# Water and Energy: A Multi-Dimensional Resource Management Challenge

**Roundtable on Science and Technology for Sustainability**

*National Academies*

*6 May, 2010*


*Michael Kavanaugh, PhD, P.E., NAE*

*Vice President*

*Global Science and Technology Leader*

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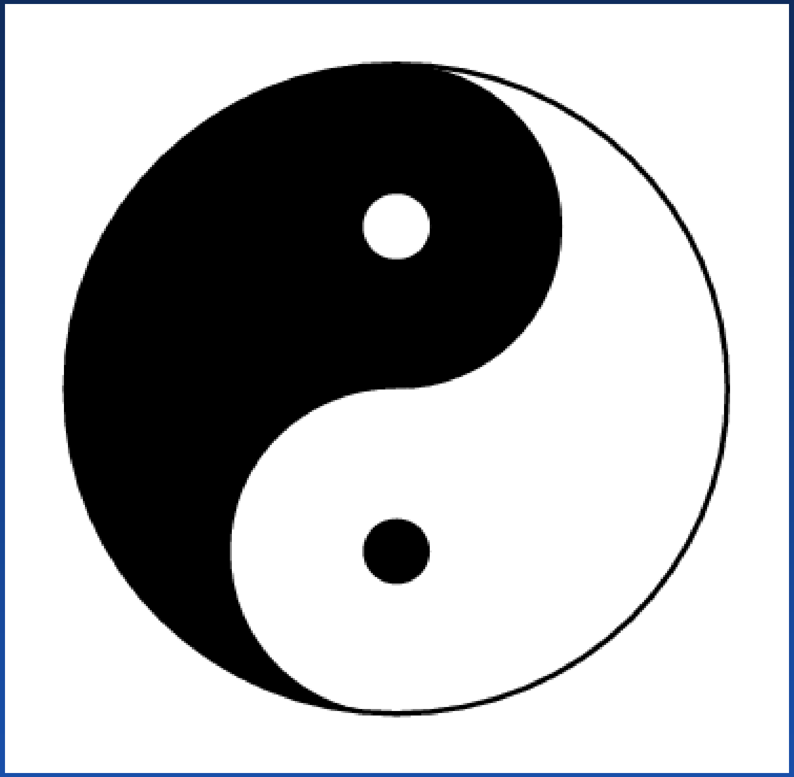

**Water and energy are inextricably linked : the "Yin and Yang" of a sustainable future**

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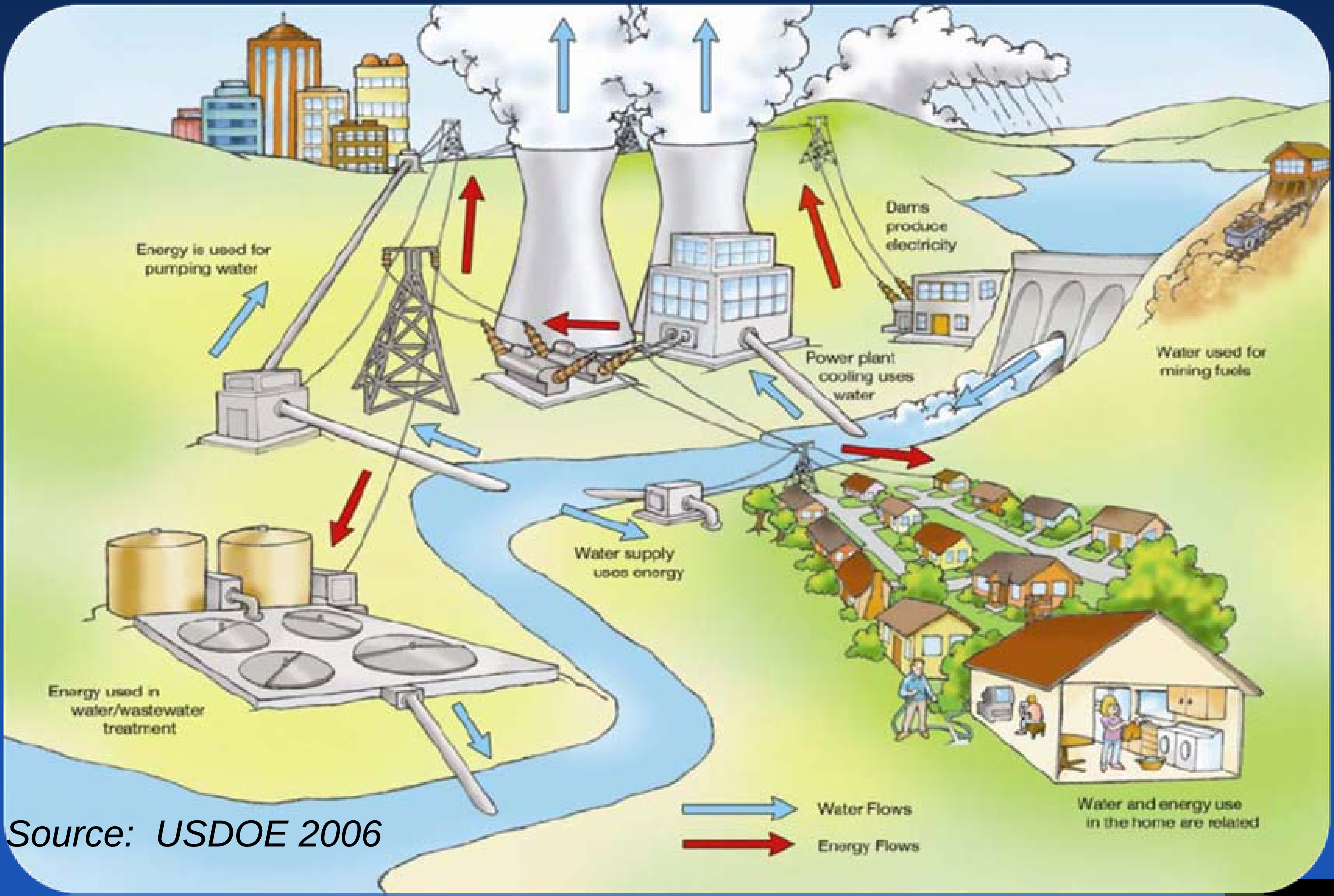
# Water and Energy




*Source: USDOE 2006*

# Overview: Water and Energy

- The water quantity dimension
- The water quality dimension
- Sustainable water-energy practices: barriers to success

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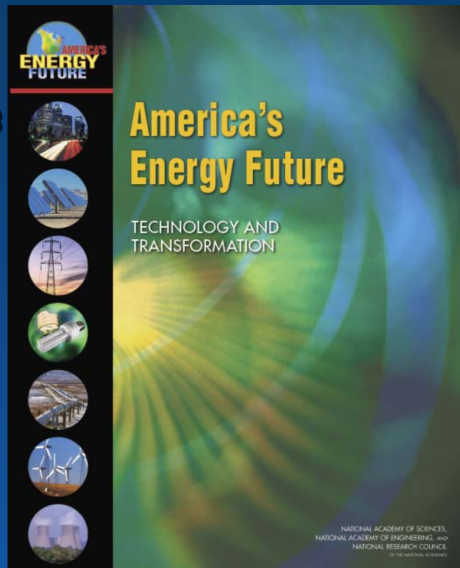
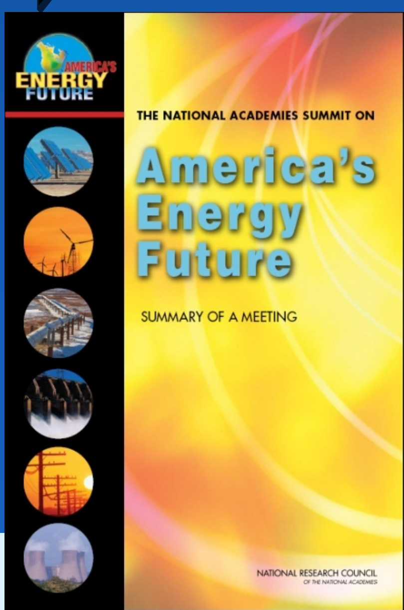



# America's Energy Future: Technology Opportunities, Risks, and Tradeoffs

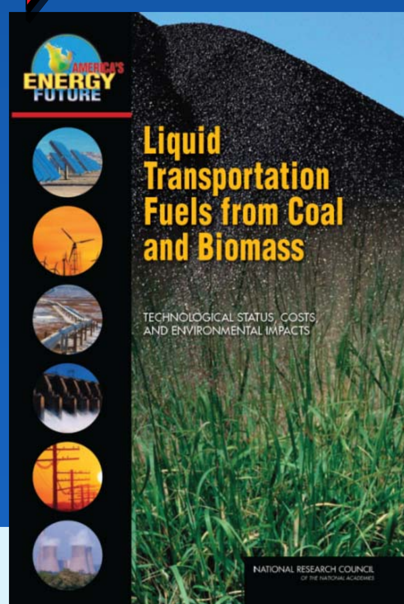
July 2009

http://www.nationalacademies.org/energy

October 2008




May 20, 2009

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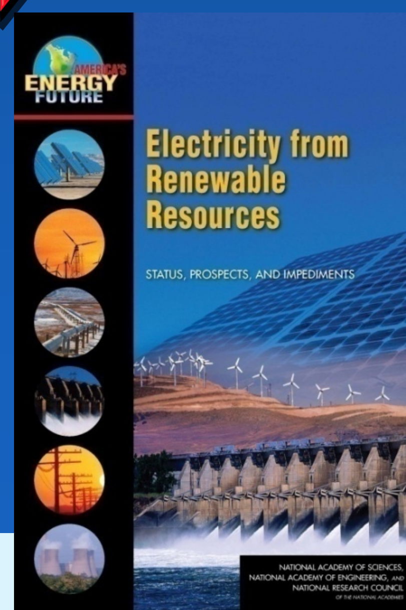


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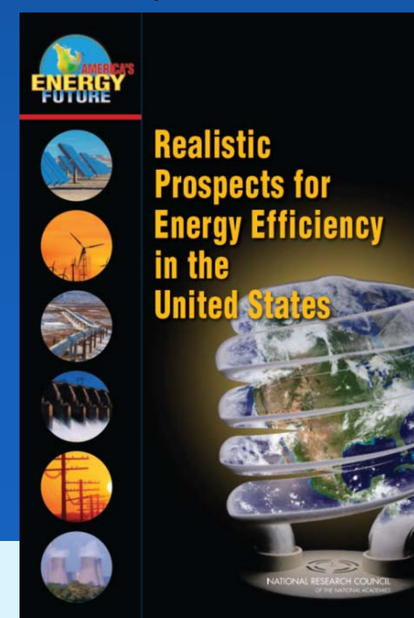


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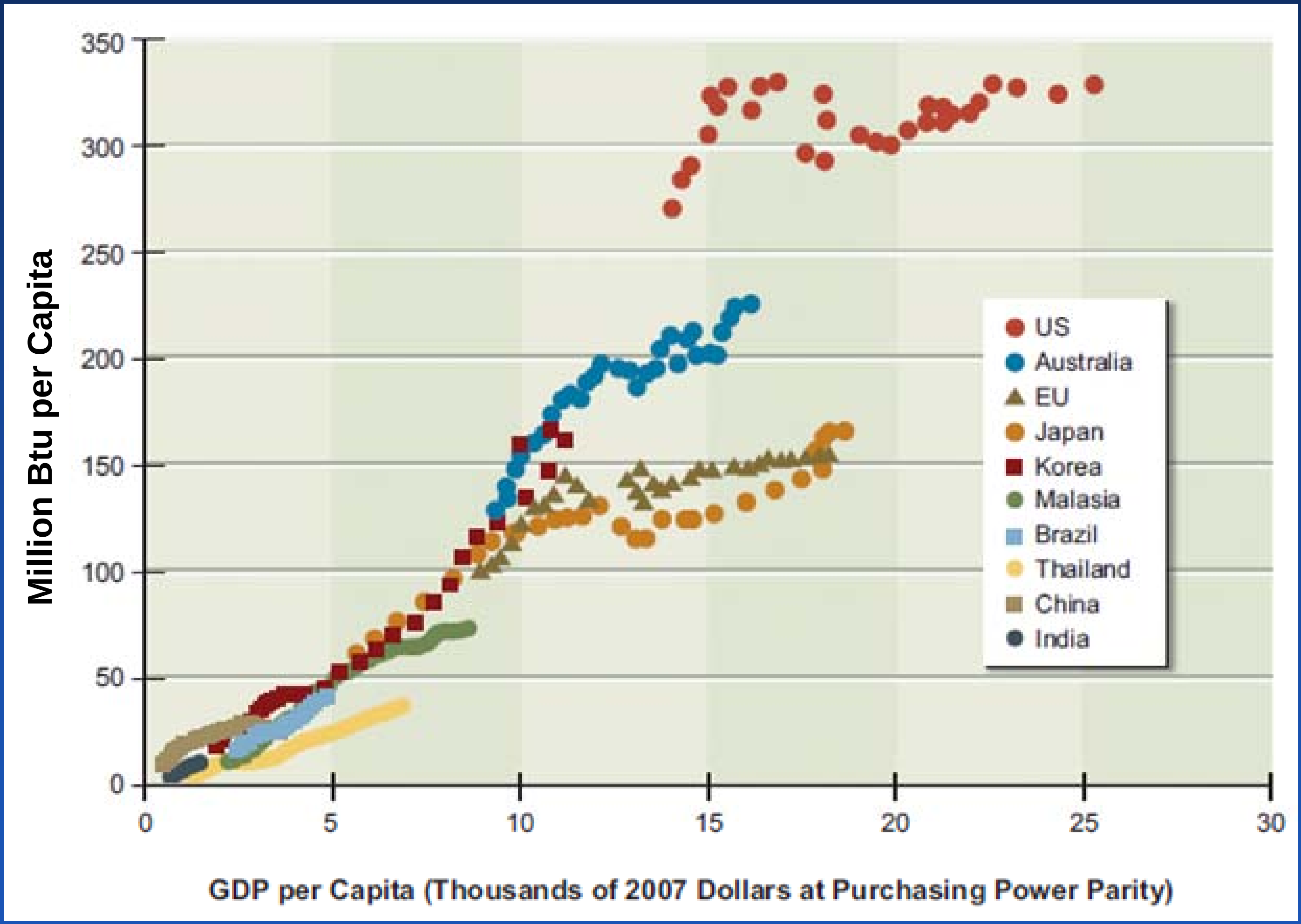
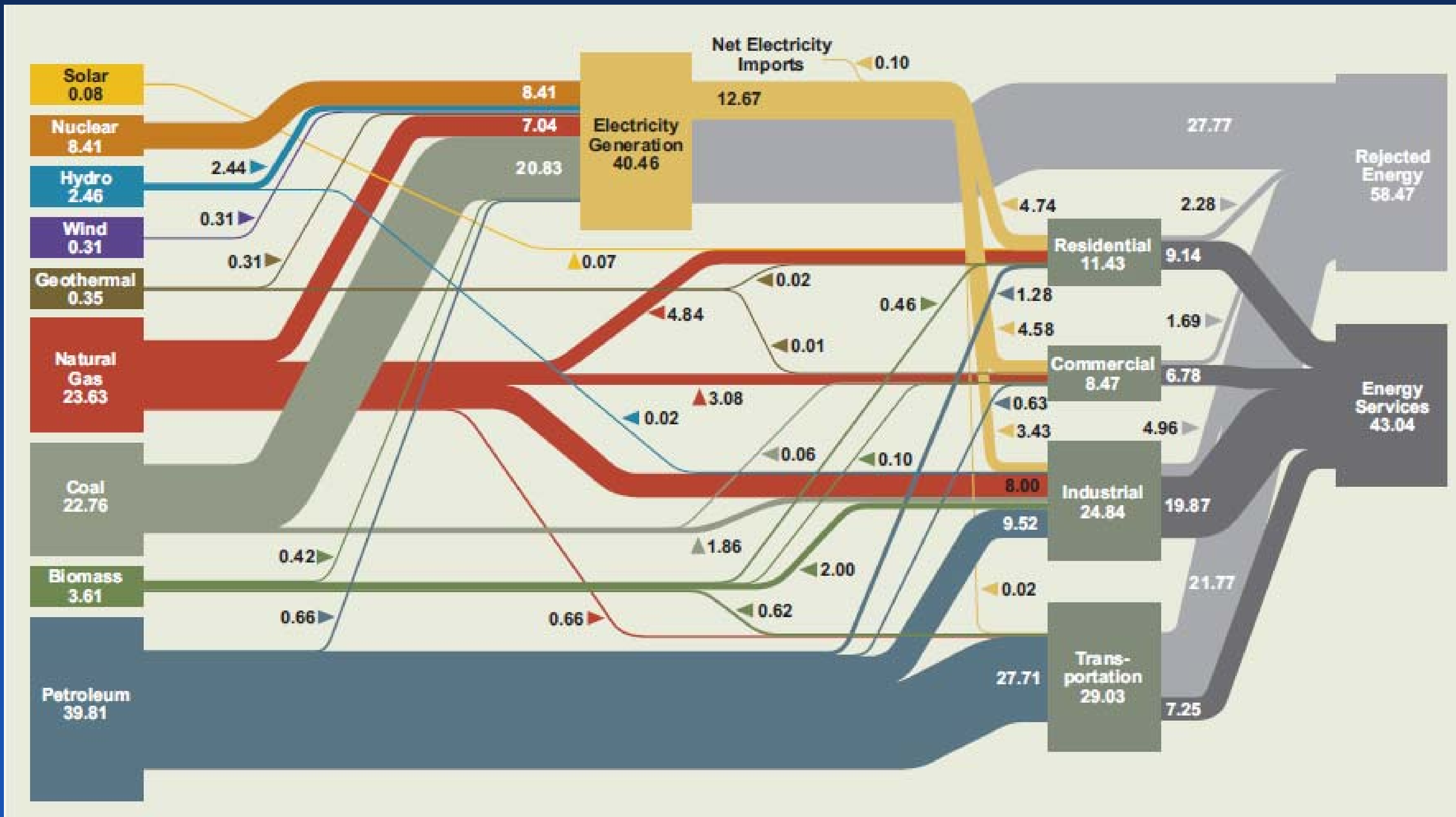
# Energy use and GDP per capita




Source: NRC, 2009

# Energy Consumption in the U.S. 2007




**Units are Quadrillion British Thermal Units (BTUs), known as Quads**

*Source: NRC, 2009*

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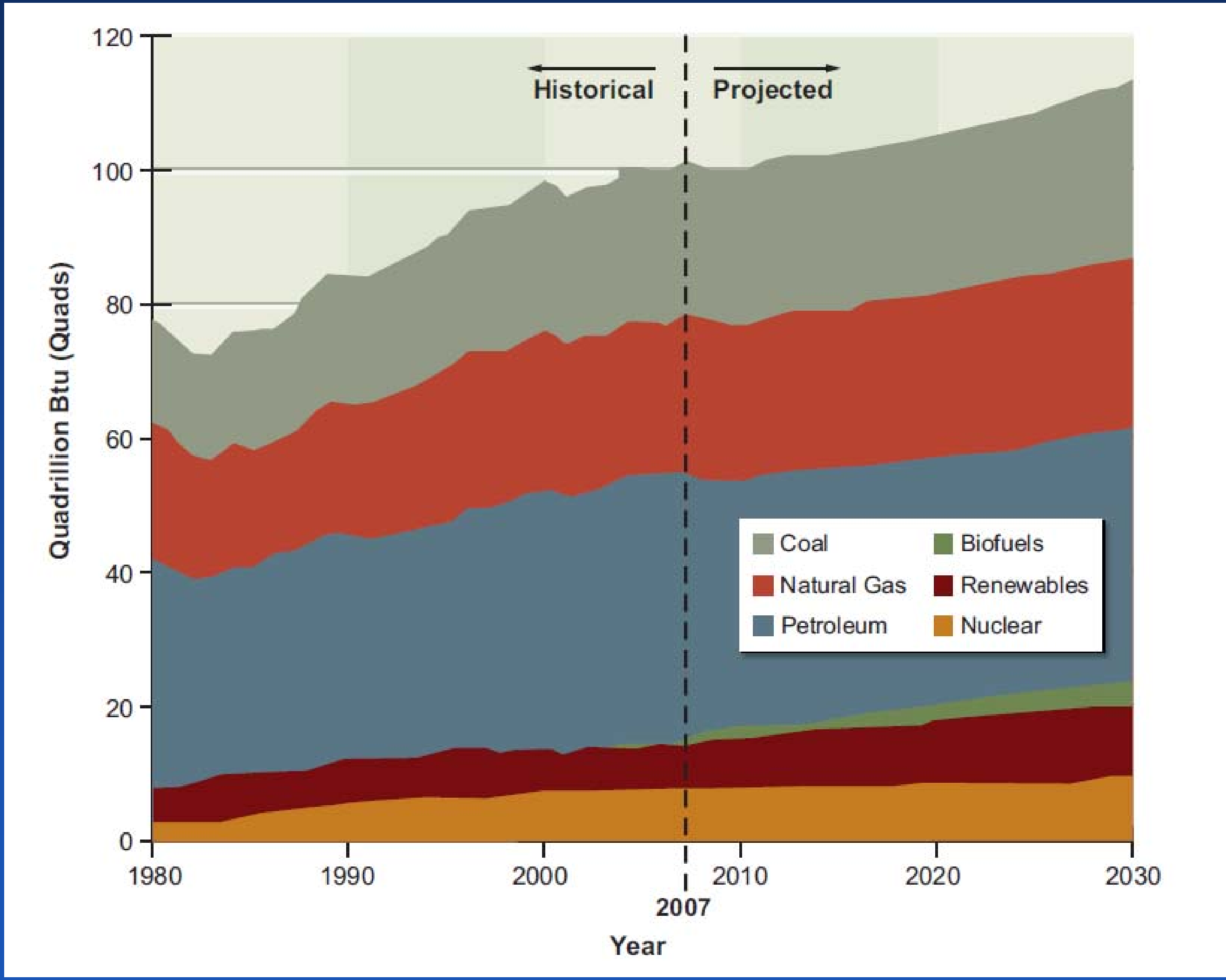
# U.S. Energy Consumption – Past, Present, Future




*Source: NRC, 2009*

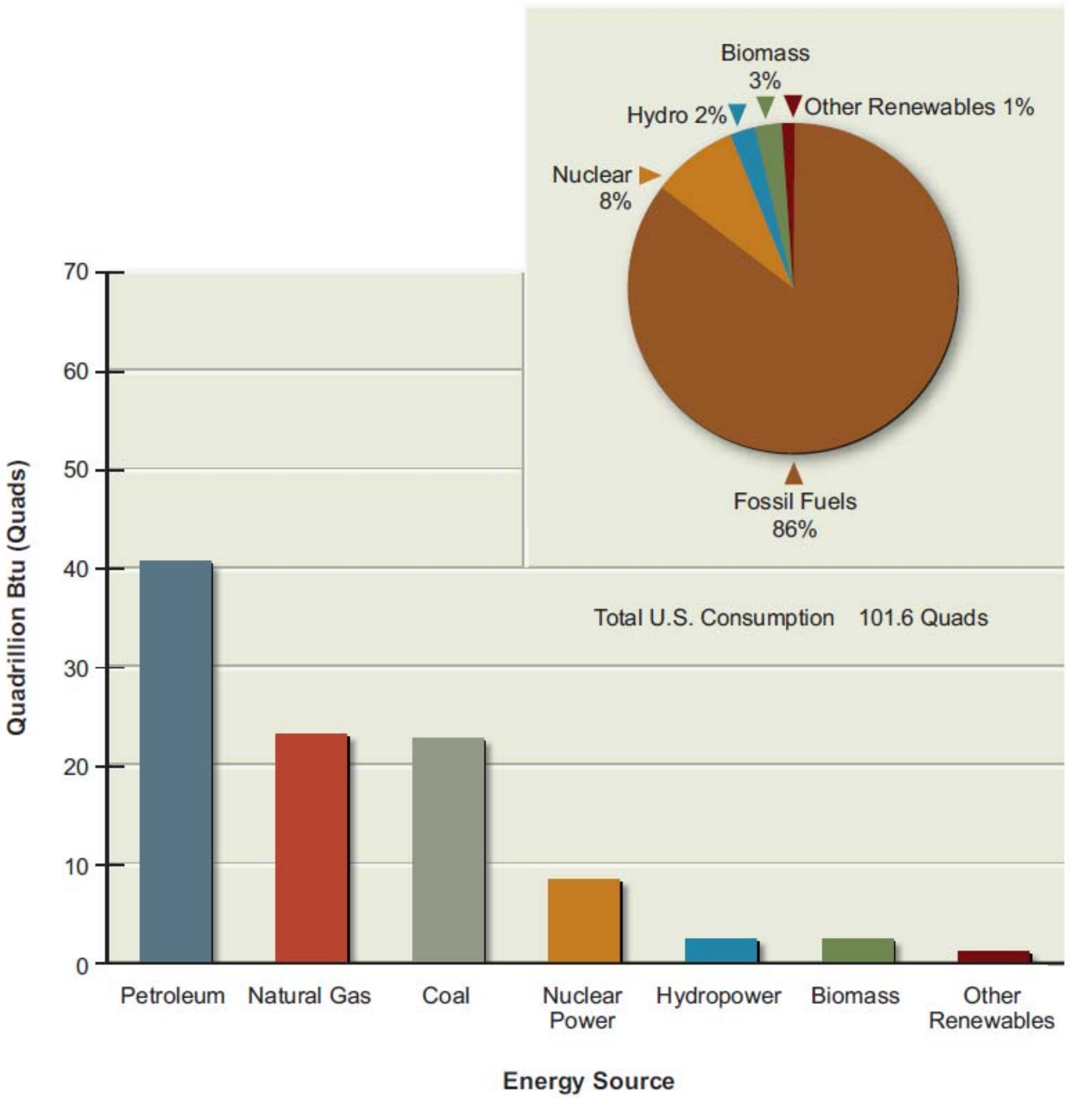



**FIGURE 1.2** *Energy consumption in the United States in 2007 by fuel source, in quads (bars) and as percentages (pie chart).*
*Source: Energy Information Administration, 2008b.*

# U.S. Energy Consumption – 2007

*Source: NRC, 2009*

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# Some Fundamentals: The Units of Energy

***The Mechanical Equivalent of Heat***

***1 calorie = 4.186 joules***

***1 BTU = 252 calories***

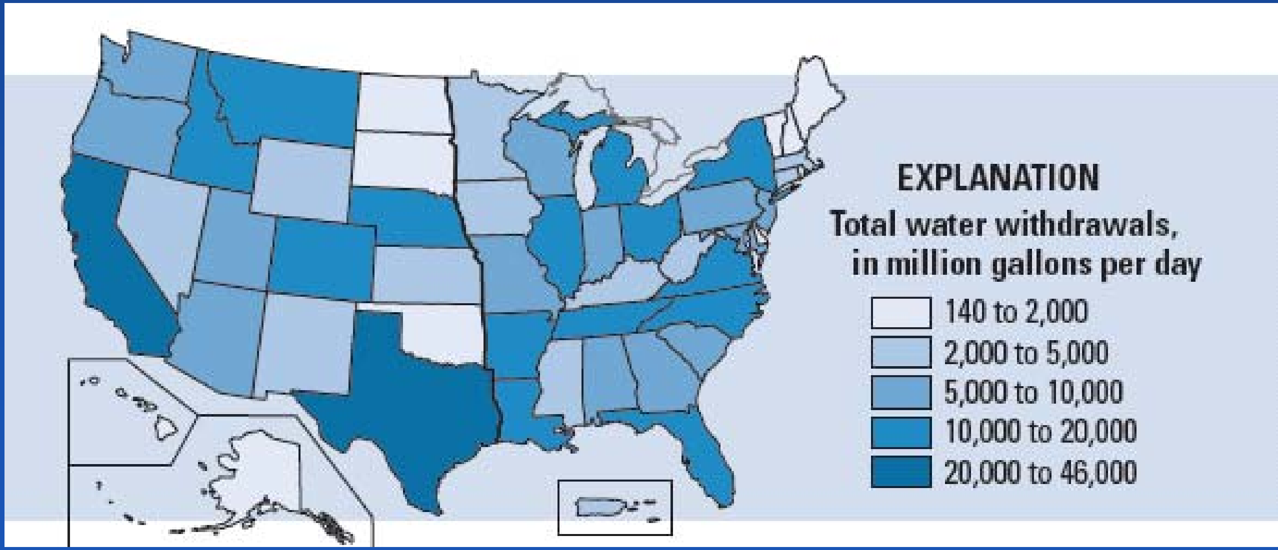
- 1 British Thermal Unit (BTU) = 0.000293 kWh
- 1 kWh = 3413 BTUs
- 1 MWh = 3.4E06 BTUs
- 1 Terrawatt hours (TWh) = 1E12 Watts
- 1 Quadrillion (Quad) BTUs = 1E15 BTUs

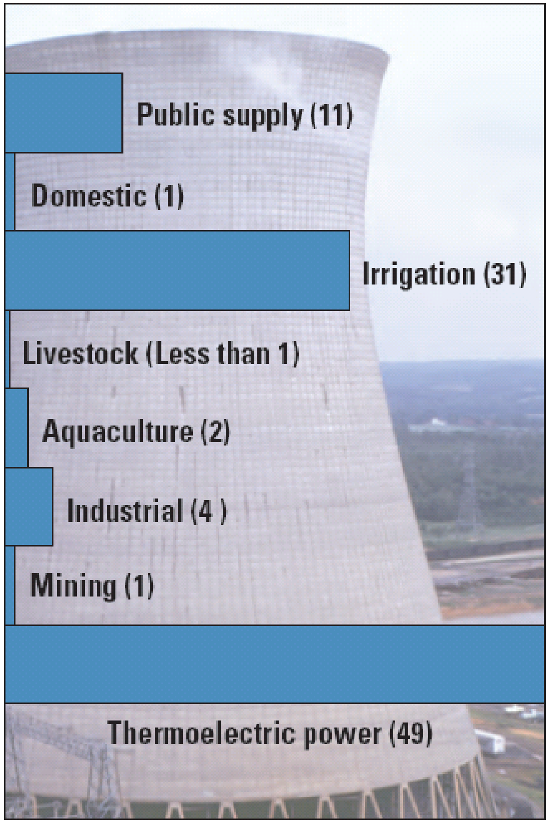
Therefore

**1 Quad = 295 TWh**

# U.S. Water Consumption – 2005

- Total withdrawals were 410,000 million gallons per day
- Freshwater withdrawals were 85 percent of the total
- Surface water supplied 80 percent of all withdrawals
- Thermoelectric-power withdrawals were 201,000 million gallons per day



2005 withdrawals by category, in percent.

Source: USGS, 2009

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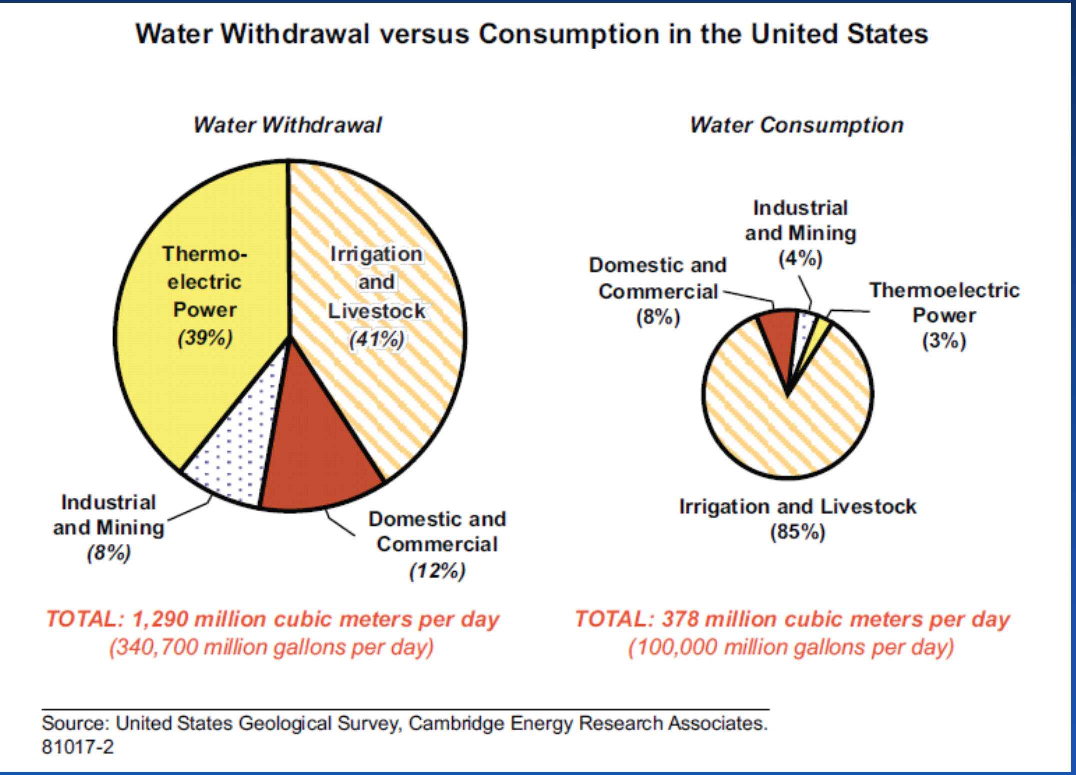
# Water Use of Energy

- The energy sector uses about 8% of freshwater withdrawn worldwide (310 billion cubic meters in 2001)
- In developed countries, water use for the energy sector can reach over 40% of total freshwater withdrawals.
- Actual water *consumption* by energy sector is much lower




*Source: World Economic Forum, 2009*

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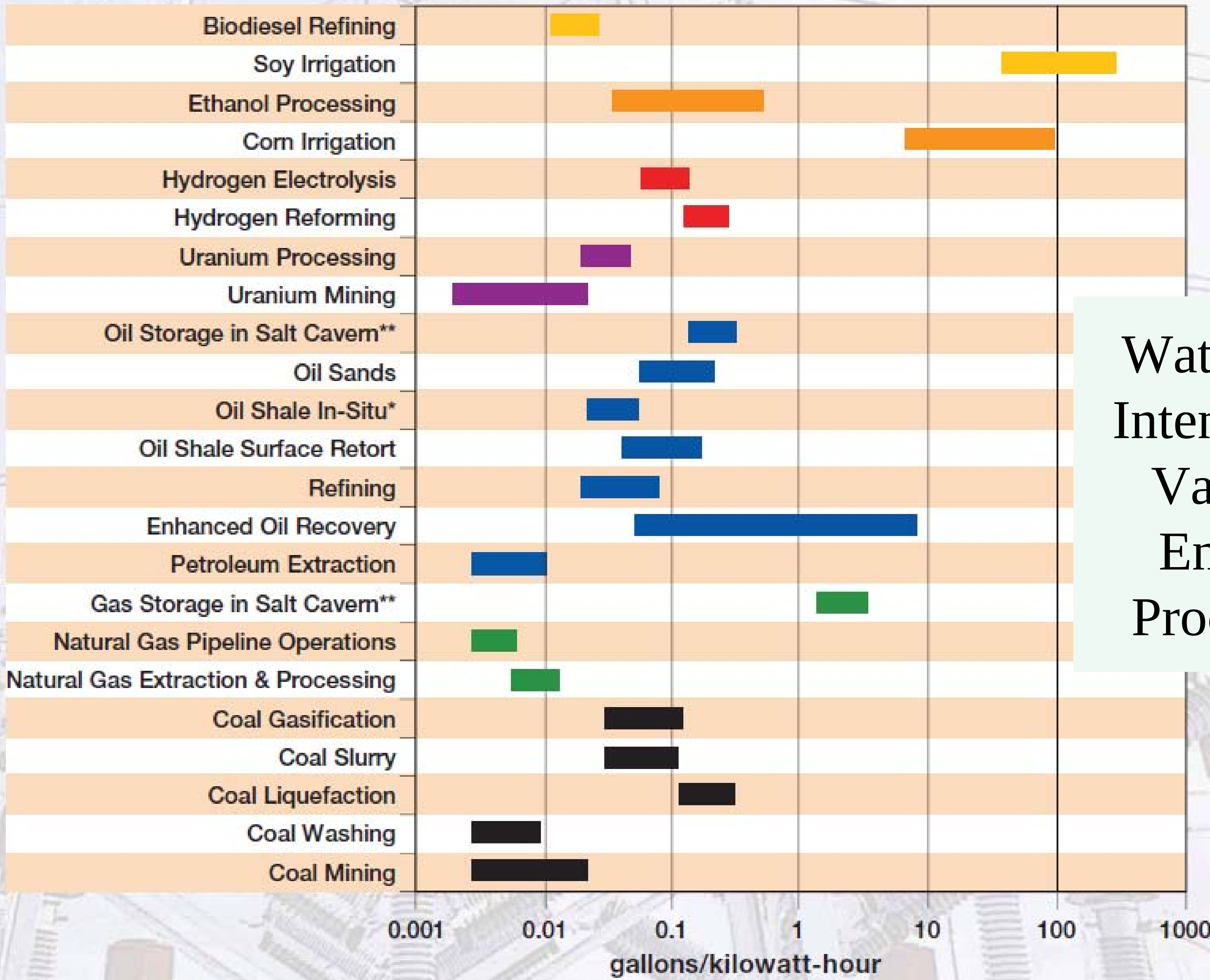
# Water Use Intensity of Various Energy Processes

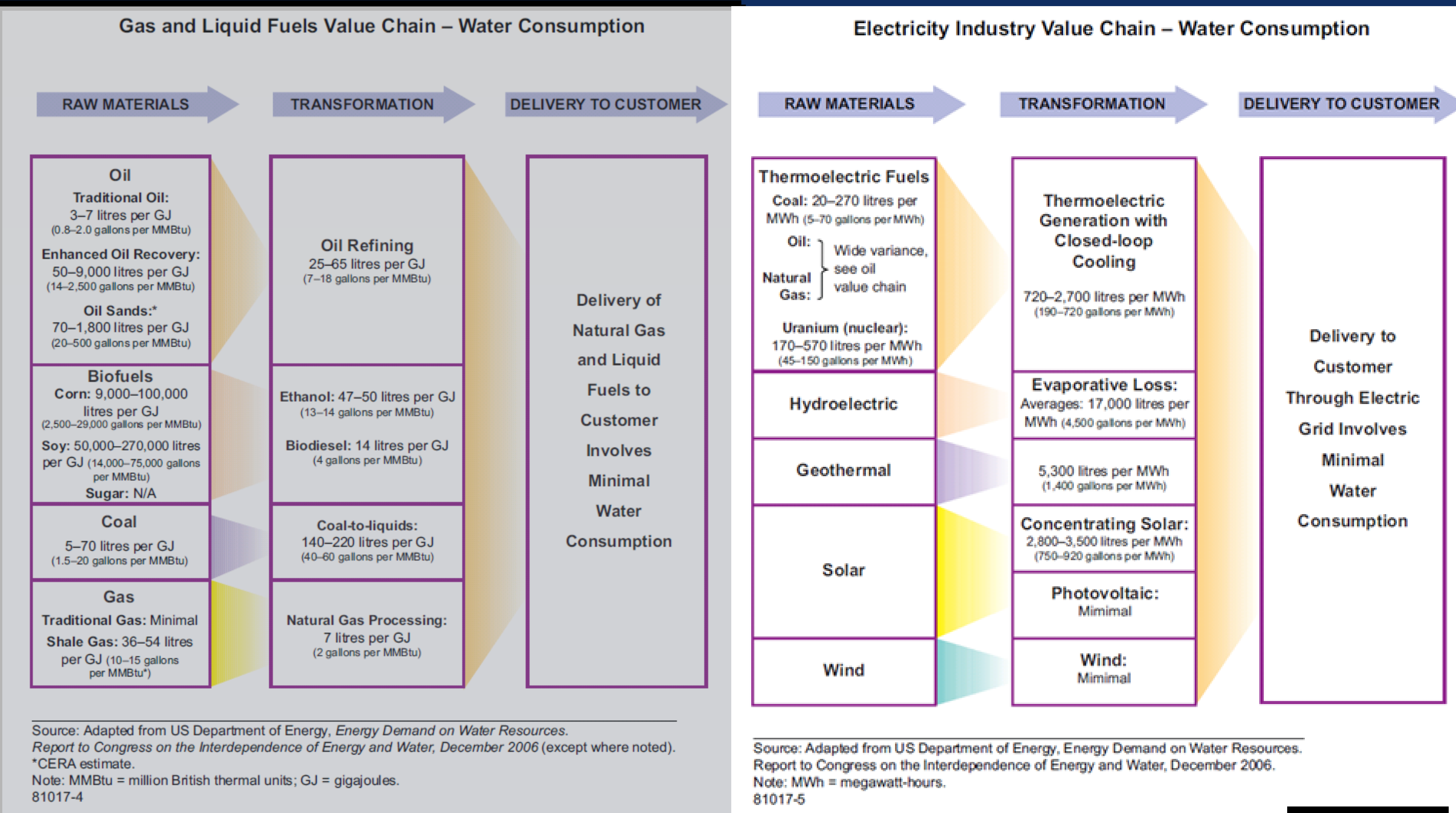



*Water Consumption for Electric Power from Evaporatively-Cooled Combined Cycle Gas Turbine

**One-Time Use for Solution Mining of Salt Cavern

*Source: Woodhouse 2007*

# Other ways of looking at water use intensity




*Source: World Economic Forum, 2009*

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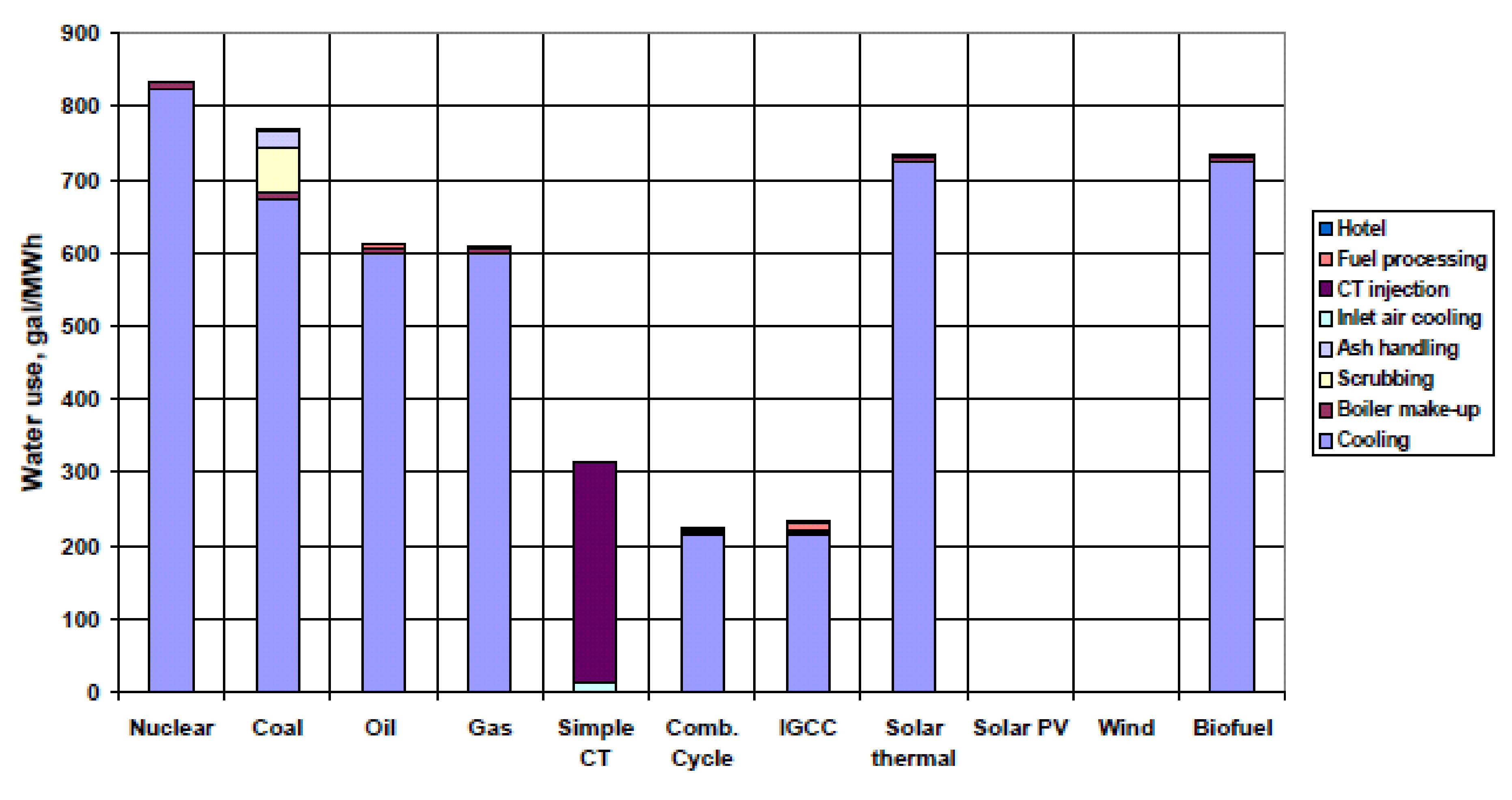
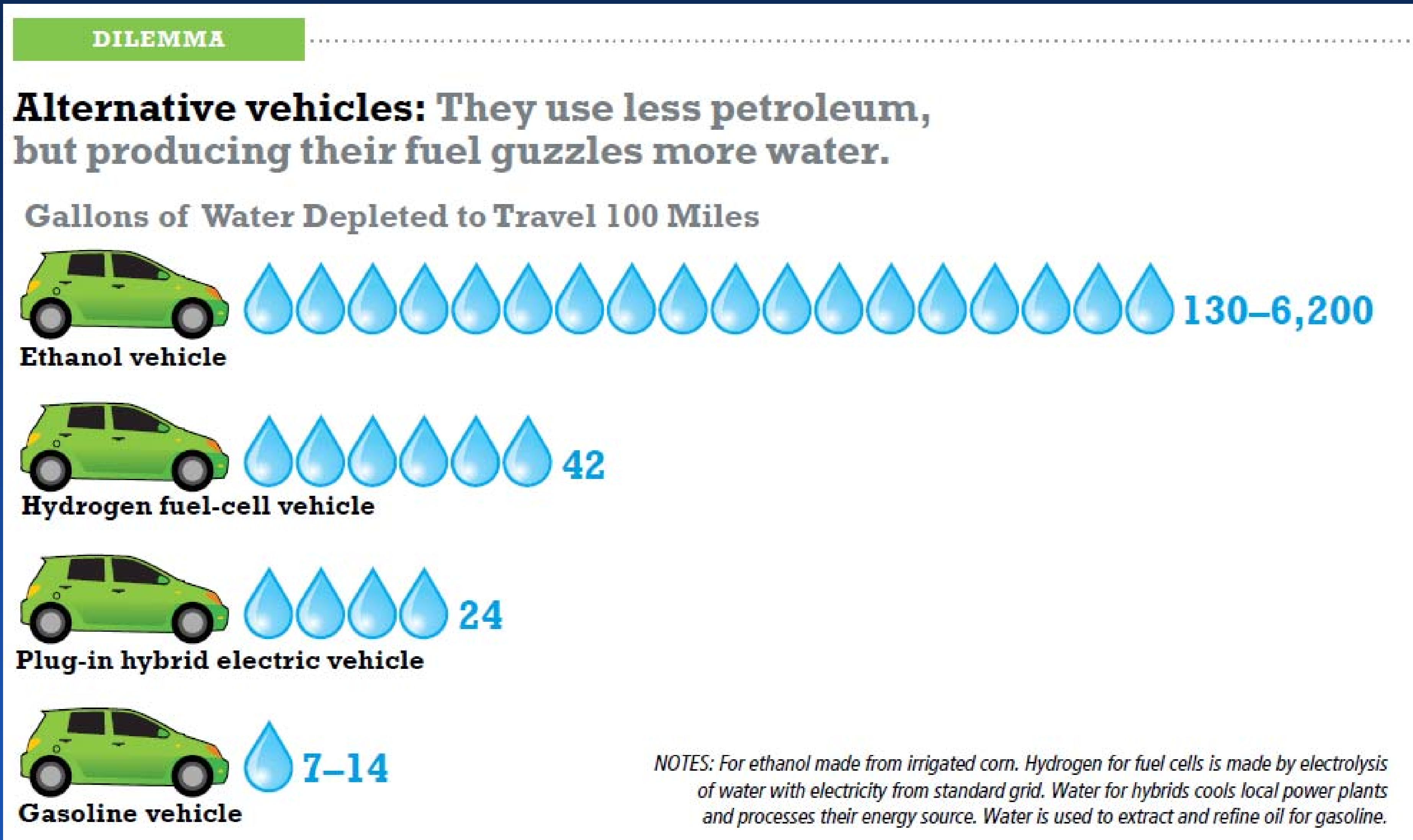
# Water Use by Plant/Fuel Type




*Source: Goldstein, 2009*




*Source: Webber, 2008*

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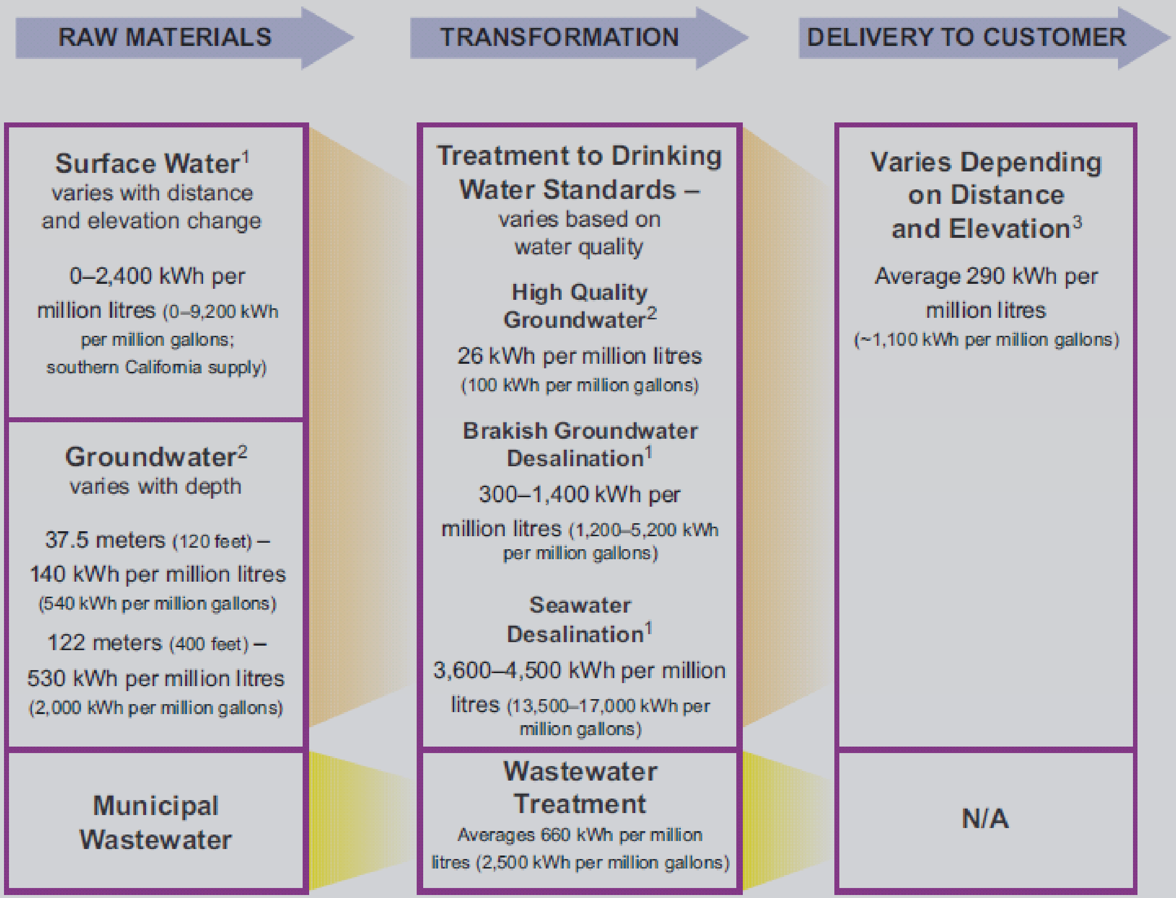
## Domestic Water Industry Value Chain – Energy Consumption




Source: Cambridge Energy Research Associates.
1. *Energy Down the Drain: The Hidden Costs of California's Water Supply.* Natural Resourse Defense Council and Pacific Institute, August 2004.
2. *Energy Demand on Water Resources: Report to Congress on the Interdependence of Energy and Water.* US Department of Energy, December 2006.
3. Electric Power Research Institute: *Water and Sustainability (Volume 4): US Electricity Consumption for Water Supply and Treatment – The Next Half Century, 2000.*
Note: kWh= kilowatt-hour.
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# Energy Use in the Water Industry

In Southern California, surface water delivery uses up to 9,200 kWh per million gallons

*Source: World Economic Forum, 2009*

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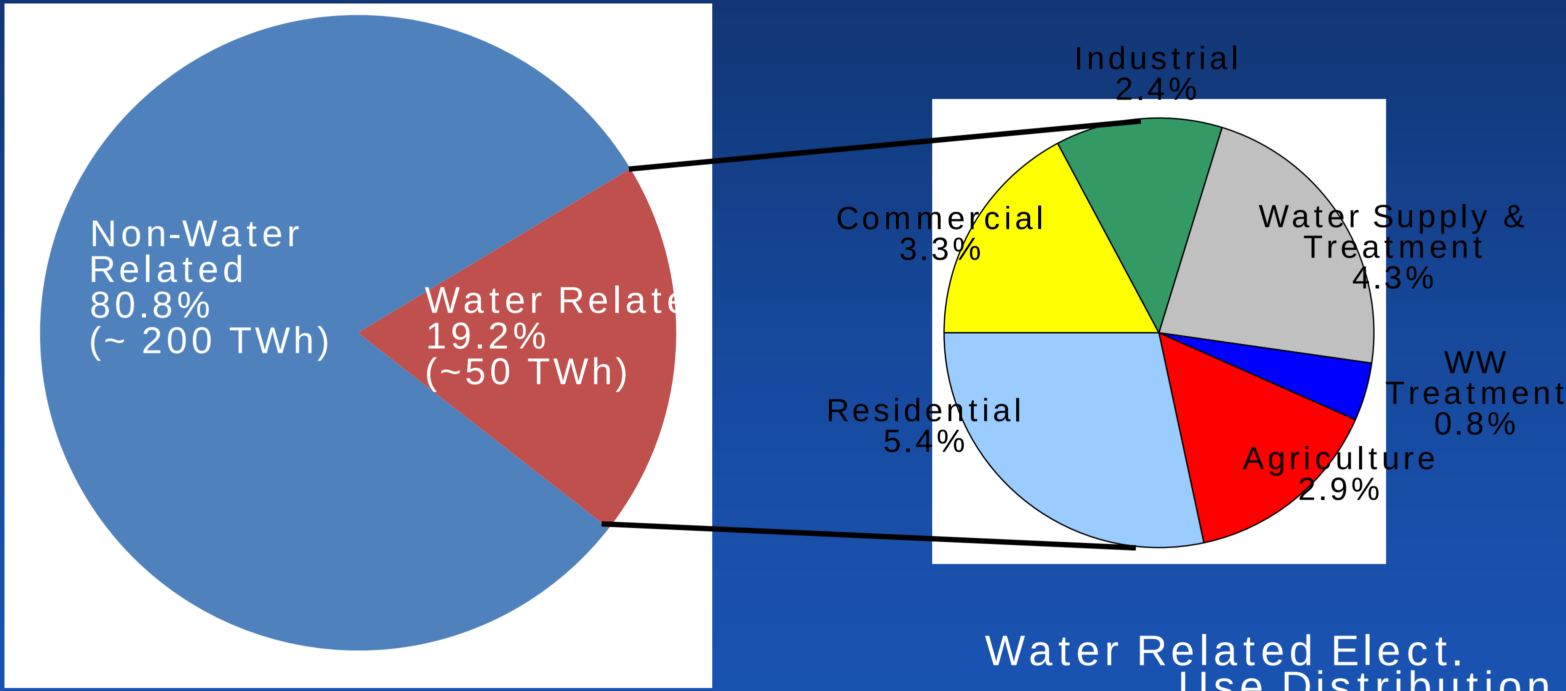
## Electricity Use by Water Sector: *California Case Study*

Electricity Use: Cold Water Boundary 5.1%
End Use 14.1%

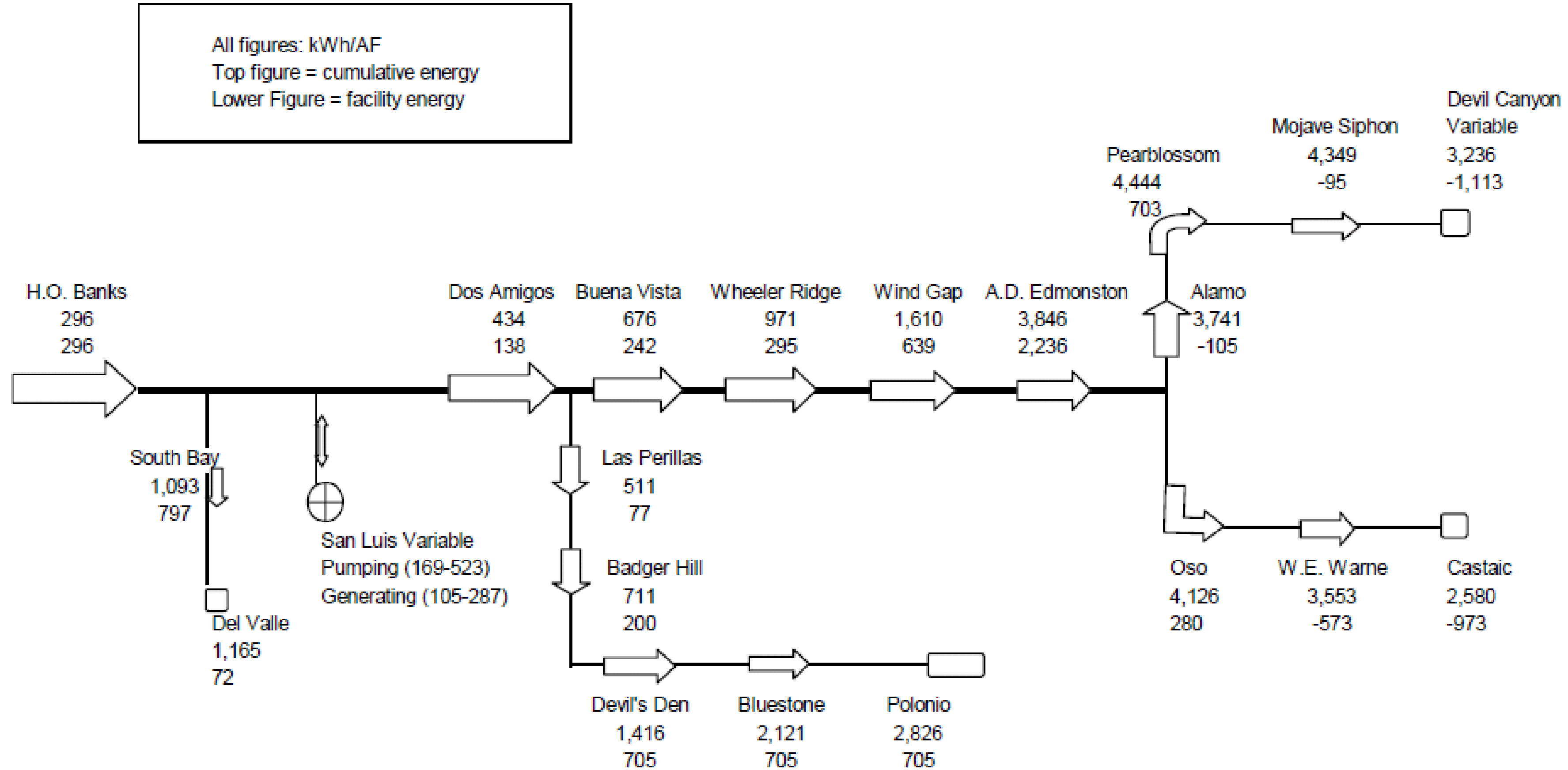



CA Electricity Use (250 TWh)

Water Related Elect. Use Distribution

CEC: W-E Report 2005 (using data for 2001)

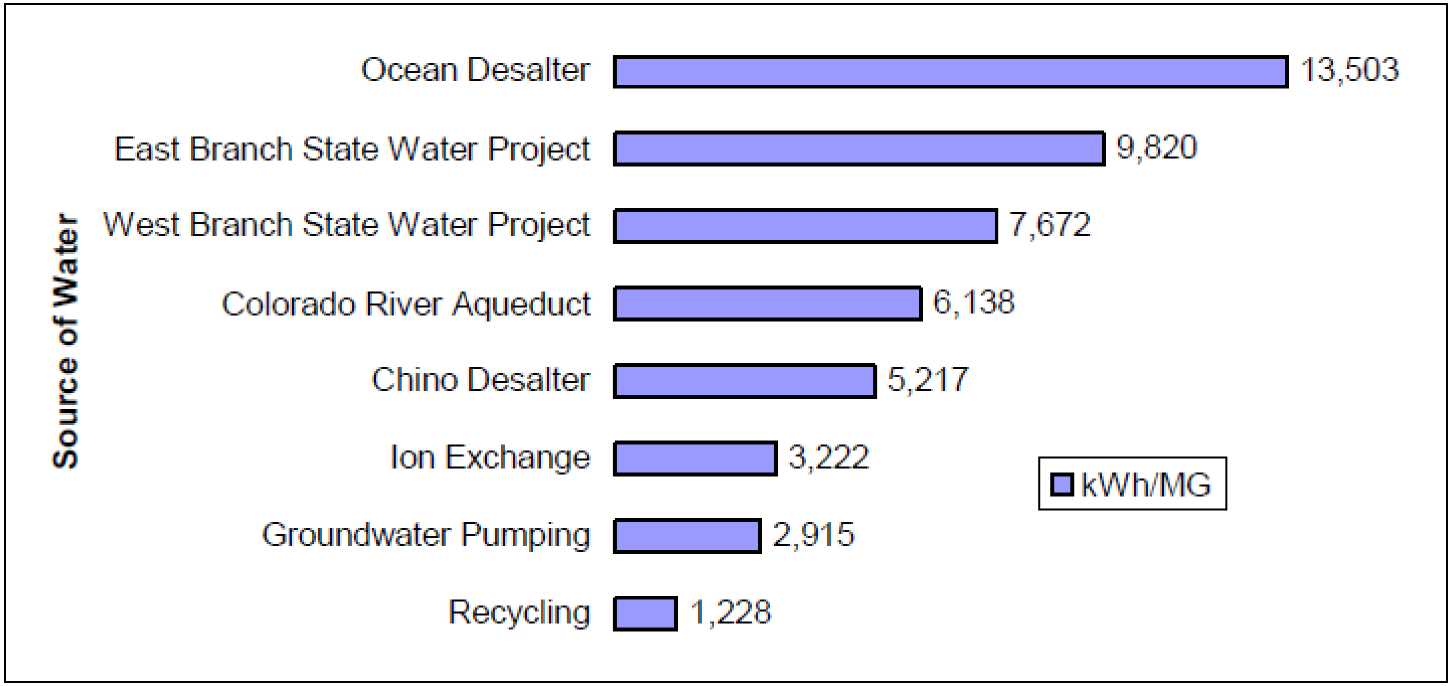
# California State Water Project Pumping Energy




Source: Dr. Robert Wilkinson, PhD, University of California, Santa Barbara, based on DWR data.

*Source: CEC, 2005*

# Energy Intensity of Water Supply Options in Southern California




Source: Dr. Robert Wilkinson, Environmental Studies Program, University of California, Santa Barbara, and Martha Davis, IEUA.

*Source: CEC, 2005*

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# Water Quality Impacts of Energy

| Energy Element | Water Quality Impact |
|---|---|
| Any type of thermo-electric plant | Thermal and air emissions impact surface waters and ecology |
| Hydroelectric plants | Impacts water temperatures, quality, ecology |
| Biofuels and ethanol | Fertilizer runoff impacts water quality<br>Refinery wastewater treatment required |
| Solar PV and wind | None during operation, minimal water use for panel and blade washing |
| Synfuels and hydrogen | Wastewater treatment required |
| Coal Slurry Pipelines | Final water is poor quality, requires treatment |

*Source: USDOE 2006*

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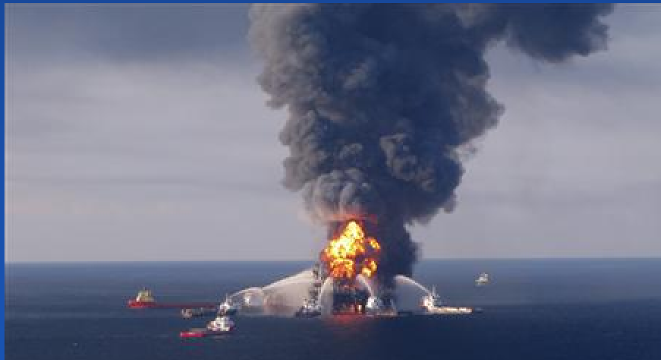
# Water Quality Impacts of Energy:
## Oil and gas as energy sources

- Onshore oil and gas exploration can impair shallow groundwater quality
- Offshore drilling can lead to disastrous oil spills (such as the recent spill in the Gulf of Mexico)
- Other ways that use of oil and gas can lead to surface and/or groundwater contamination:
  - Traditional oil and gas refining
  - Barge or truck transport can lead to spills or accidents
  - Oil and gas storage caverns
  - Energy pipeline wastewater



**Oil exploration explosion in Gulf of Mexico**

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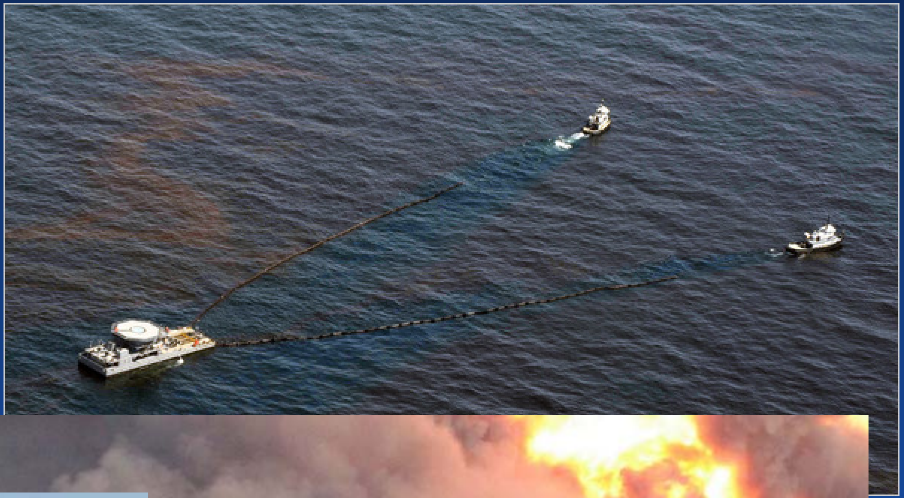
*Source: USDOE, 2006*

# Water Quality Impacts of Energy:

## BP Gulf of Mexico Spill

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# Water Quality Impacts of Energy:

## Mountaintop Removal with Valley Fills (MTR/VF)

- Mountaintops cleared, debris and excess rock is pushed into valleys and buries streams
- Water quality data from West Virginia streams indicate severe, negative impacts to the environment
  - Streams show increases in metals, pH, electrical conductivity, and total dissolved solids (sulfate, calcium, magnesium, bicarbonate ions)
  - Groundwater also shows increases in mine-derived chemicals
- High potential for human health impacts
- Huge ecological losses
- Some watersheds in WV have more than

10 percent of their total area disturbed by surface mining

**Water downstream from a mountaintop removal coal mine**

*Source: Palmer et al., 2010*

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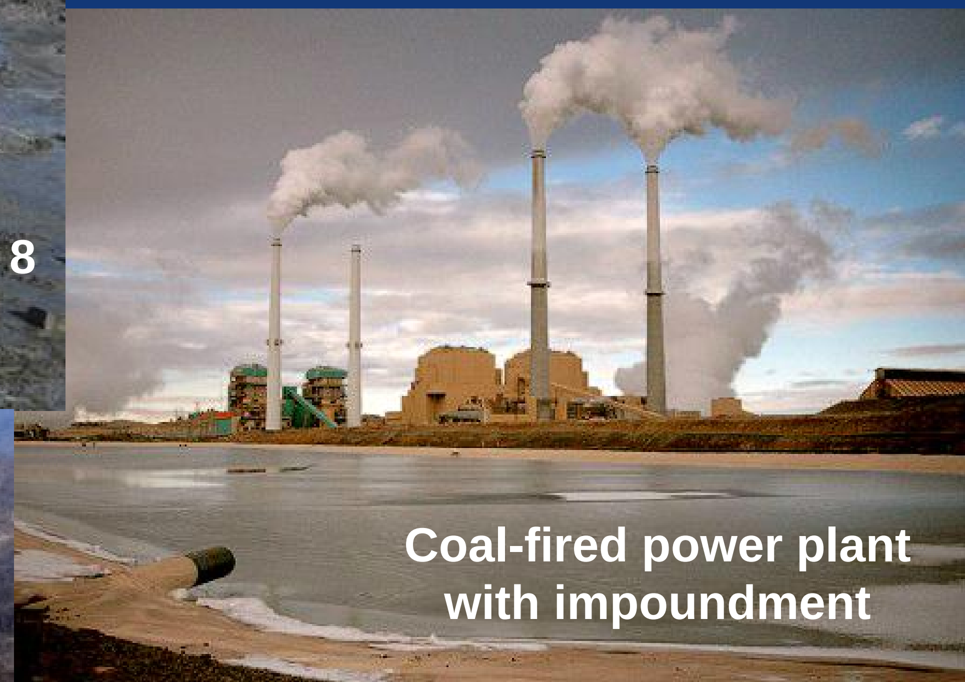
# Water Quality Impacts of Energy:

## Coal mining and Coal-fired Power Plants

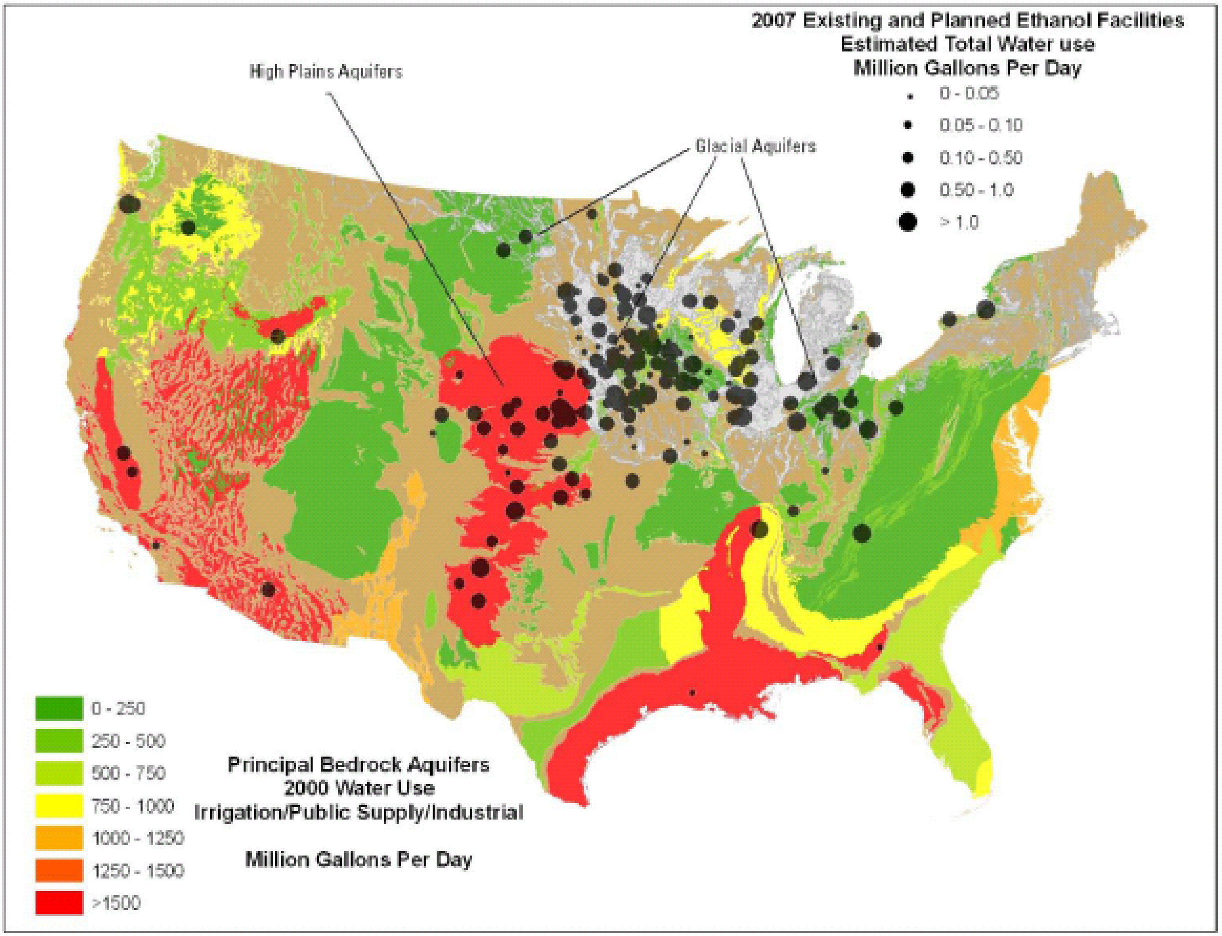
“Public utility dike bursts, floods 8 to 10 homes”
TVA coal slurry spill in 2008



Coal-fired power plant with impoundment

Slurry impoundment in West Virginia

# Energy Independence and Security Act 2007 (EISA)
# 15 Bg/yr biofuels production by 2015 and 36 Bg/yr by 2022 - Ethanol Facilities and Major Aquifers (Ward, 2007)




*Source: Ward, 2007 as cited in Schnoor, 2009*

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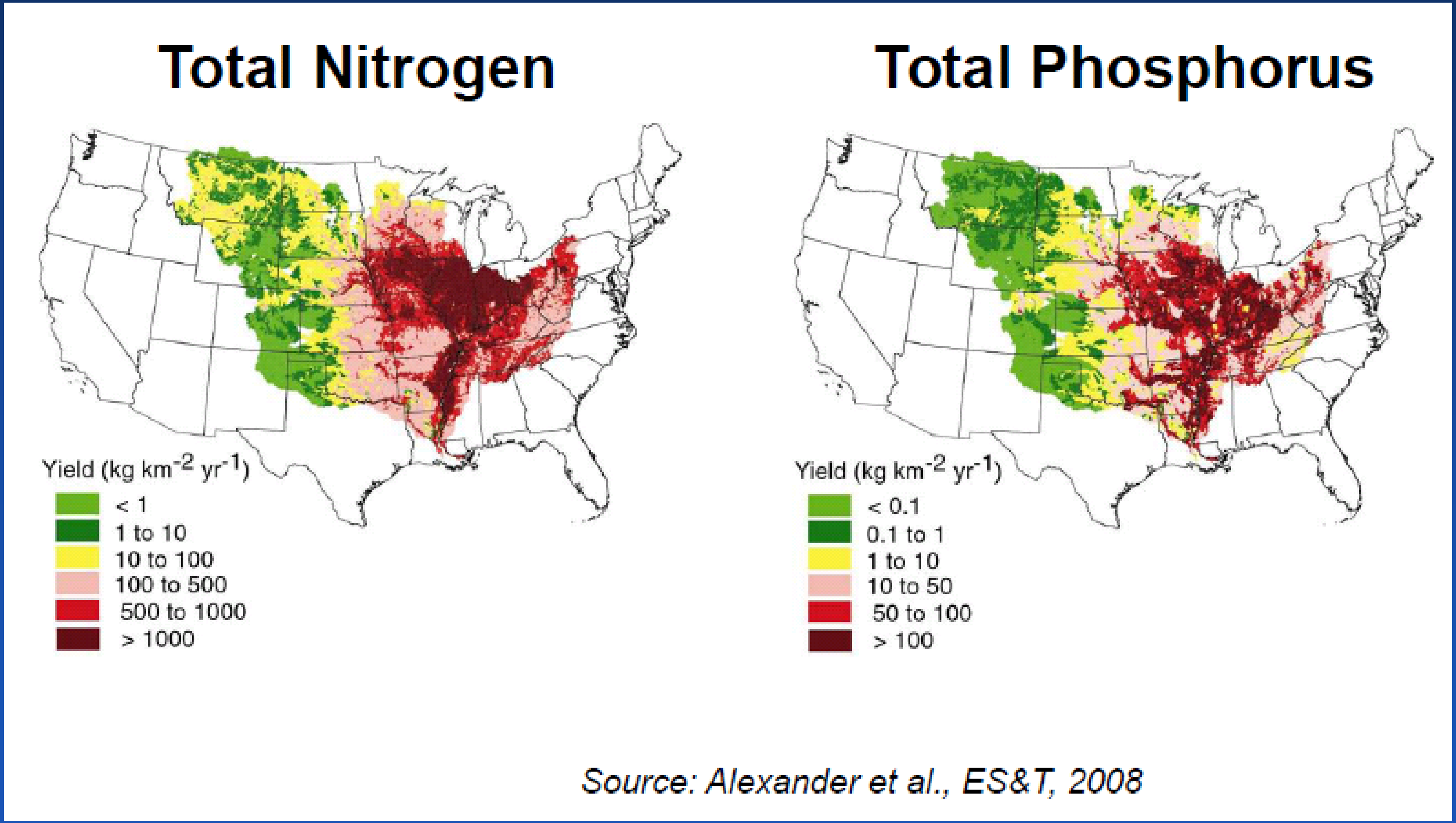
# Nutrient yield delivered to Gulf of Mexico




*Source: Alexander et al., ES&T, 2008 as cited in Schnoor, 2009*

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# Finding 8: Barriers to Accelerated Deployment

*A number of barriers could delay or even prevent the accelerated deployment of the energy-supply and end-use technologies described in this report.*

*Policy and regulatory actions, as well as other incentives, will be required to overcome these barriers.*

*Source: National Academies, July 2009*

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# Barriers to Accelerated Deployment

(National Academies Report – 2009)

- *Lack of private-sector investments for technology deployment*
- *The low turnover rate of the energy system's capital-intensive infrastructure,*
- *Resource and supply barriers to technology deployment*
- *Uncertainties arising from the nature and timing of public policies and regulations related to carbon controls*
- *Coupling the commercial deployment of energy-supply technologies  with key supporting technologies*
- *The lack of energy efficiency standards for many products*

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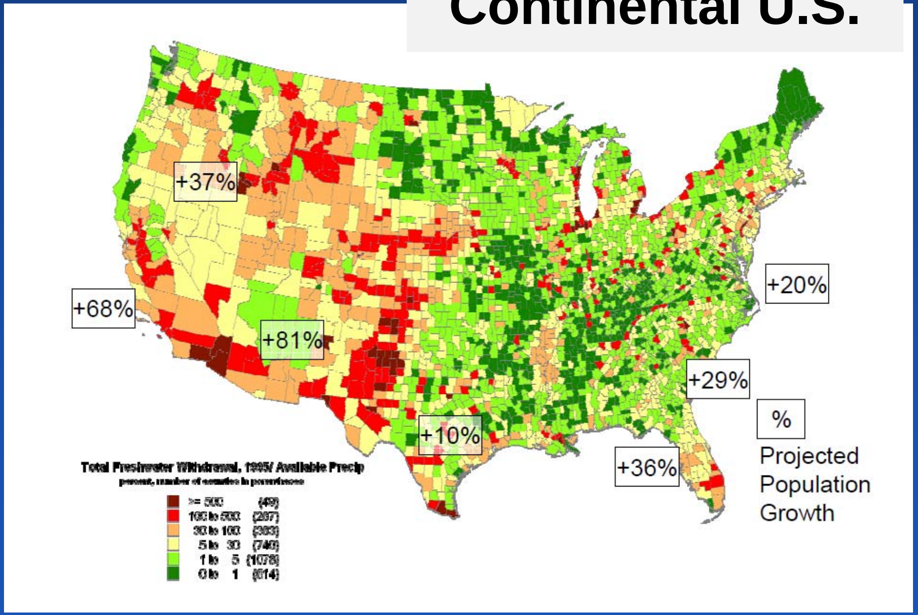
# Access to and Cost of Water – A Market Driver

- Access to water increasingly seen as a risk in siting new power plants, especially in water-stressed areas
- As water becomes more scare and demand for energy increases, there will need to be a shift towards fuels and processes that consume less and/or pollute less water

**Water Stress in Continental U.S.**




*Source: World Economic Forum, 2009.; Map: USDOE 2006.*

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# Summary of Major National Needs and Issues Identified in the Regional Workshops on the Water/Energy Nexus - 2005

- 1. Need for Integrated regional energy and water resource planning and decision support
- 2 .Oil and gas produced water treatment for use
- 3. Water needs for emerging/renewable energy resources
- 4. Improved biofuels/biomass water use efficiency
- 5. Improved water efficiency in thermoelectric power generation
- 6. Energy efficiency for impaired water treatment and use
- 7. Improved water supply and demand characterization/monitoring
- 8. Infrastructure changes for improved energy/water efficiency

Sandia National Labs, M. Hightower, 2006, *“Energy-Water Science and Technology Research Roadmap”*
*www.sandia.gov/energy-water*

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# Final Thoughts: Water – Energy Nexus

- Water – energy conflicts are increasing – clear need for innovative resource management strategies
- Water supply demands will increase energy requirements for water value chain – increased costs to consumers.
- Water quality impacts of activities within energy value chain not fully appreciated at national scale – a factor to consider in integrated resource management
- Strategies to reduce GHGs and meet sustainability goals on climate will generally reduce water intensity of energy production

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Mkavanaugh@pirnie.com

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