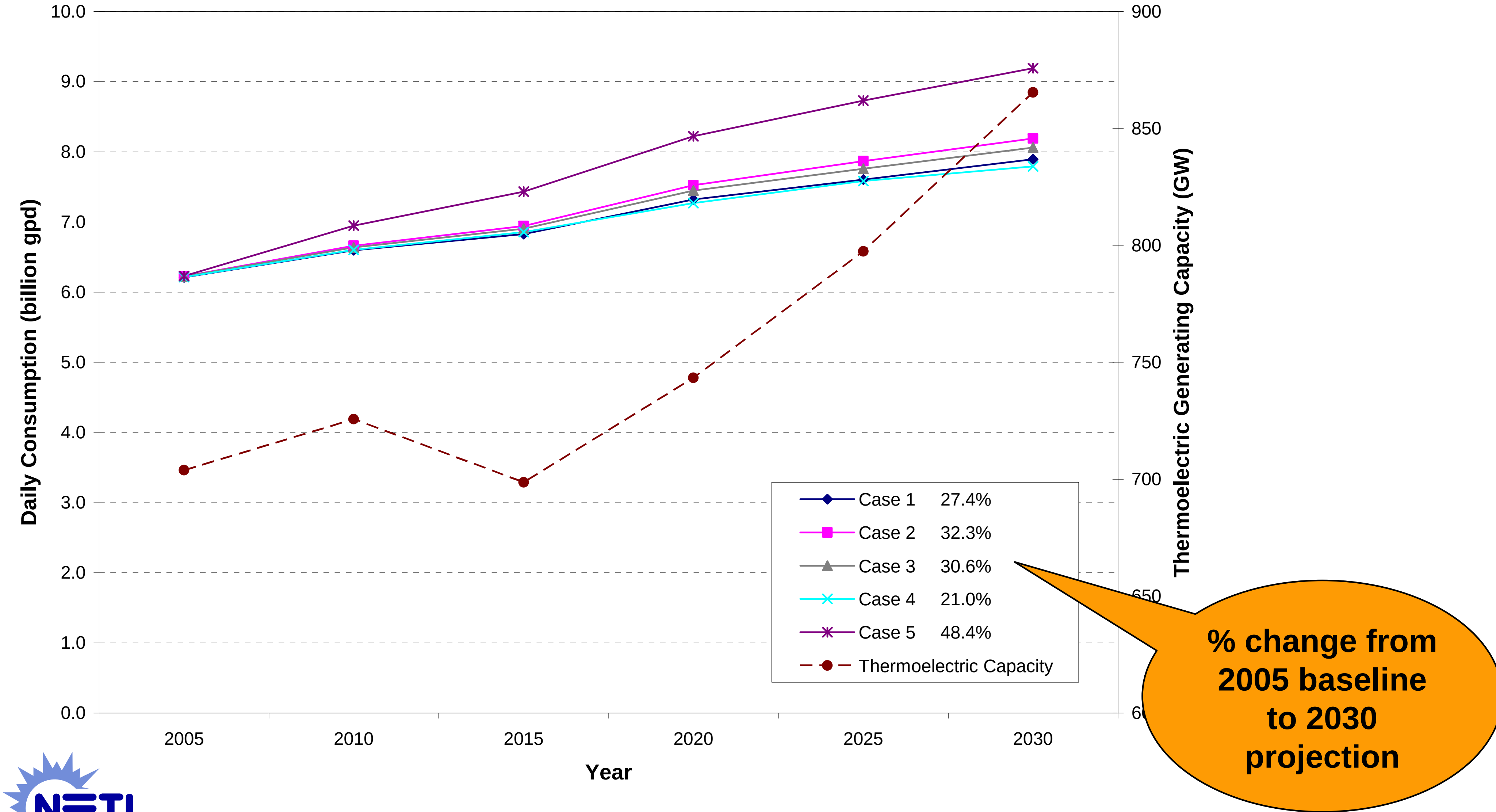
Water Needs Analysis

- Case 1 – Additions and retirements proportional to current use.
- Case 2 – All additions use wet recirculating cooling.
- Case 3 – 90% of additions use wet recirculating cooling, 10% of additions use saline water and once-through cooling.
- Case 4 – 25% of additions use dry cooling, 75% of additions use wet recirculating cooling.
- Case 5 – Additions use wet recirculating cooling, 5% of existing freshwater once-through cooling capacity is retrofitted with wet recirculating cooling every five years starting in 2010.

Average National Freshwater Withdrawal for Thermoelectric Power Generation



Average National Freshwater Consumption for Thermoelectric Power Generation



Regional Results Overview

- **EIA thermoelectric capacity increase projections:**

  704 GW (2005) → 872 GW (2030)   +168 GW

  (coal) 309 GW (2005) → 457 GW (2030) +148 GW

  - 24% nationally
  - 66% western US
  - 61% southeast US
- **Case 2 withdrawal projections:**
  - 8.6% decrease nationally
  - 30% decline in Texas
  - 25% increase in Florida
- **Case 2 consumption projections:**
  - 32.3% increase nationally
  - 12.0 % increase in SPP
  - 352% increase in California

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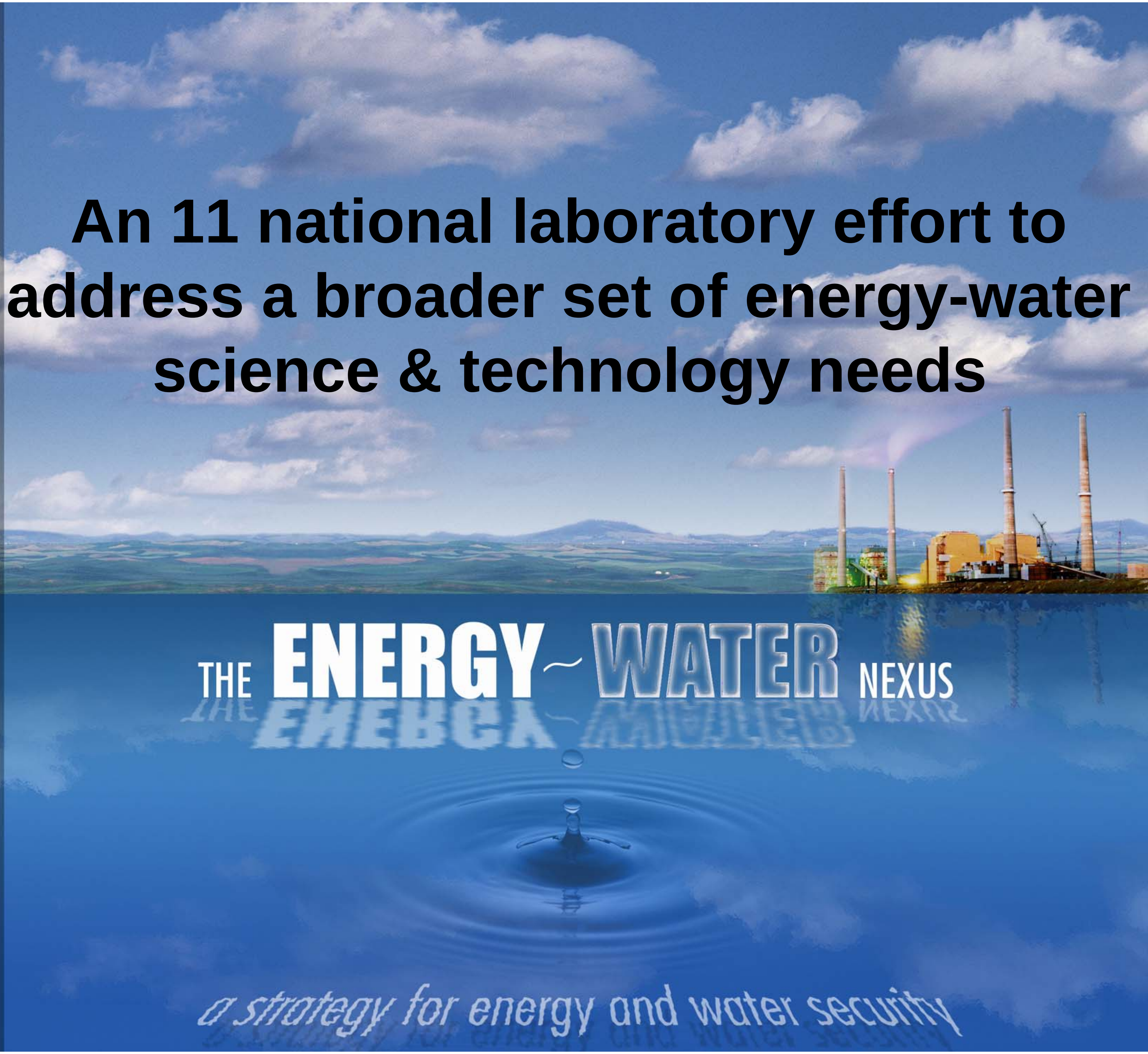
An 11 national laboratory effort to address a broader set of energy-water science & technology needs



Argonne National Laboratory
Berkeley Lab
Brookhaven National Laboratory
INEEL
Los Alamos National Laboratory
NETL National Energy Technology Laboratory
NREL
ORNL Oak Ridge National Laboratory
Pacific Northwest National Laboratory
Sandia National Laboratories

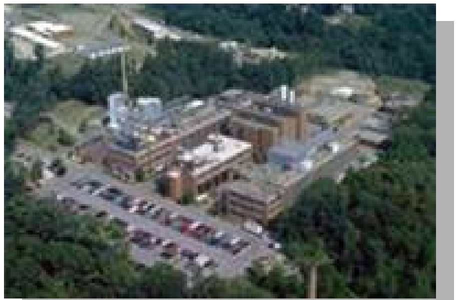
National Energy Technology Laboratory

- **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

DOE/NETL Water-Energy R&D Activities

Power Generation

- Alternative "non-traditional" water sources
- Advanced cooling/treatment technology
- Regulatory analysis and assessment

Watershed Science & Technology

- Remote sensing
- AMD treatment and remediation
- TMDL trading
- Water quality sampling and analysis

Water Supply & Demand Issues

Oil & Gas Exploration

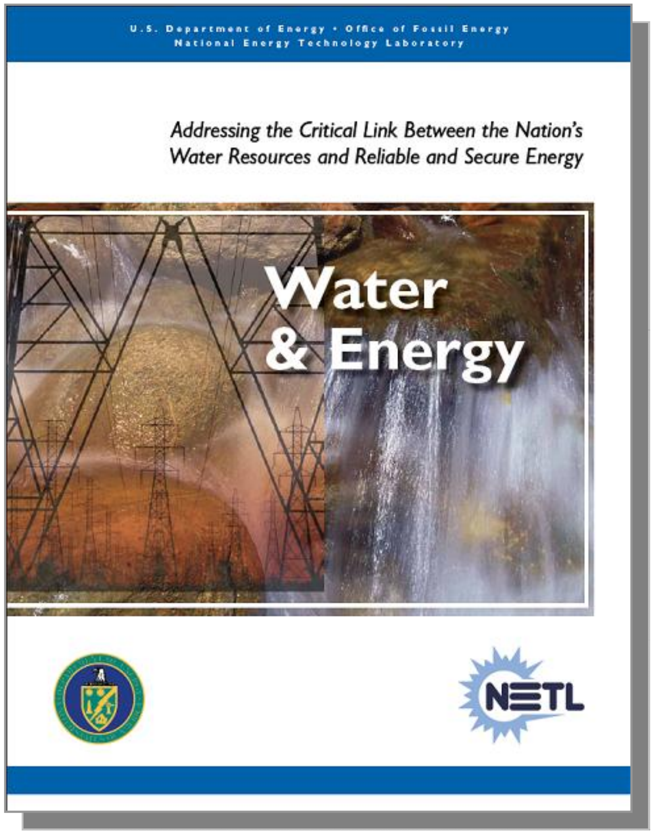
- Water management technology
- Coal bed methane and produced water
- Regulatory analysis and assessment

Carbon Sequestration

- Terrestrial sequestration/ eco-assets
- Geological sequestration

NETL Energy/Water Activities

- **Fossil Fuel Based Thermoelectric Power**
  - Non-Traditional Sources of Process and Cooling Water
  - Innovative Water Reuse and Recovery
  - Advanced Cooling Technologies
  - Advanced Water Treatment and Detection Technology
  - Advanced Power Systems
- **Coal Mining**
  - Airborne Geophysical Mapping
  - Mine Pool Treatment and Beneficial Use
- **Natural Gas and Oil Production**
  - Water Management Approaches and Analyses
  - Produced Water Management Technologies and Beneficial Use

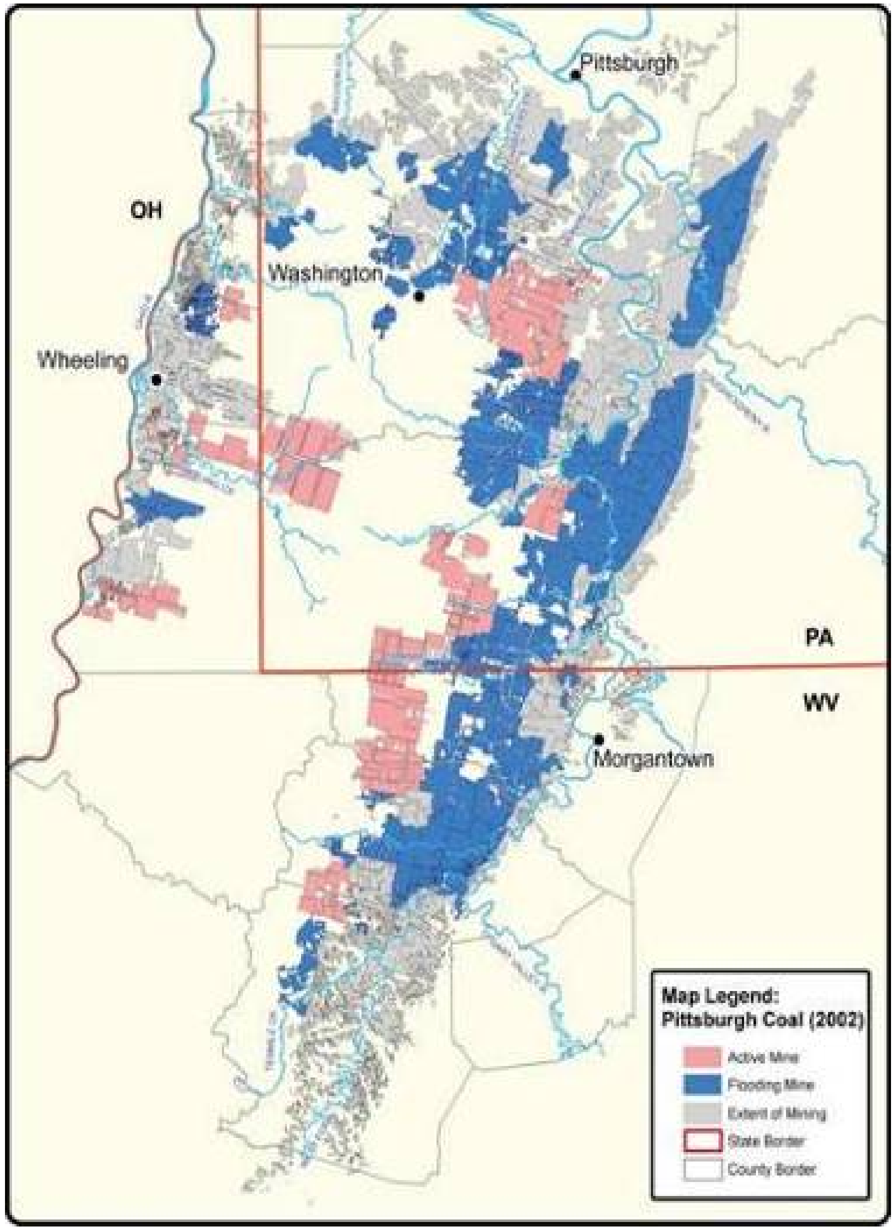


Innovations for Existing Plants

- **Alternative Water Sources**
  - Treated municipal wastewater
  - Mine pool water
  - Produced water
- **Power Plant Water Savings**

Reclaimed Water Use-Panda-Brandywine Power Plant

Alternative Sources of Cooling Water Mine Pools



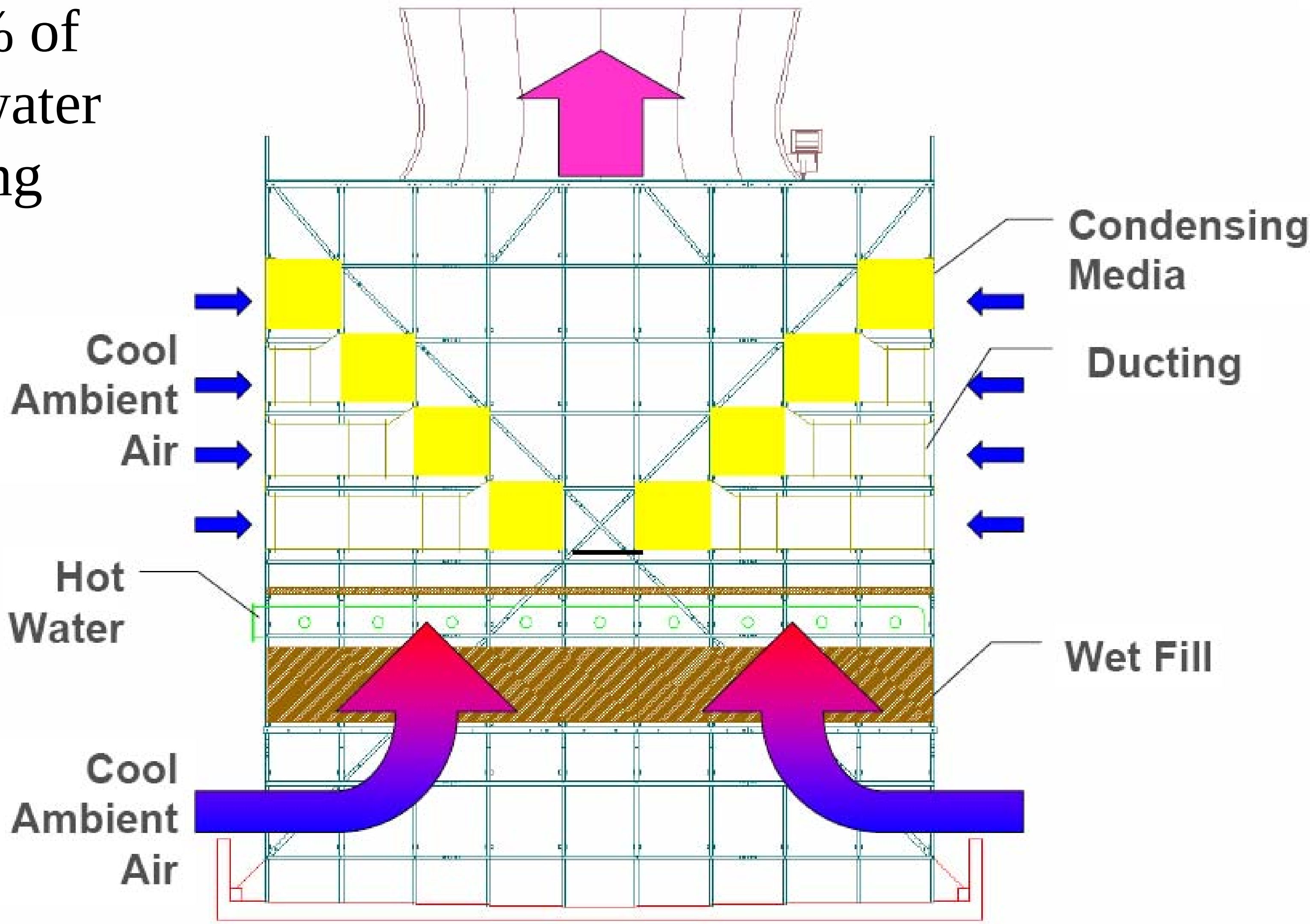
Power Plants in Anthracite Region Using Mine Pool Water

Company Name	Plant Location	Generating Capacity (MW)	Cooling Water Source
Gilberton Power Co.	Frackville, PA	80	Unnamed mine pool
Northeastern Power Co.	McAdoo, PA	50	Siverbrook Mine
Panther Creek Generating Station	Nesquehoning, PA	83	Lausanne Mine
Schuykill Energy Resources	Shenandoah, PA	80	Maple Hill Mine
WPS – Westwood Generation	Tremont, PA	31	Lyken Mine
Wheelabrator Frackville Energy Co.	Frackville, PA	42	Morea Mine

Source: Draft DOE/NETL Report, “ Use of Mine Pool Water for Power Plant Cooling,” August 2003

Air2Air™ Condensing Technology
SPX Cooling Technologies

Recover 20% of evaporated water from a cooling tower.



San Juan Generation Station
Demolishing the Old

Constructing the New

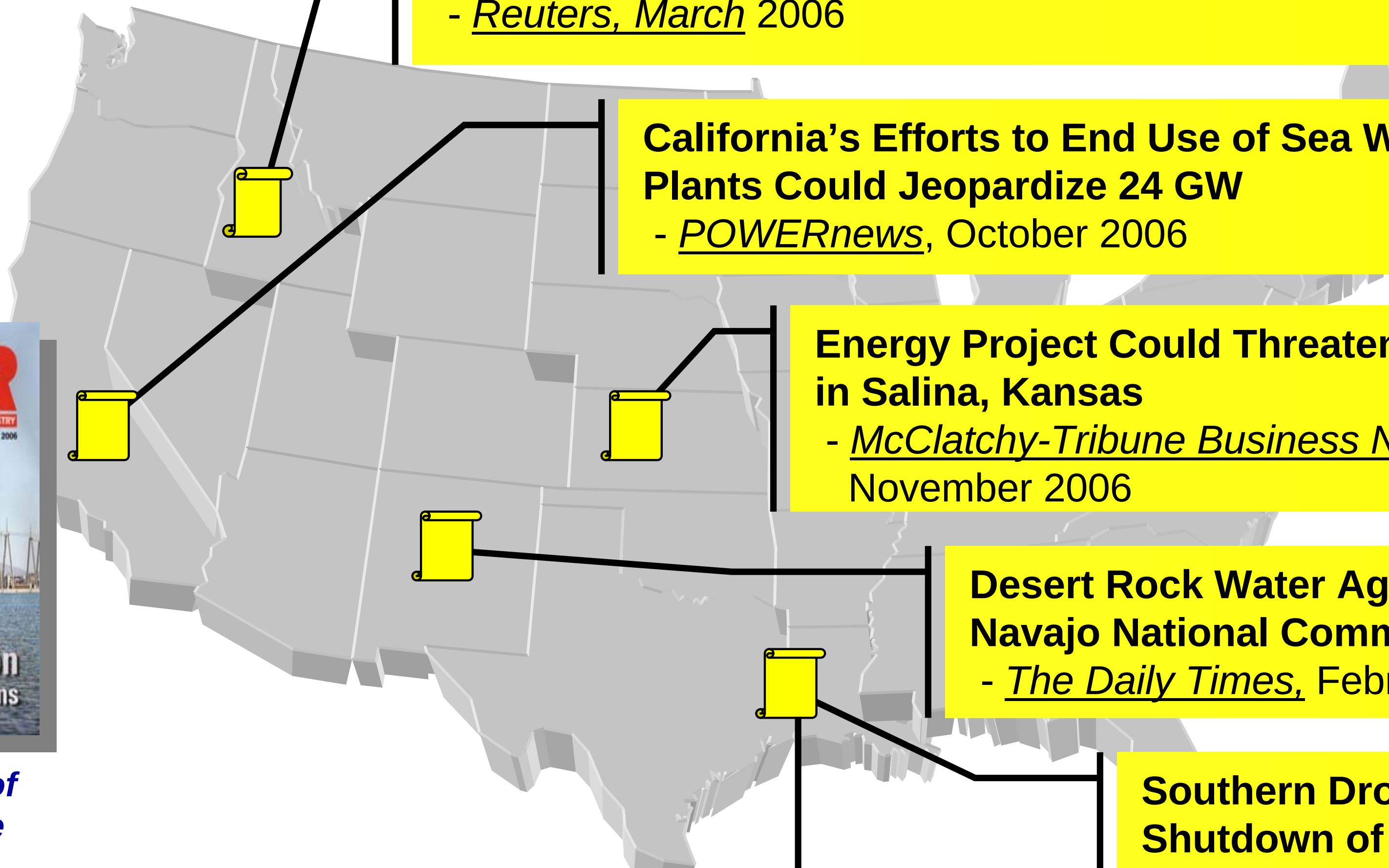
Ready for Testing in 2008

Air2Air™

Future Concerns

- Keeping up with demand
- Drought—Energy Security
- Climate change—Carbon Capture

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



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

TVA reactor shut down; cooling water from river too hot
- Athens, Alabama, Aug. 16, 2007

May 2006 Issue of Power Magazine

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Electricity Versus Water
Sempra Energy Example

- Nevada[1]
  - 1,200 MW proposed plant to be downsized or scrapped

"*There's no way Washoe County has the luxury anymore to have a fossil-fuel plant site in the county with the water issues we now have. It's too important for the county's economic health to allow water to be <u>blown up in the air in a cooling tower</u>*." – Nevada Assemblyman Pete Goicoechea

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[1]The Associated Press, Reno, Nevada, March 8, 2006

Drought Could Significantly Impact Missouri River Power Plants

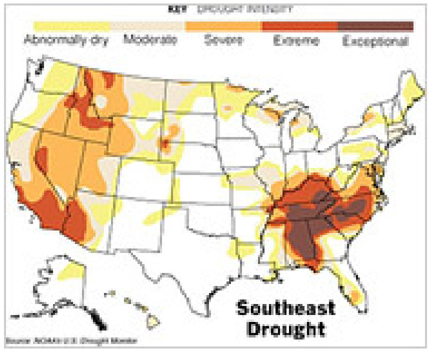
South Dakota Gov. Mike Rounds suggests current drought could be particularly bad for power plants that use Missouri River water for cooling

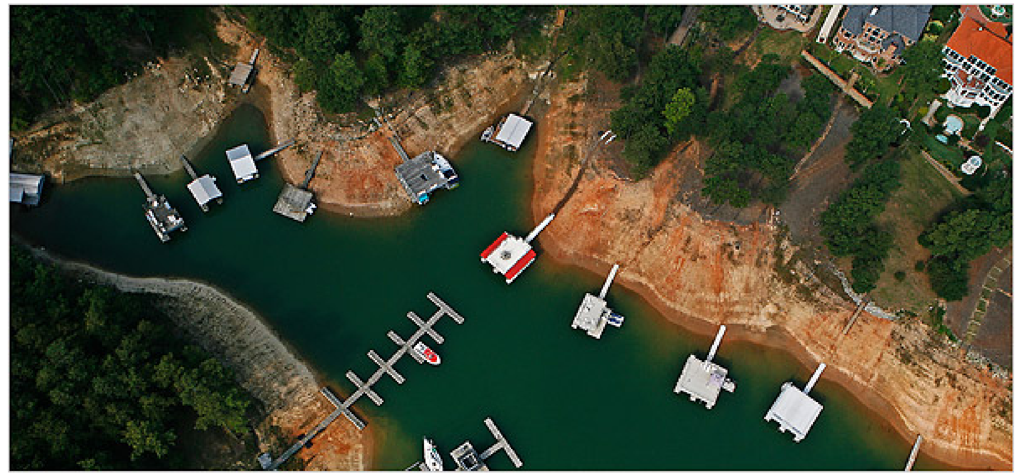
Ref. www.billingsgazette.com

Source: www.maps.platts.com

Drought

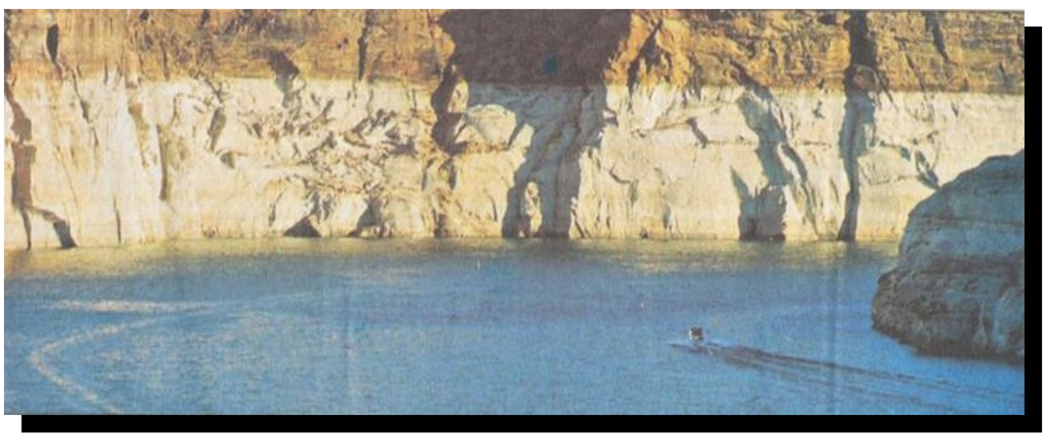
Southeast





Lake Lanier, Atlanta

Southwest



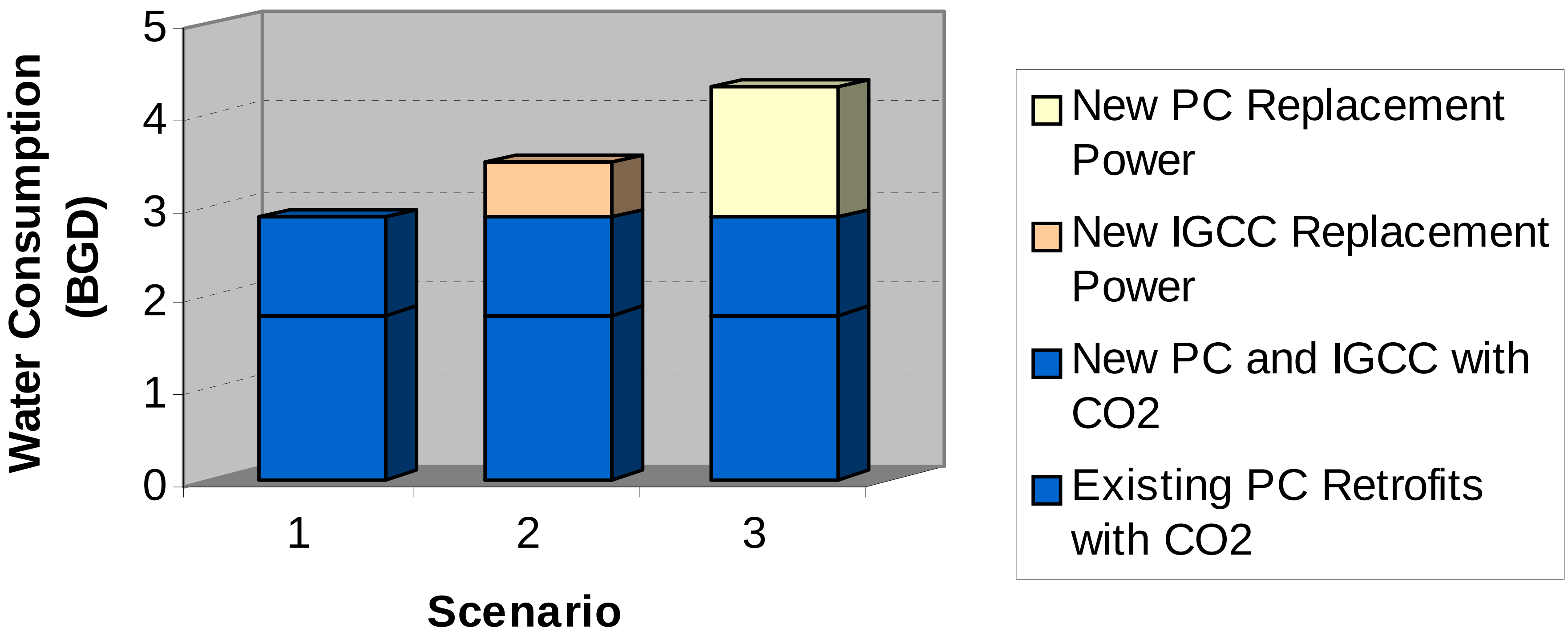
Lake Powell, Utah

Lake Mead, Nevada

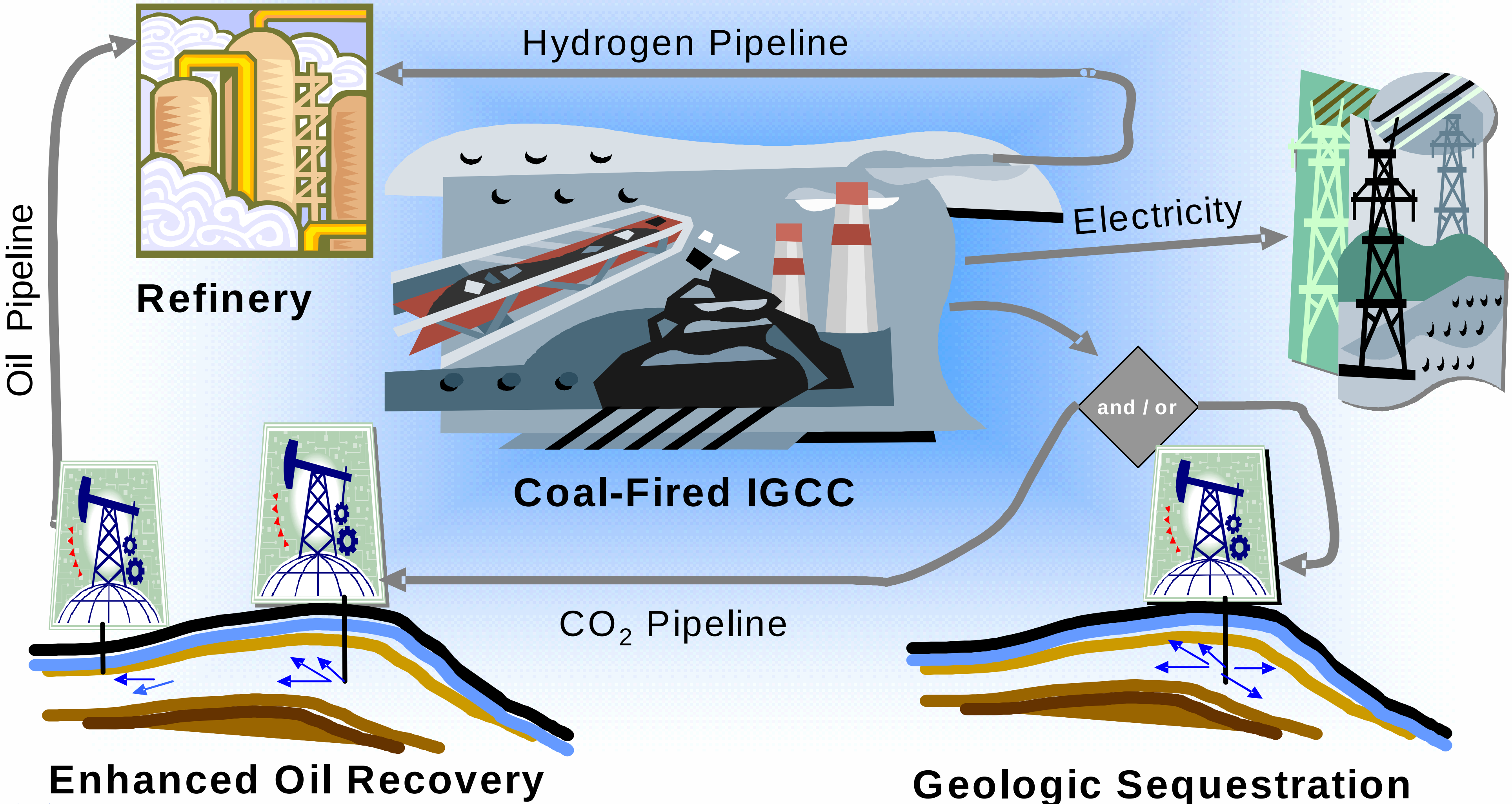
Carbon Capture Water Use Analysis

- **Additional water used for carbon capture technologies**
- **1st order approach**
- **Provides several boundaries or points to make further analysis**

Additional Water Consumption for CO_2 Capture Scenarios



FutureGen Concept



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Nevada Draft Permit-Toquop

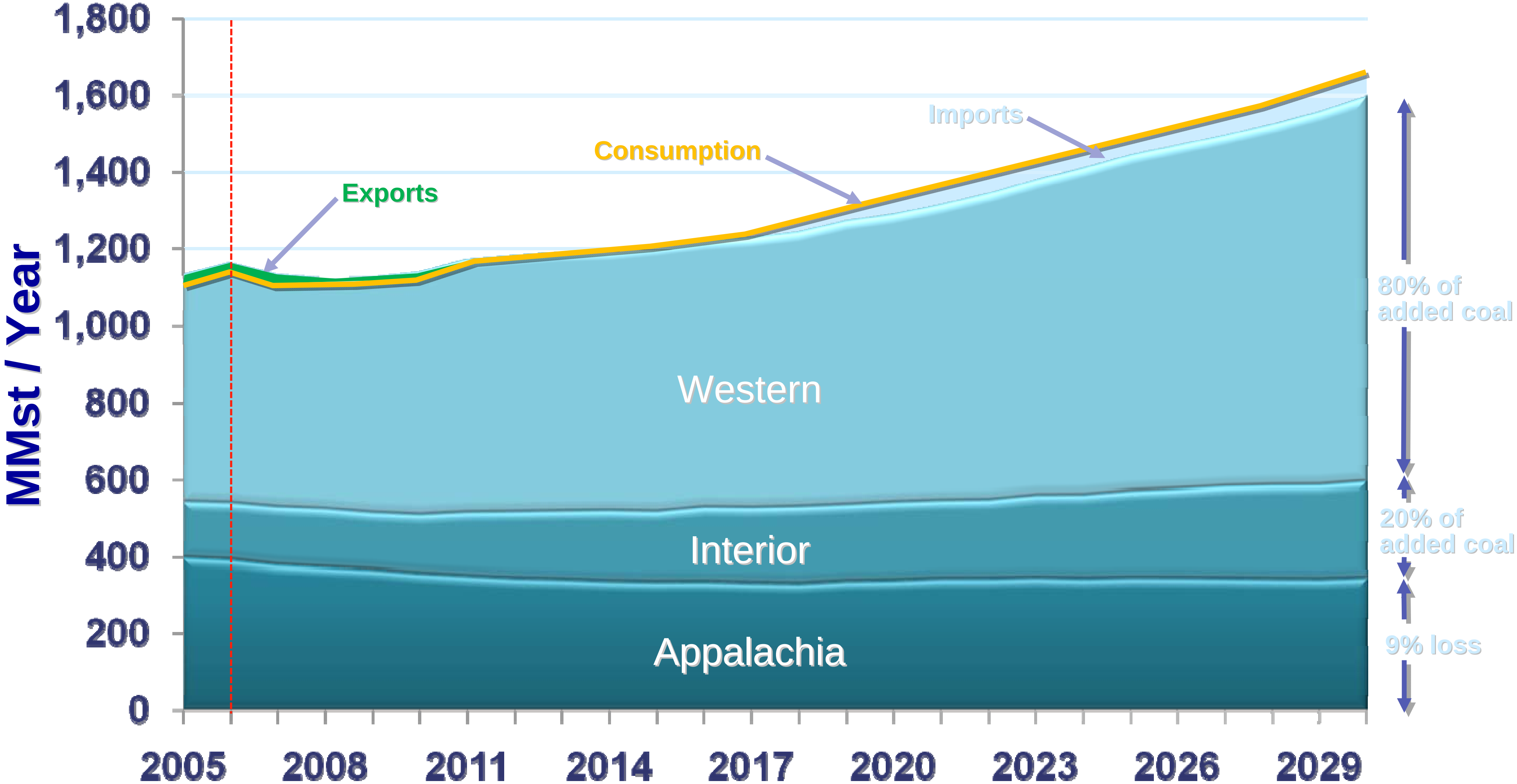
- Base-load coal-fired, 750 MW
- Western bituminous or subbituminous coal
- Heller type dry cooling
- Wet flue gas desulfurization with lime for SO_2
- Fabric Filter for particulates
- Activated carbon for mercury/toxics

Water Impacts of Fossil Fuel Extraction

- **Coal**
- **Petroleum**
- **Natural Gas**
- **Nontraditional**

Coal Production

Forecast AEO'08er



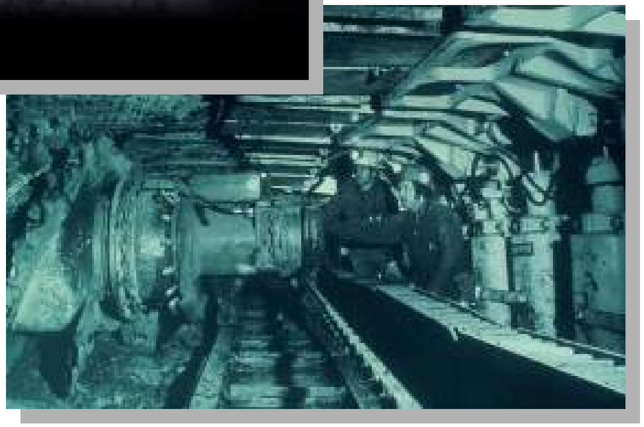
80% of Added Coal from West (+ 400 MMst / yr by 2030);
Imports Overtake Exports by 2014

Annual Energy Outlook 2008 early release

Coal Mining/Coal Prep
Underground Operations

Continuous Miner

Prep Plant and Impoundment



Longwall Operations

Underground Operations
Water Affects Working Conditions/Safety

Mining Operations
Water Requirements Summary

- **Water needs are variable**
  - Method of extraction
  - Prep
  - Reclamation
- **Mining Ops**
  - 10-150 gallons/Ton
- **Washing, etc.**
  - 20-40 gallons/Ton

Source: DOE/NETL-2006/1233

<u>Legacy</u> Operations Encumber Today's Industry

Images by JRDuda

Current Practices are Environmentally *Aligned*

Surface Extraction
Large Scale Operations/Western Coal

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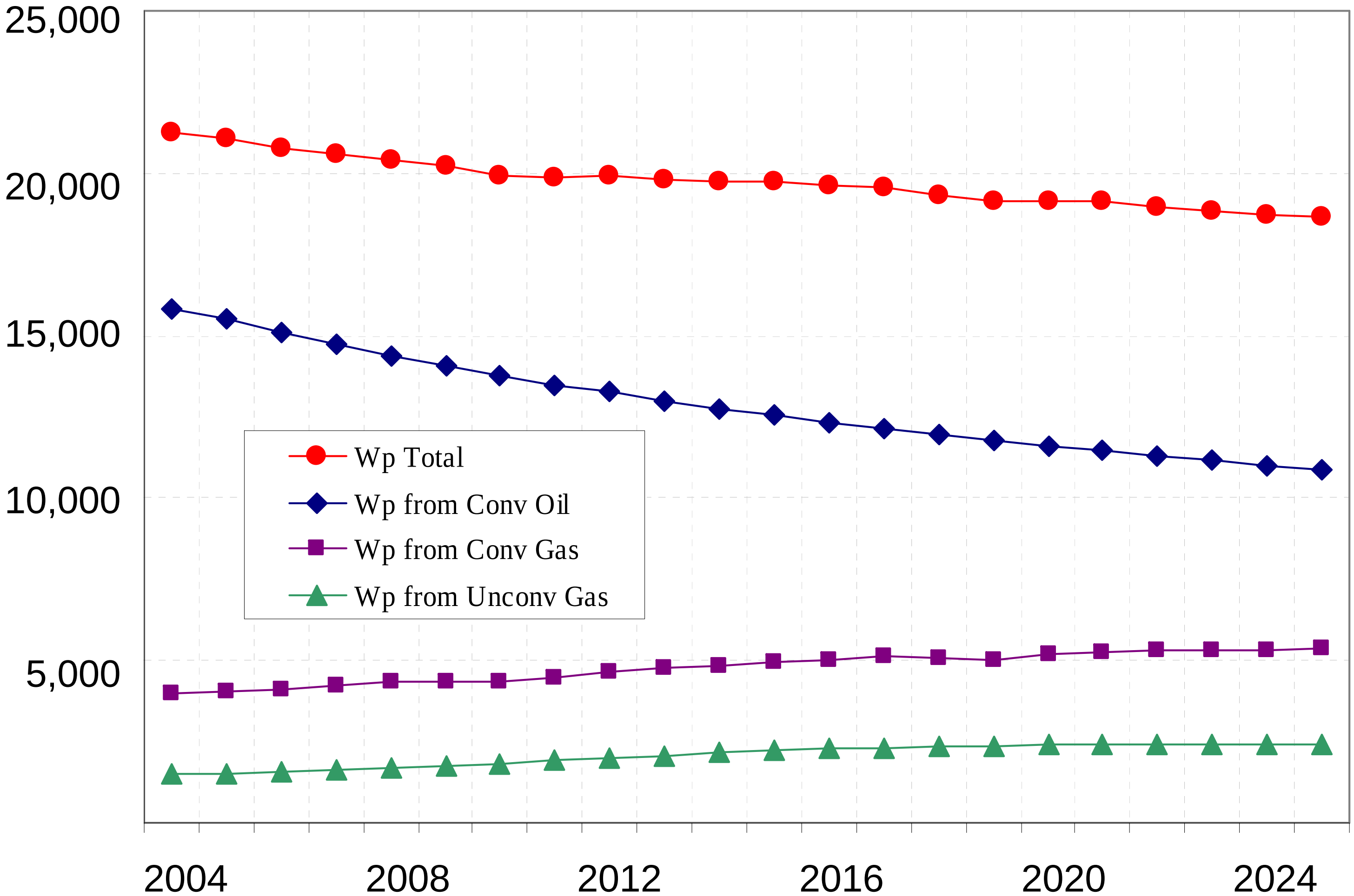
Water Management/Use
Large Scale Operations/Western Coal

Feasibility and Costs Dictate Options

$W_{p\ (total)}$ Volume Declines But Remains Significant

Produced Water Forecast (million bbls) by AEO Resource Type
Lower 48 Onshore



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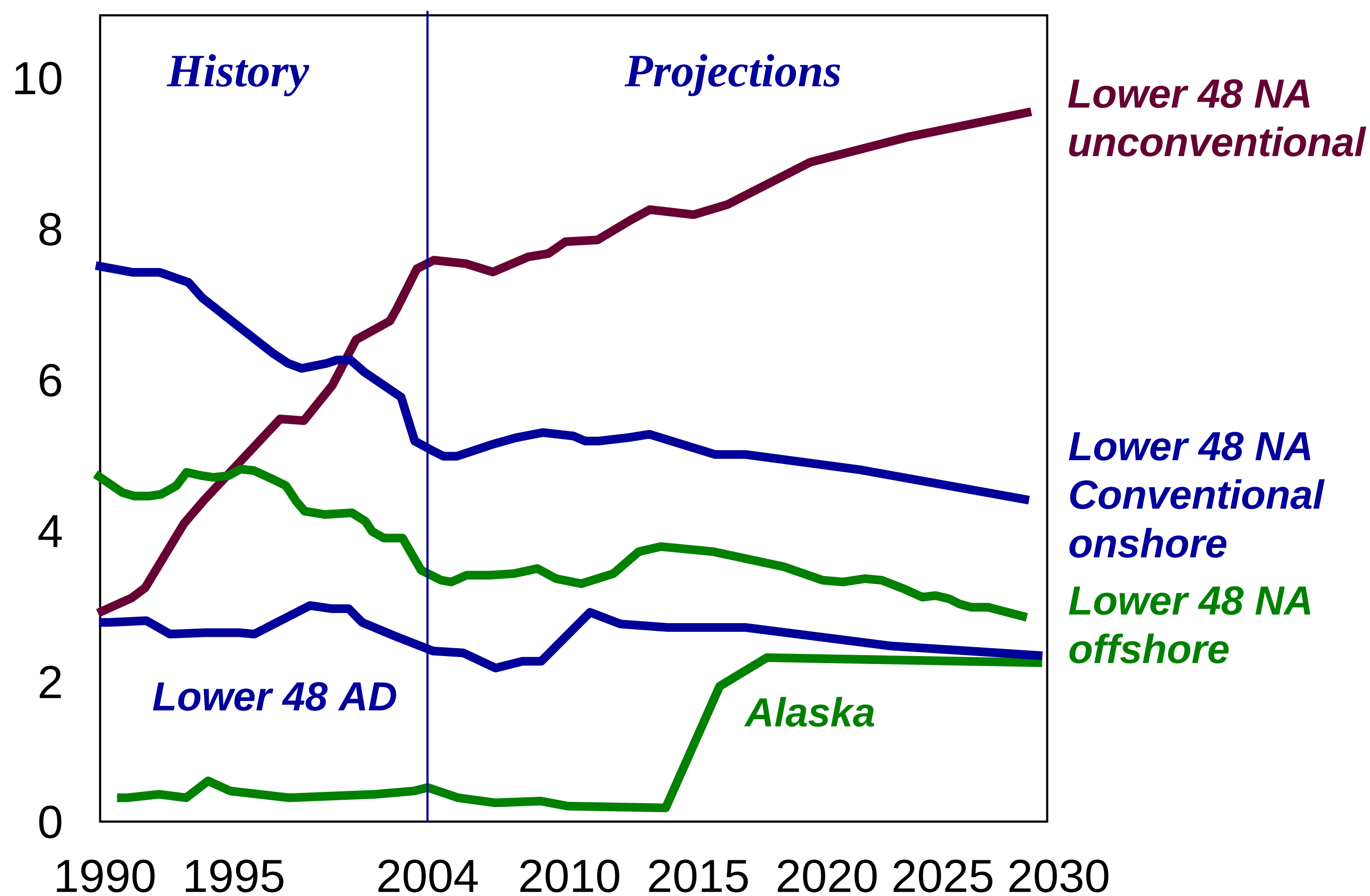
Domestic Supply Trends to Continue Increasing *Reliance on Unconventional Gas Resources*

Natural gas production by source, 1980-2030 (trillion cubic feet)



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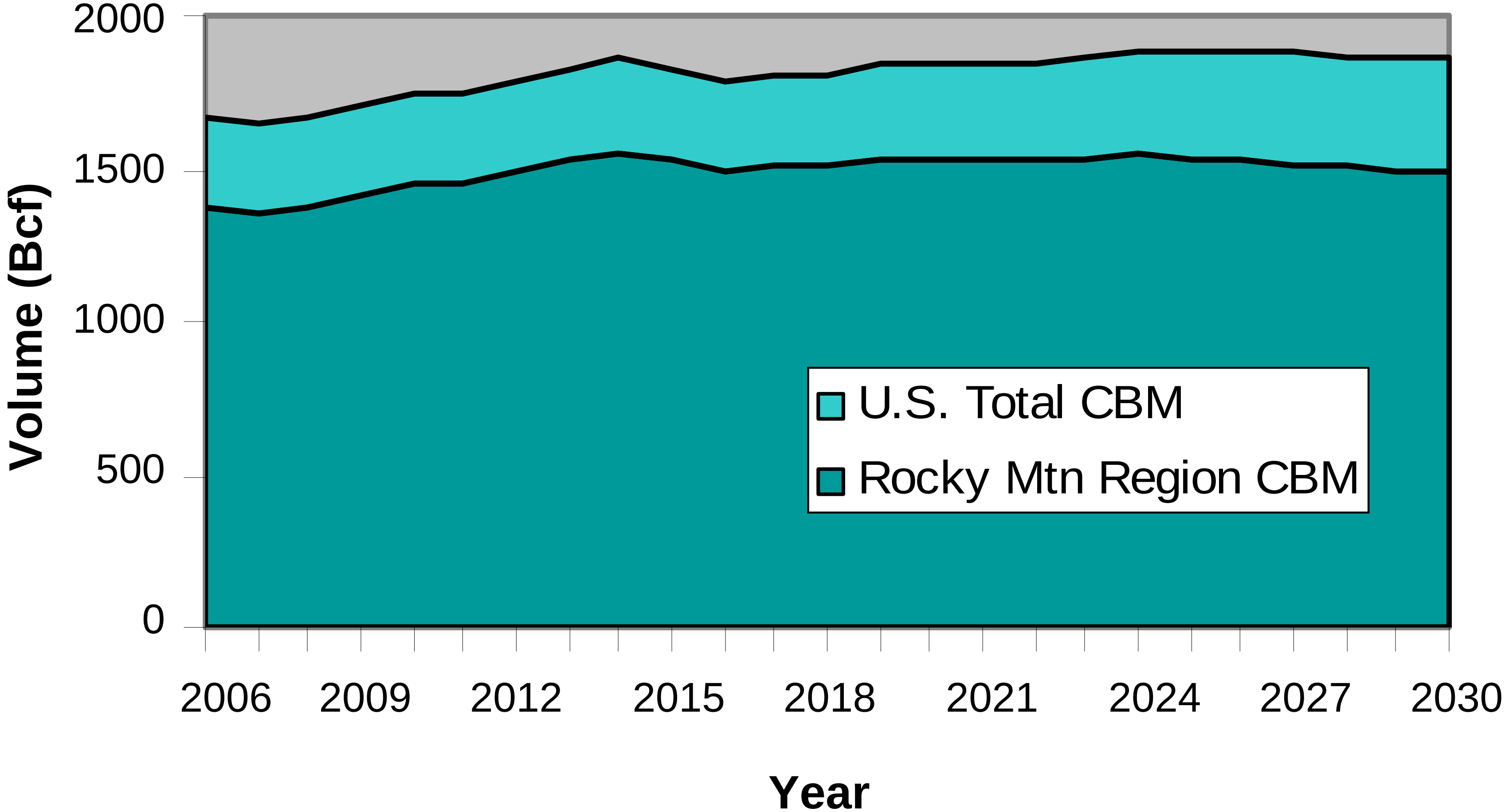
Water Management Strategies
Natural Gas Operations

Images by JRDuda

Surface Discharge as an Alternative to Injection
Coordination/Cooperation with Regulators is a Must

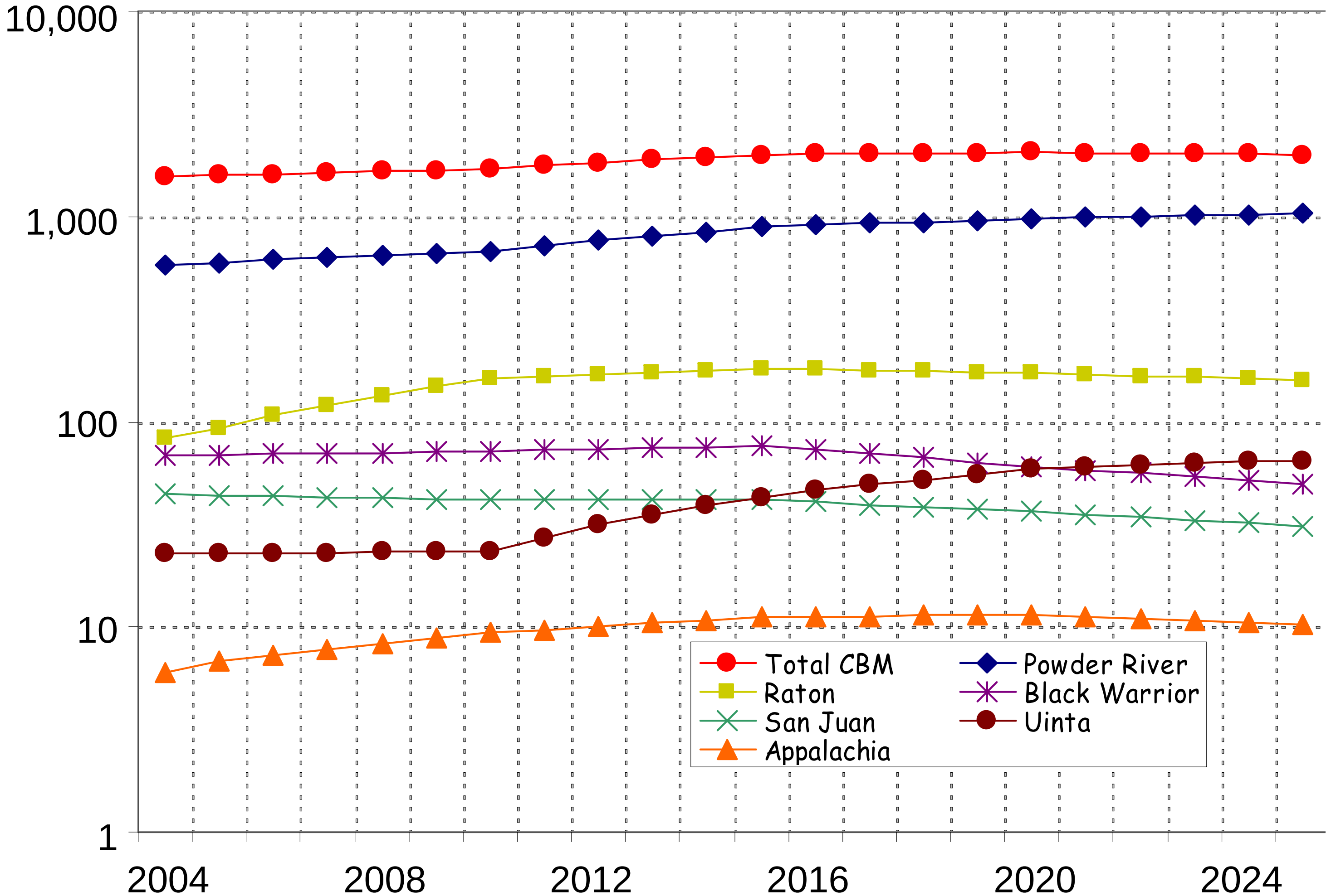
Images by JRDuda

CBM Production Increases to Nearly 2 Tcf/yr
Rocky Mtn. Basins/Plays Remain Dominant

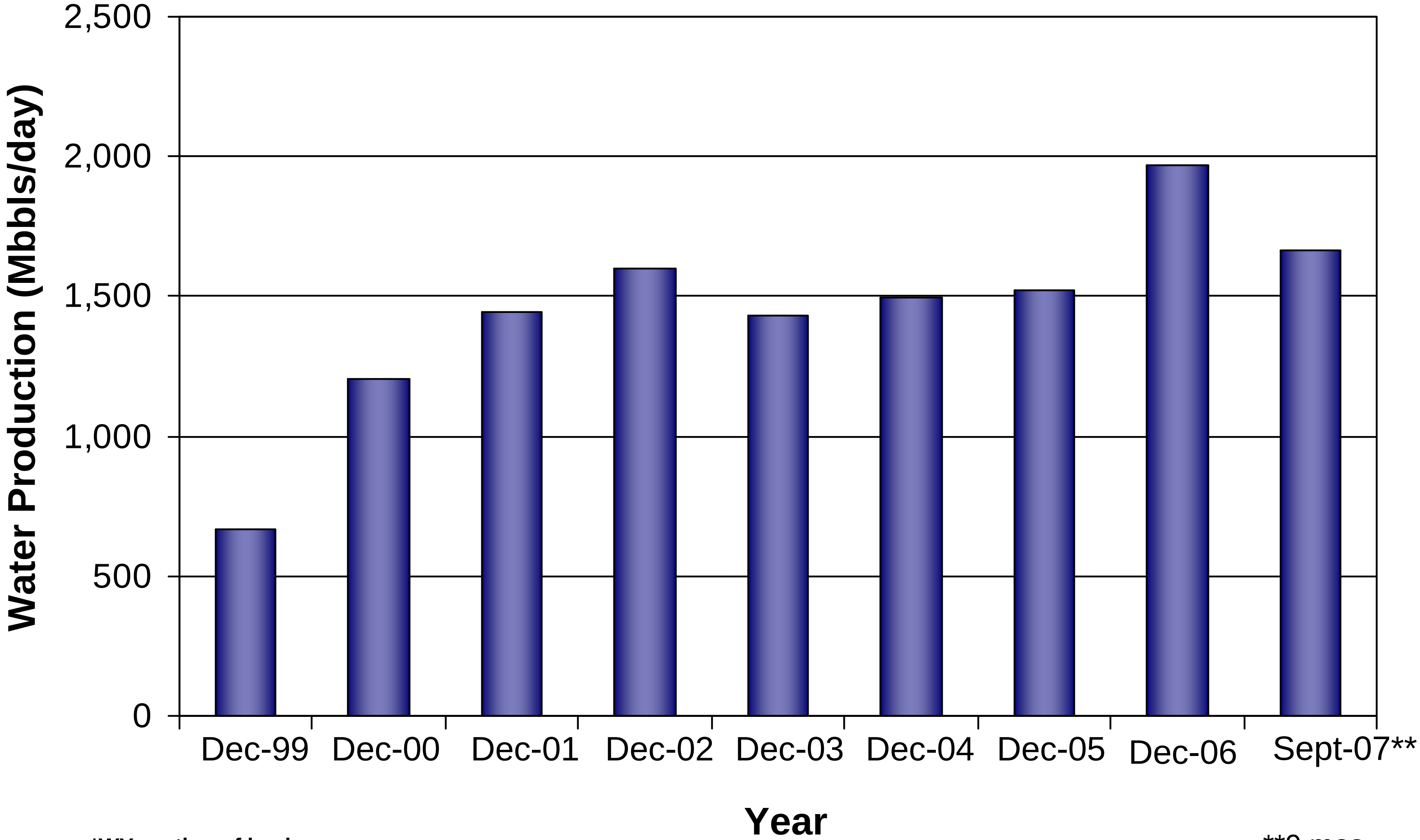


Expect a Commensurate Increase in W_p Volumes
Water Management *Key* for Rocky Mountain Region

Produced Water Forecast (MMbbls) by UnConv CBM Gas Play



Produced Water is an Issue
Powder River Basin CBM Play*



***WY portion of basin**

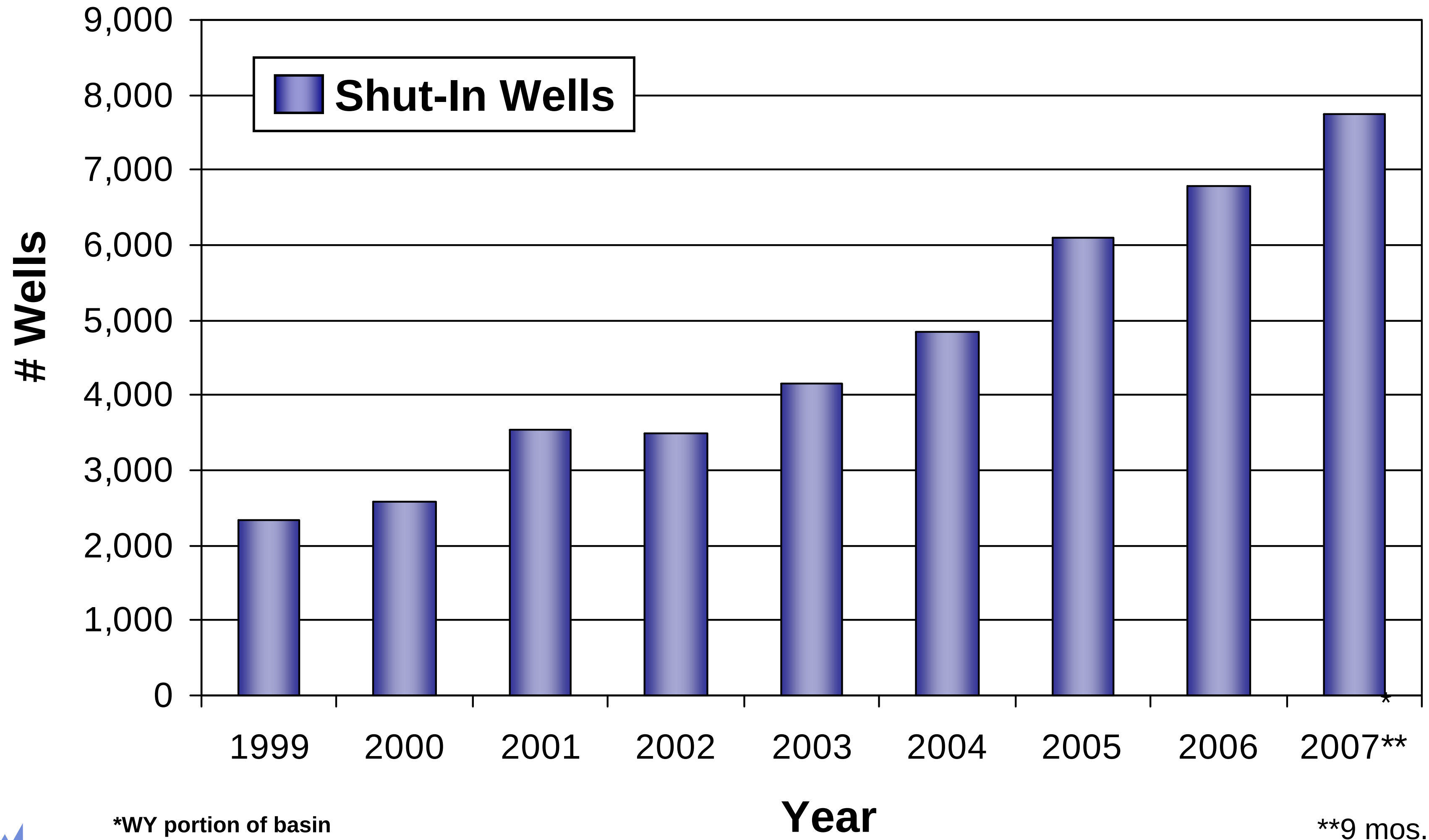
**9 mos.

Source: http://wogcc.state.wy.us/coalbedchart.cfm

W_p Management Issues ARE of Consequence!

Powder River Basin CBM*

Average number of shut-in coalbed methane wells



*WY portion of basin

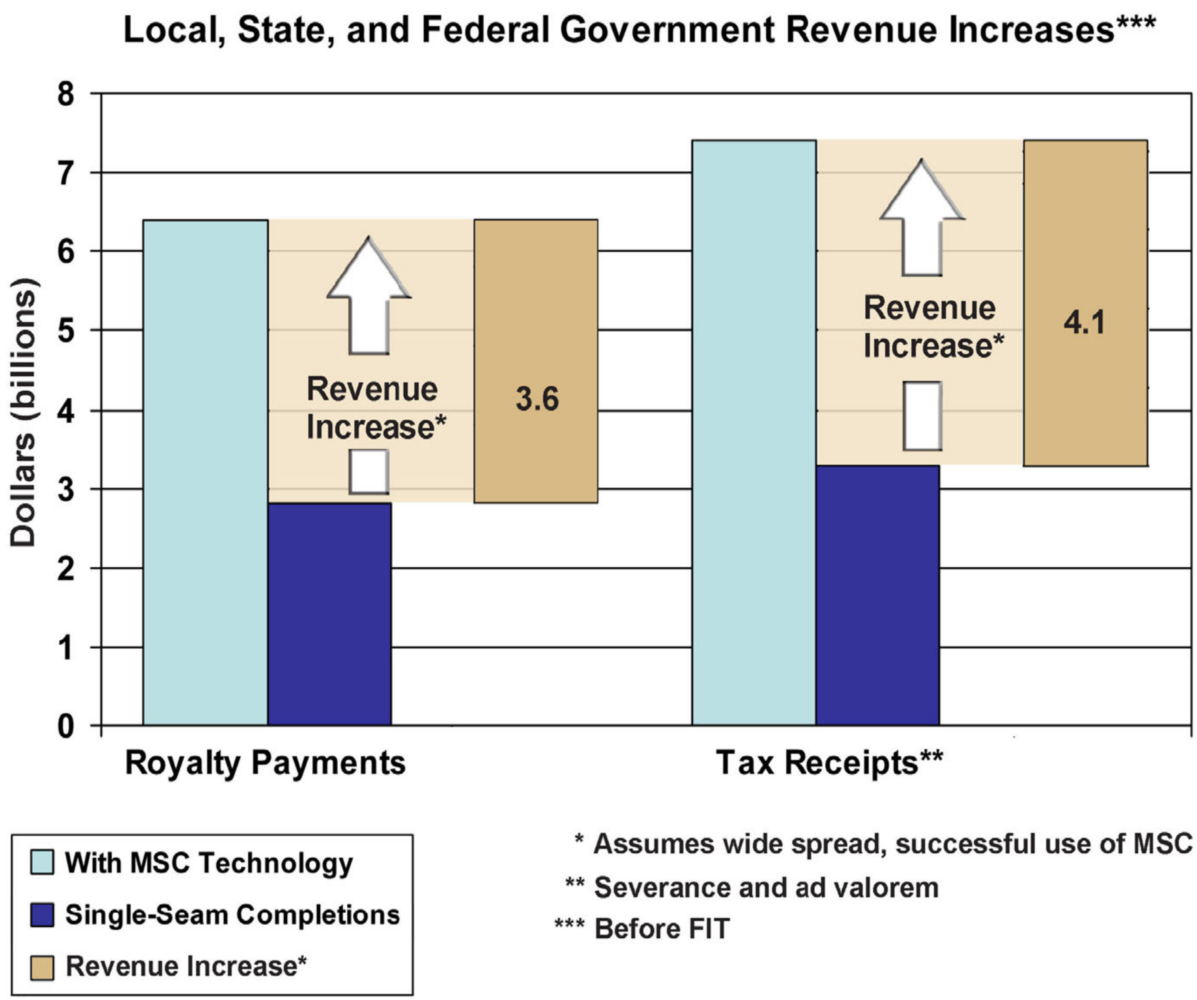
**9 mos.

Source: http://wogcc.state.wy.us/coalbedchart.cfm

"W_p *Impacts*" on Energy are Far-Reaching *"Translation"*…

- **3000 wells**
- **60 Mcf/d**
- **365 day/yr**
- **$4/Mcf**
- **~ $263 <u>m</u>illion/yr (gross)**
  - Royalties
  - Taxes
  - Reinvestment capital
  - …etc.

Technology Advances Can Yield Sign. Benefits
Water Management Requires Equal Attention



Potential Economic Benefits Associated with MSC

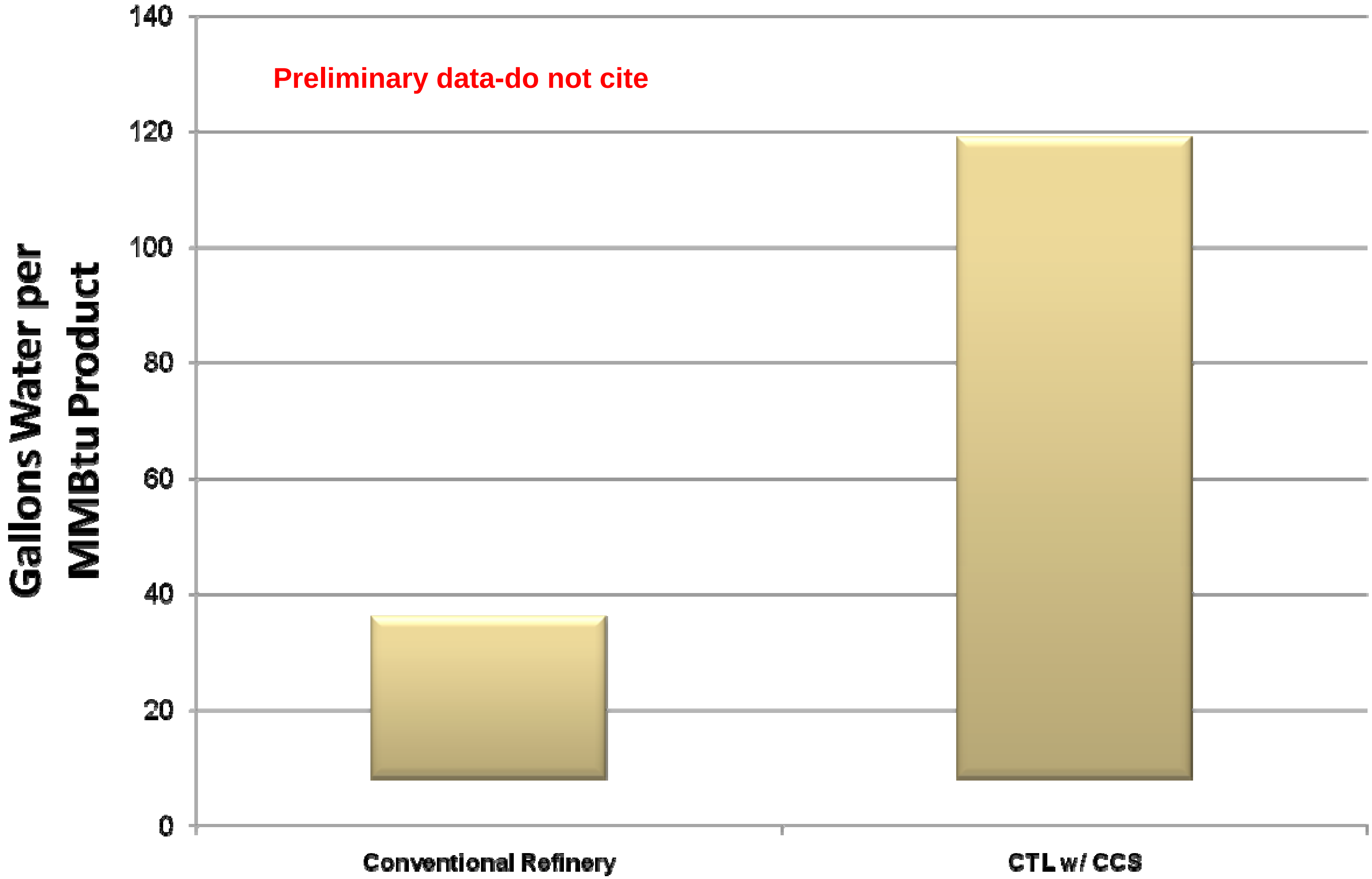
Water Management via Impoundments, etc.

Powder River Basin CBM Play

Post-Drilling Operations are Benign
Powder River Basin CBM Play

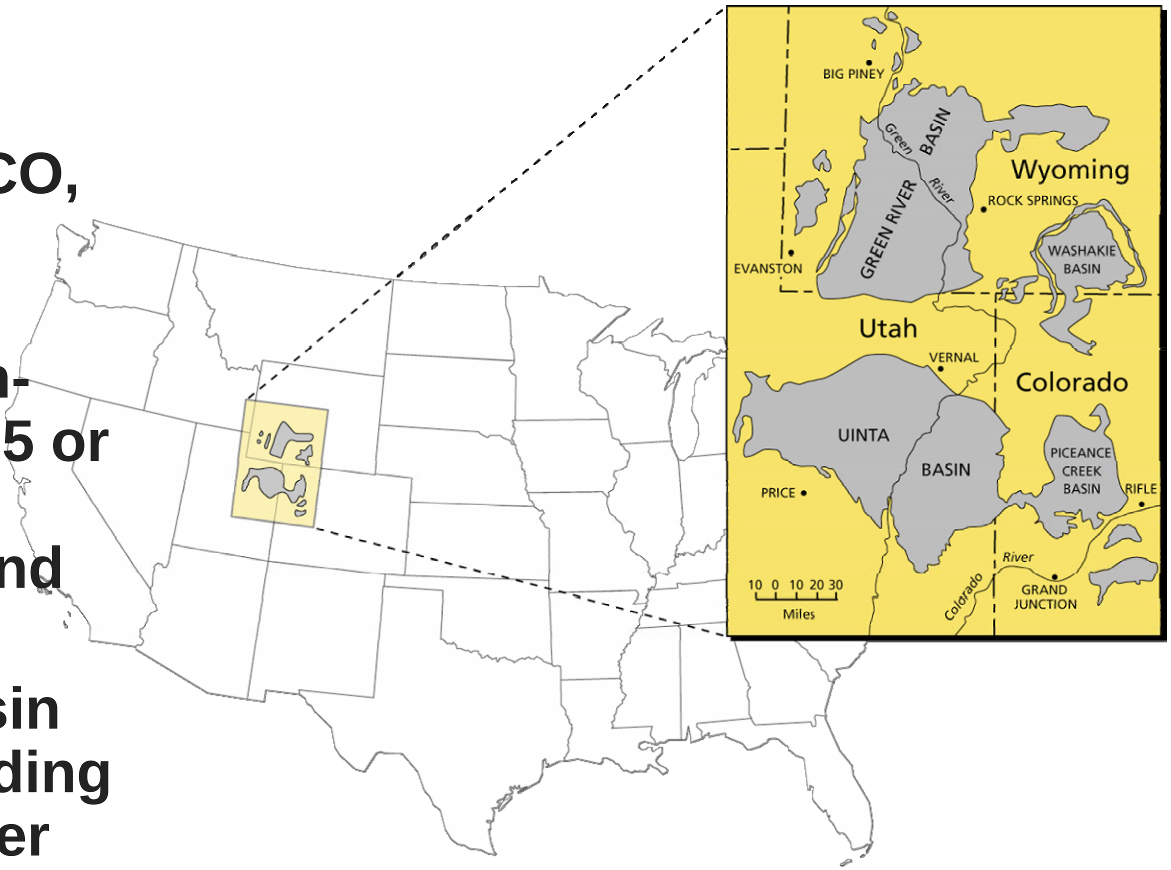
Even Energy Imports Impacted by H_2O *Concerns*
Open Rack Vaporizers

Estimated Water Requirements
Coal to Liquids Plants



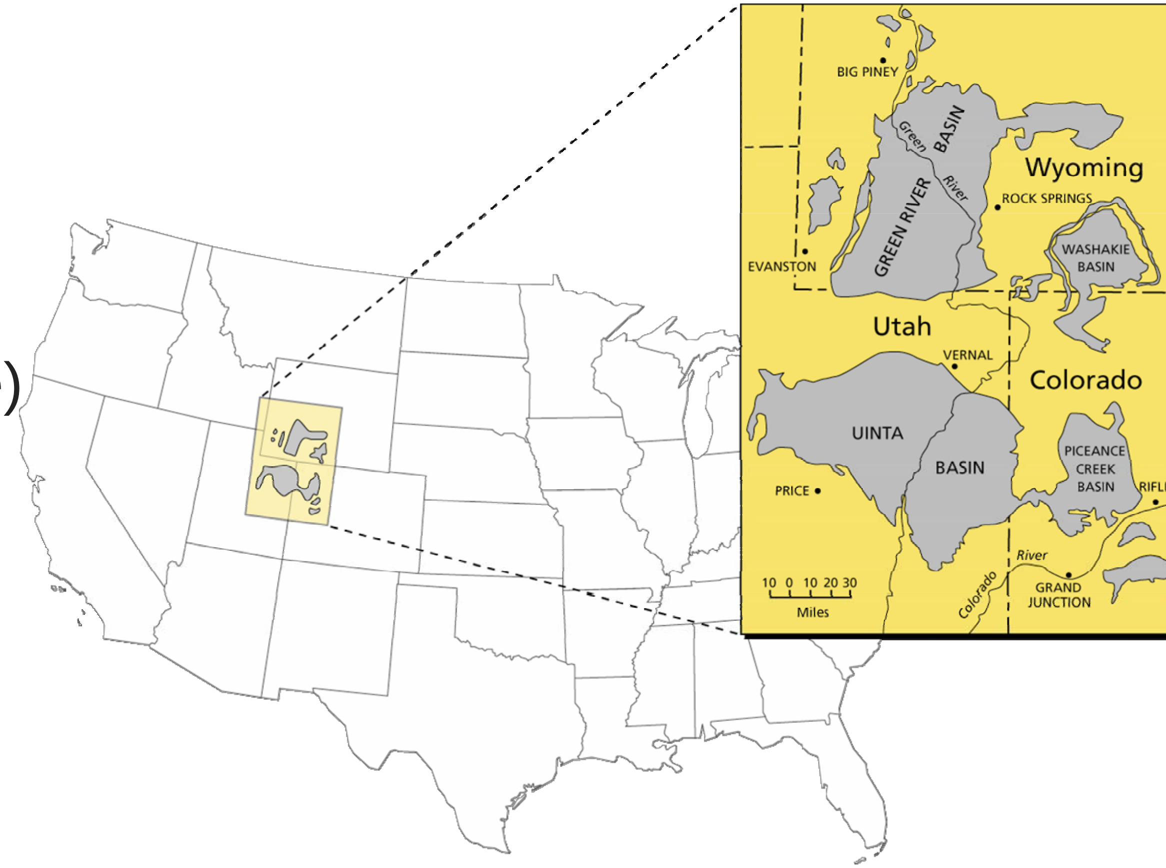
Western Oil Shale
A Most Significant In-Place Resource

- **Green River Formation (CO, UT, WY) - estimated 1.5 trillion barrels**
- **Initial development - high-grade oil shale yielding 25 or more gallons per ton; estimated between 400 and 750 billion barrels**
- **Some portions of the basin have the potential of yielding over 2.5 million barrels per acre**



Western Oil Shale Resources
Water Requirements? – Do the Algebra

- **Water needs will vary**
  - Above ground retorting
  - In-situ extraction
  - Efficiencies (of the future)
  - General requirements
    - 2 - 5 bbls H_20 per bbl product
    - Contemporary data required!



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Oil Sands
Significant Resources and Water Requirements

- **Massive operation in Canada**
- **Predicted to increase to 2.8 million bbls/day in 2015**
- **Water needed for steam recovery and hot water separation**
  - 2 – 3.5 bbls of water/bbl product
- **U.S. oil sands deposits**
  - Utah, Texas
  - KY, AL, and CA to a lesser extent

Closing Remarks

- The U.S. to remain reliant on fossil fuels
- One can expect increased competition for water
- Evolving regulations and policies will impact “energy and water”
- Cooling systems have a significant impact on water withdrawal and consumption
- Carbon capture will impact water needs

For Additional Information

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www.netl.doe.gov

Office of Fossil Energy

www.fe.doe.gov