Water Implications of Advanced Energy Choices: *Understanding the challenges and opportunities*

National Renewable Energy Laboratory
Innovation for Our Energy Future

NACWA
2010 Summer Conference and 40th Annual Meeting

July 21, 2010

Robin L. Newmark
Director, Strategic Energy Analysis Center

"Hot, Flat and Crowded"

(Thomas Friedman, 2008)"

Global Warming

Water resources increasingly stressed

Rise of the middle class

…all wanting to consume like Americans, with resource implications!

Population growth

*Between now and 2020, there will be another 1 billion people in the world. If Tom gives each of them a 60W light bulb, it will require about 20 new 500-MW coal-burning power plants, just so they can turn on their light bulb. That requires about 160 billion gallons/day (**nearly 500 acre-ft**) of water to produce. If I give them each a glass of water, it will require almost **200 acre-ft**!*

Hot, Flat and Crowded: California in 2050

Global Warming

Rise of the middle class?

Population growth

- Mean temperature may rise 1.5-5.0°F
- Sierra Nevada snowpack may decrease by 25-40%
- Average annual precipitation may show little change, but more intense wet and dry periods can be expected– more floods and more droughts.
- Flood peaks will become higher and natural spring/summer runoff will become lower.
- A possible sea level rise of 4-16 inches
- Higher sea levels will increase salinity in the Delta.

Source: State of California, Department of Water Resources, Water Plan Update 2009 Highlights

- Population at 60 million (up from 36 million today)
- Demographic shifts
- Movement inland

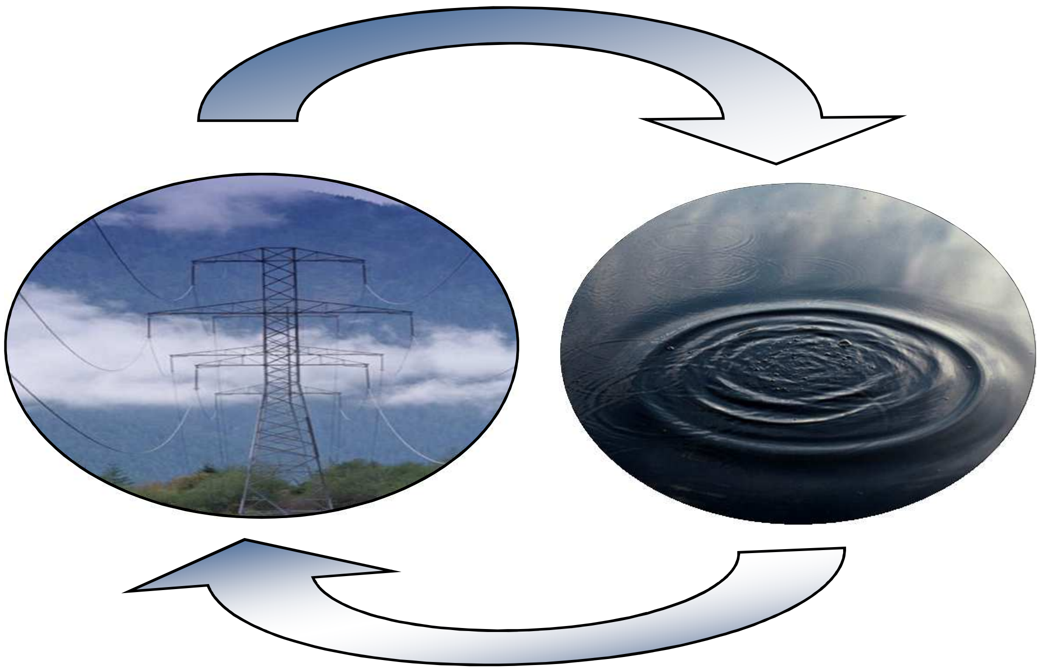
Source: State of California, Department of Finance, Population Projections for California and Its Counties 2000-2050, Sacramento, California, July 2007

Energy and Water are linked:

Energy for water and water for energy

Energy production requires water

- Thermoelectric cooling
- Hydropower
- Extraction and mining
- Fuel Production (H_2, ethanol, biofuels)
- Emission controls

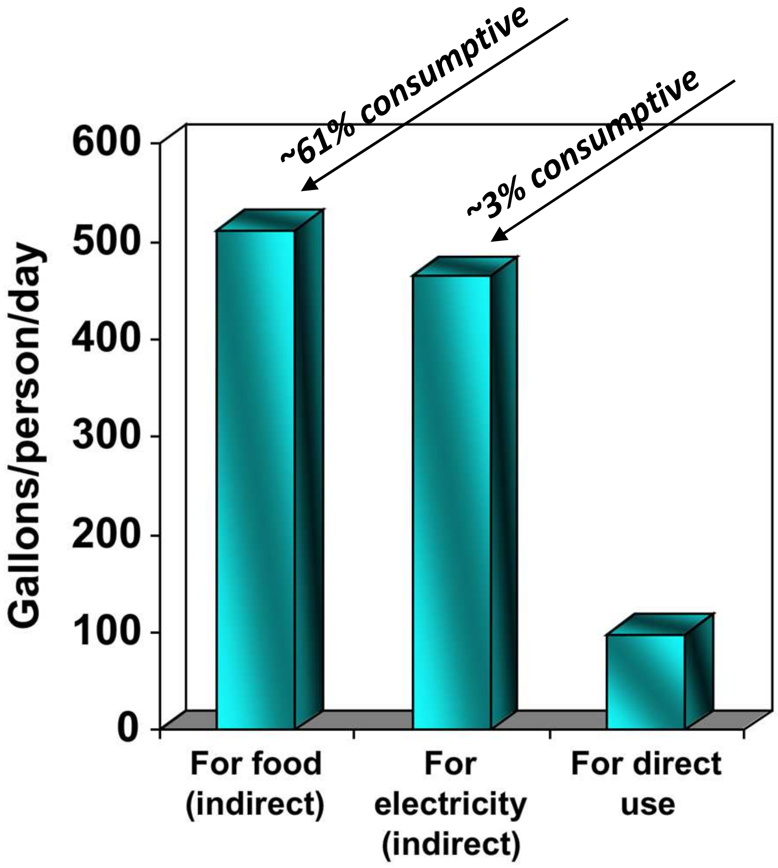


Water production and distribution require energy

- Pumping
- Treatment
- Transport

Water for Energy

Water needed to produce household electricity exceeds direct household water use



GALLONS PER PERSON PER DAY

510 for food production

- includes irrigation and livestock

465 to produce household electricity

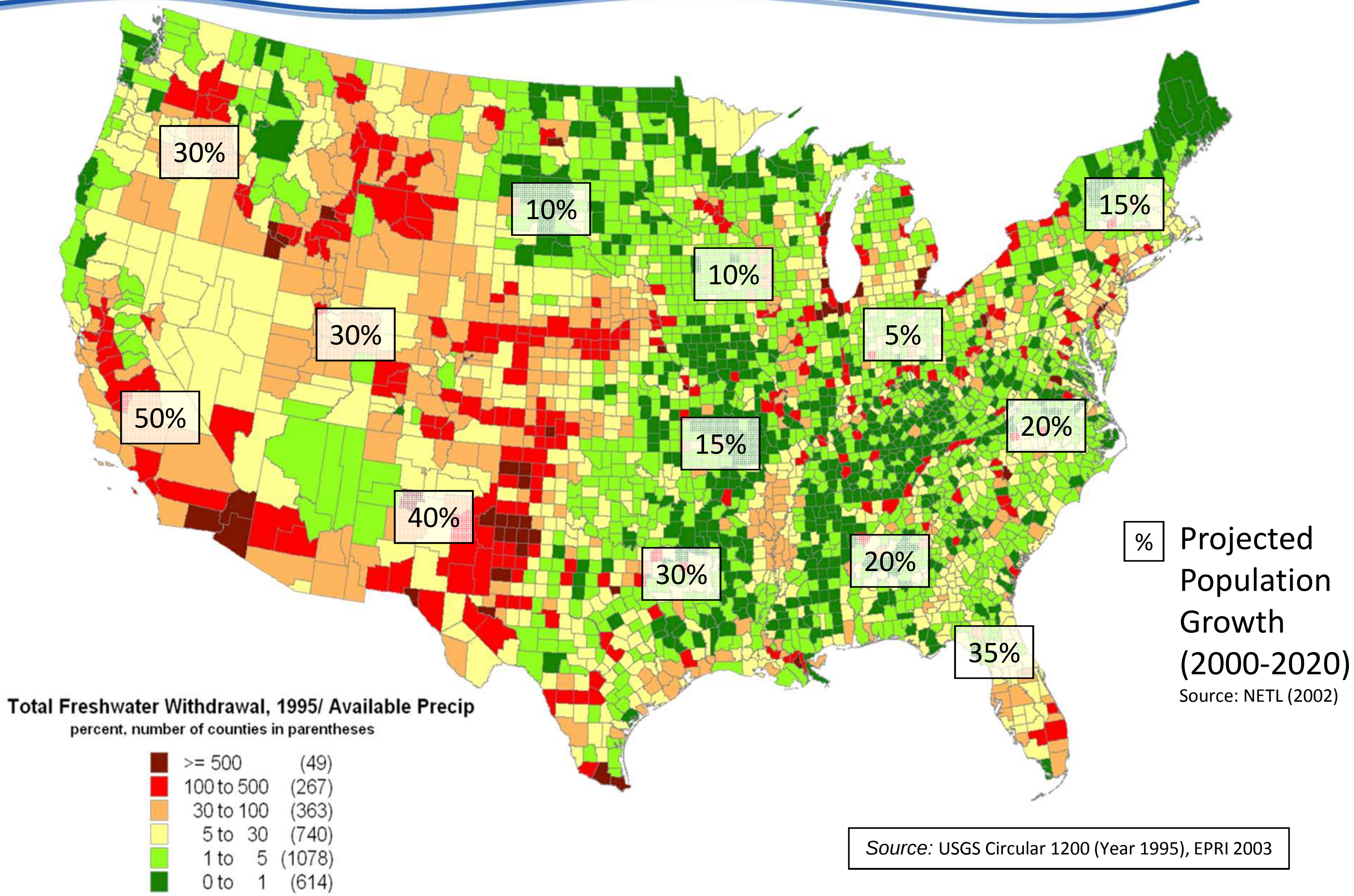
- Range: 30 to 600 depending on technology

100 direct household use

- includes bathing, laundry, lawn watering, etc.

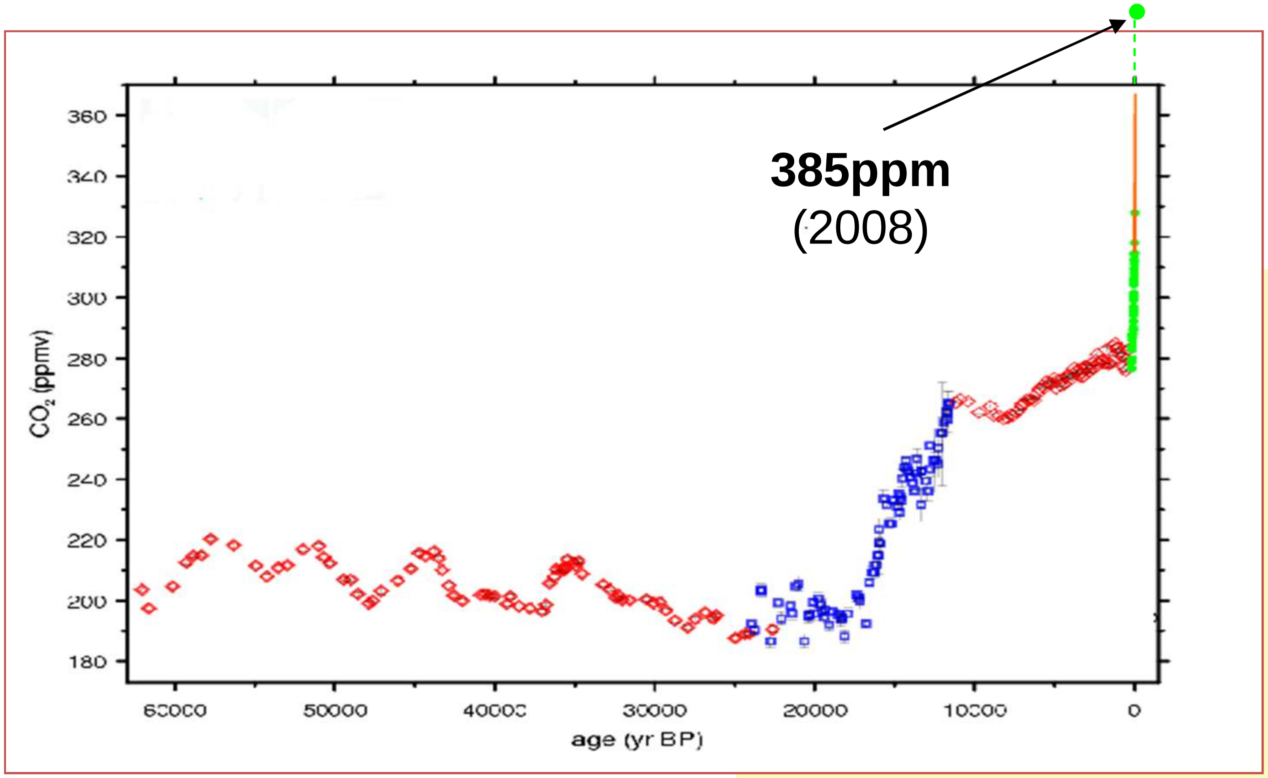
Source: derived from Gleick, P. (2002), *World's Water 2002-2003*.

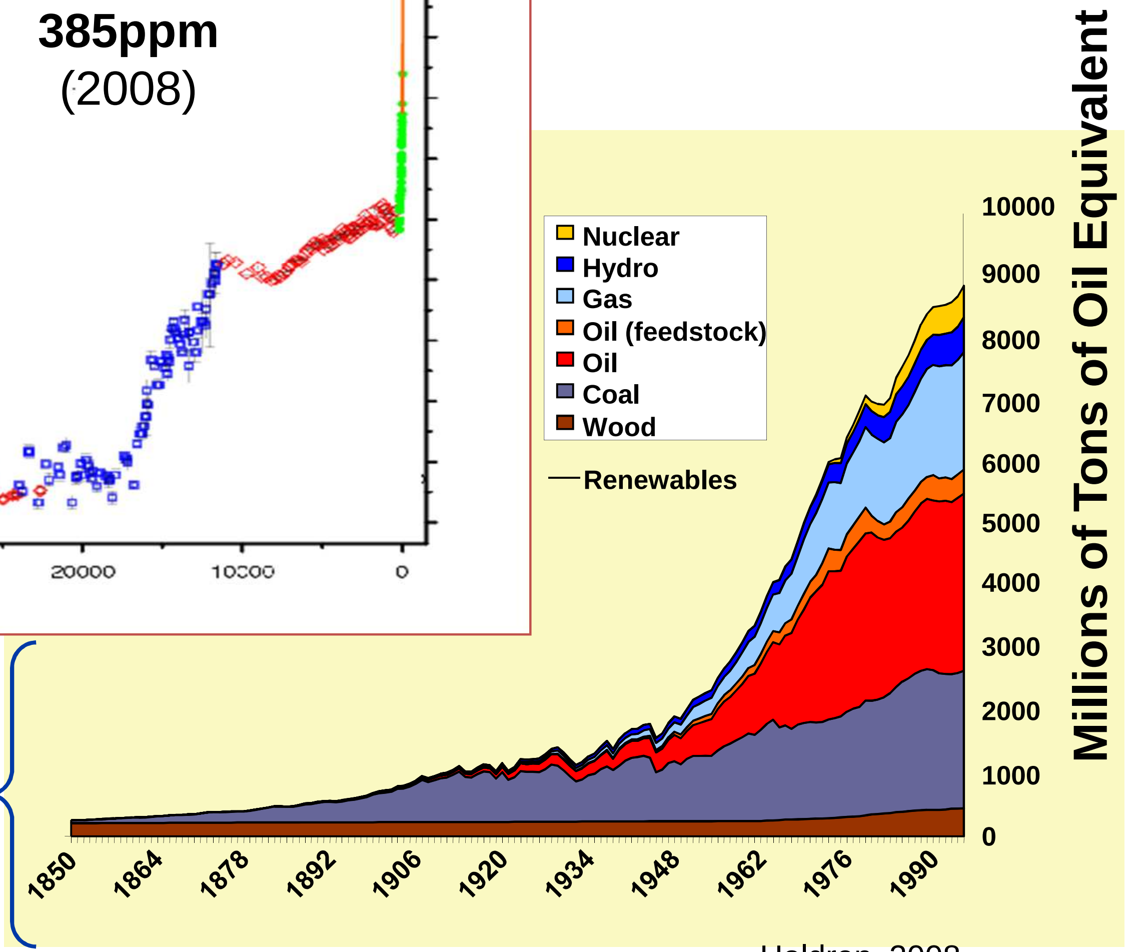
Water challenges are nationwide



Source: USGS Circular 1200 (Year 1995), EPRI 2003

The dominant energy trends are increased fuel use and increased CO_2 emissions

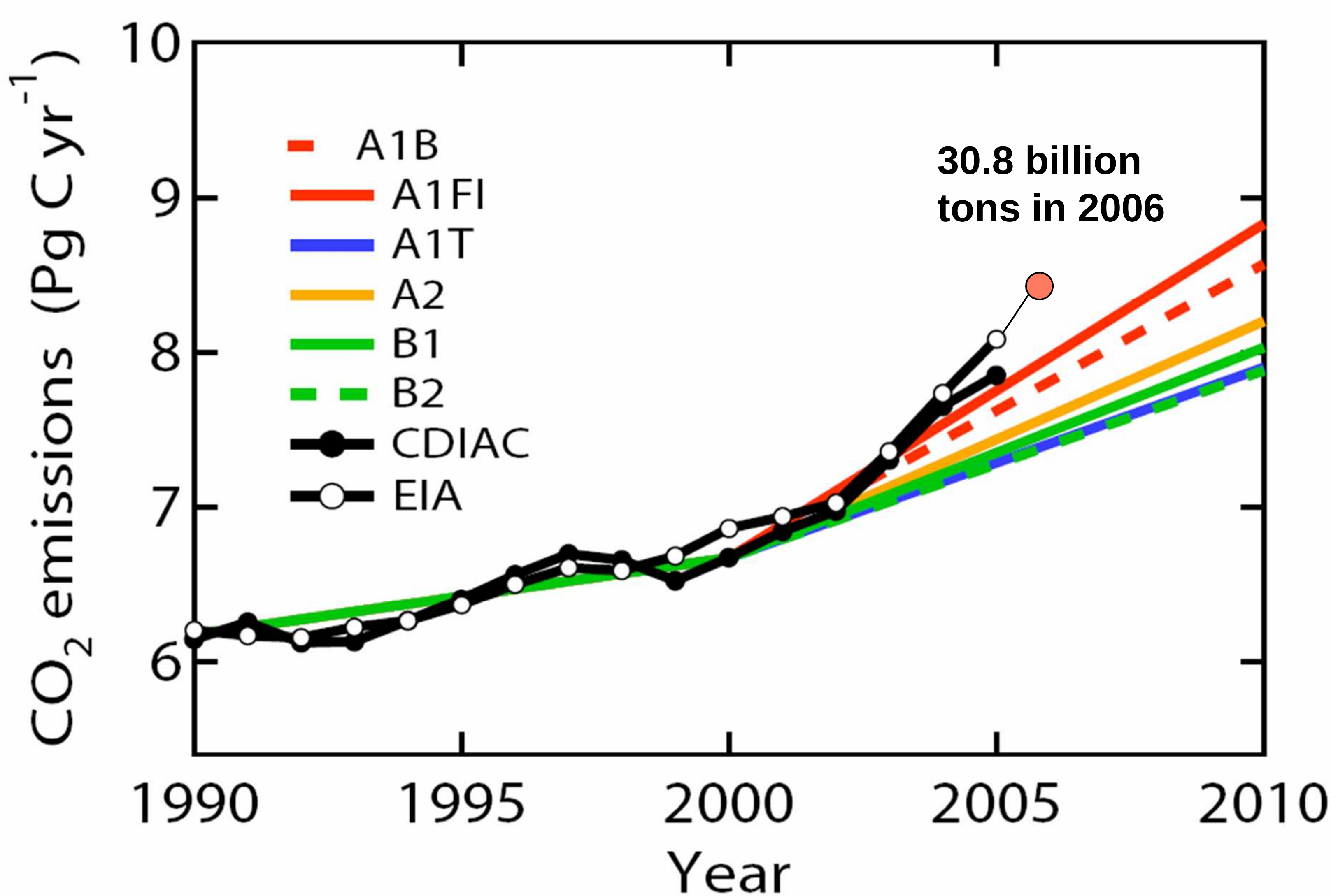




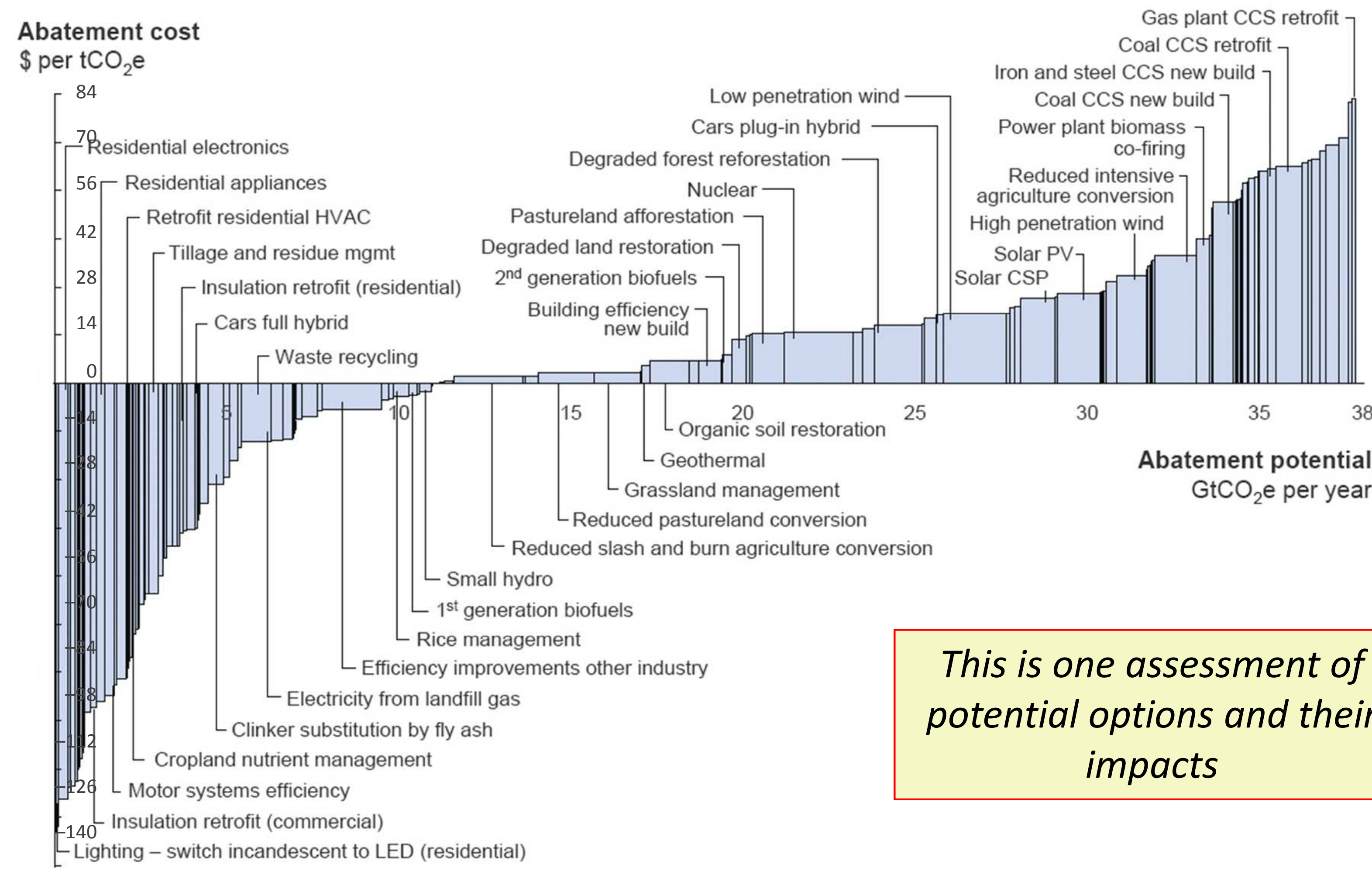
Holdren, 2008

We have never used less of any fuel
If all future demand were met by zero carbon sources, we'd have the same graph

Actual emissions for 200-2007 are well above the worst case IPCC emissions scenarios



McKinsey & Co global GHG abatement cost curve beyond business-as-usual 2030: lots of options considered



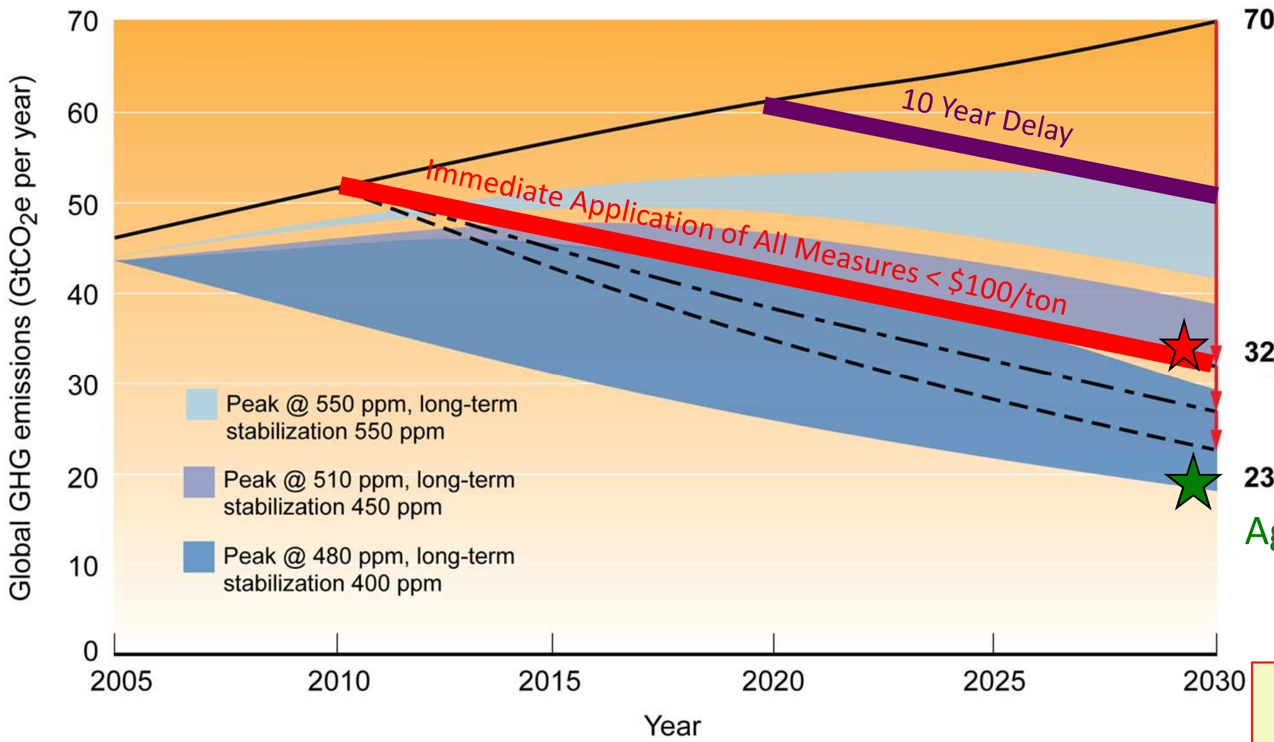
Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below $84 per tCO_2e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.
Source: Global GHG Abatement Cost Curve v2.0

This is one assessment of potential options and their impacts

Source: McKinsey&Co, 2009

Global emissions relative to different GHG concentration pathways: indications for rapid response

A 10-yr delay in taking abatement action would make it virtually impossible to keep global warming below 2ºC (McKinsey, 2009)



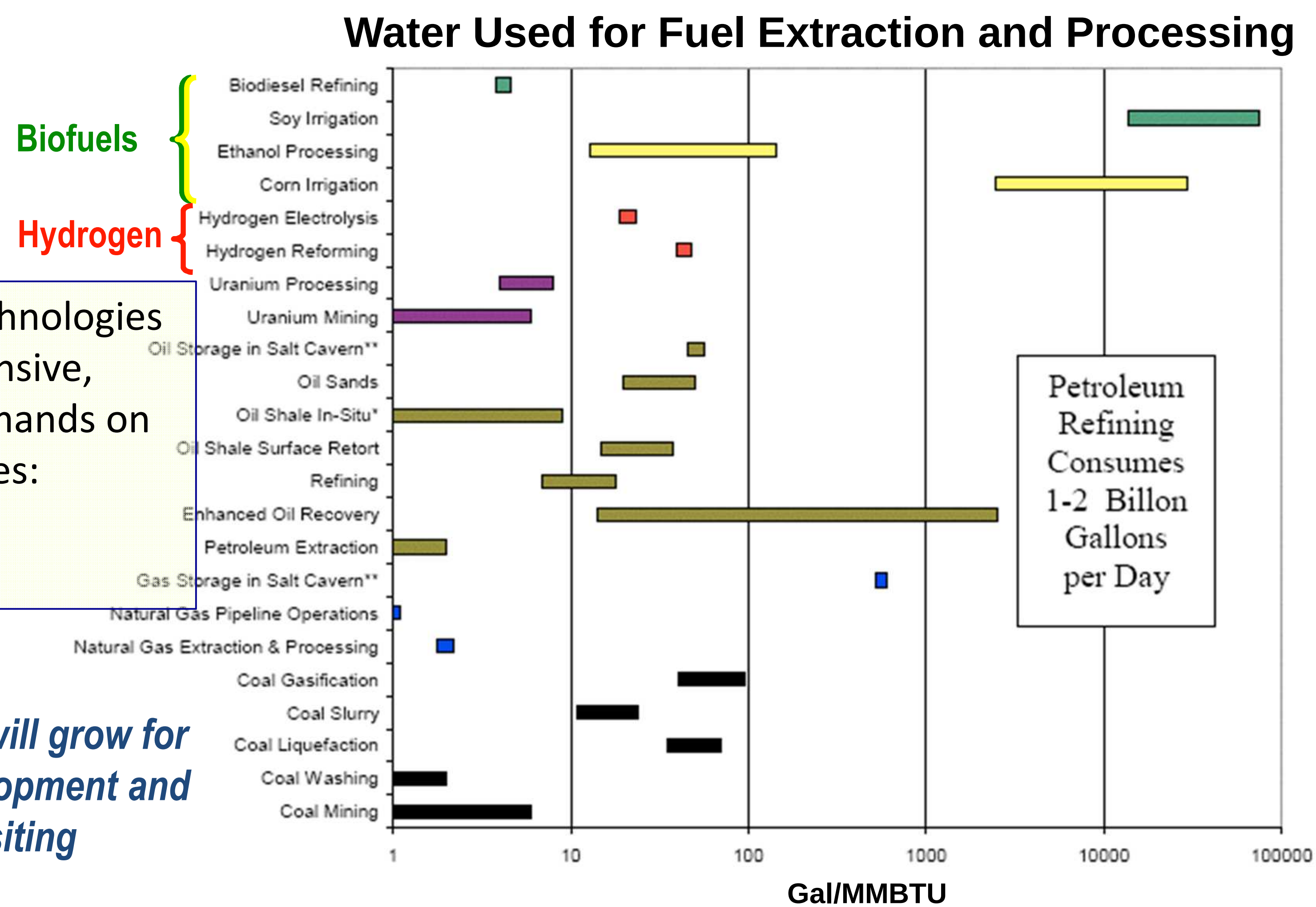
Gaps may be addressable by direct capture of CO_2 from the atmosphere

R. Aines, 2009, after McKinsey & Co., 2009

Substantial amounts of water are used in fuel extraction/processing

Future energy development will put new demands on water resources

Many new technologies are water intensive, increasing demands on water resources:
- Biofuels
- Hydrogen



Source: DOE Report to Congress (2007)

Constraints will grow for energy development and power plant siting

We will likely continue to use fossil fuel resources – because they are plentiful and we are used to them

Proved Recoverable World Reserve

Natural Gas
More than 5,000 Tcf

Coal
984 billion tons

Oil
Just over 1 trillion barrels

Estimated World Resource

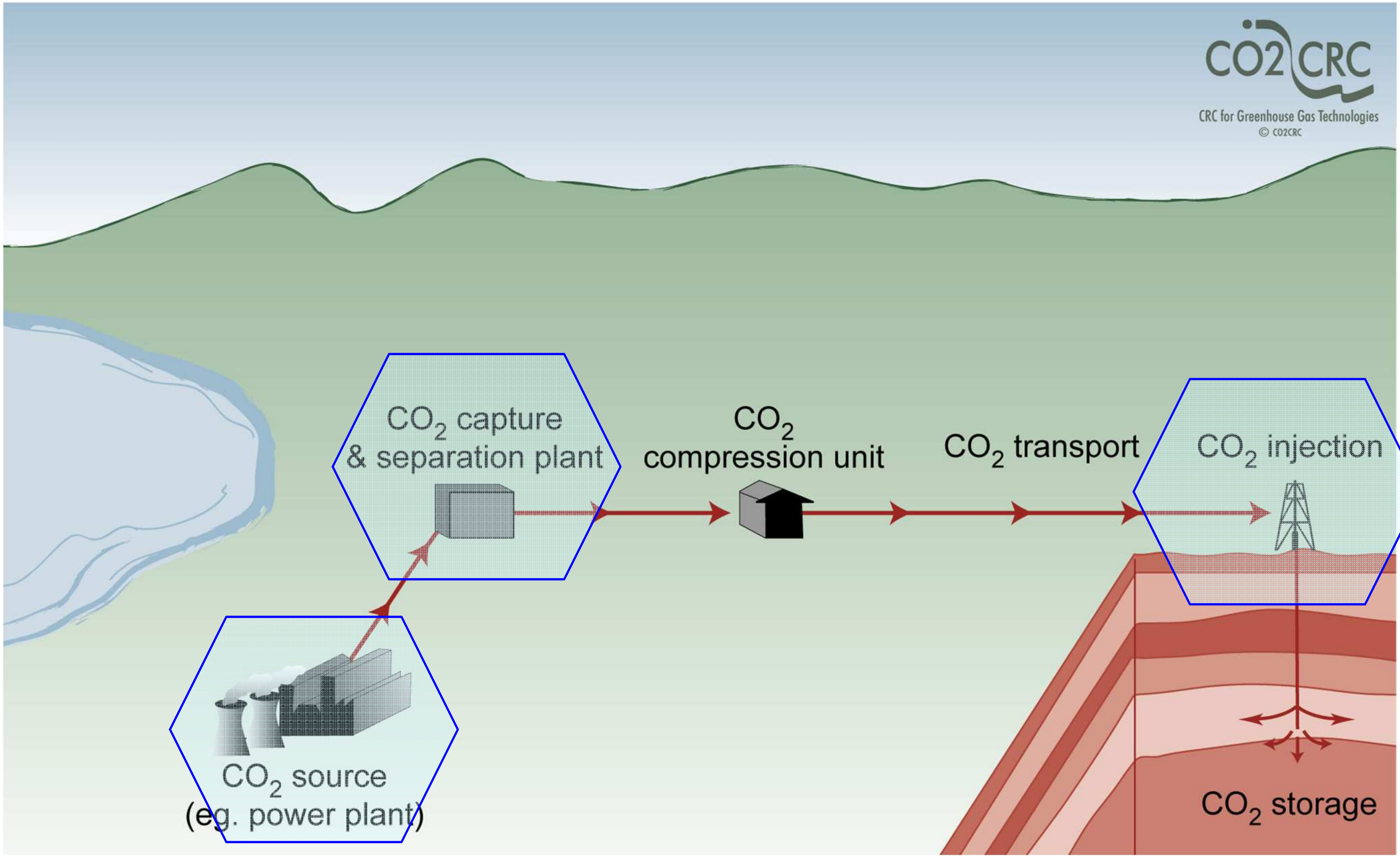
Methane Hydrates
Up to 270 Million Tcf

Proved recoverable reserves should last most of the 21st century

World Energy Council
1998 Survey of Energy Resources

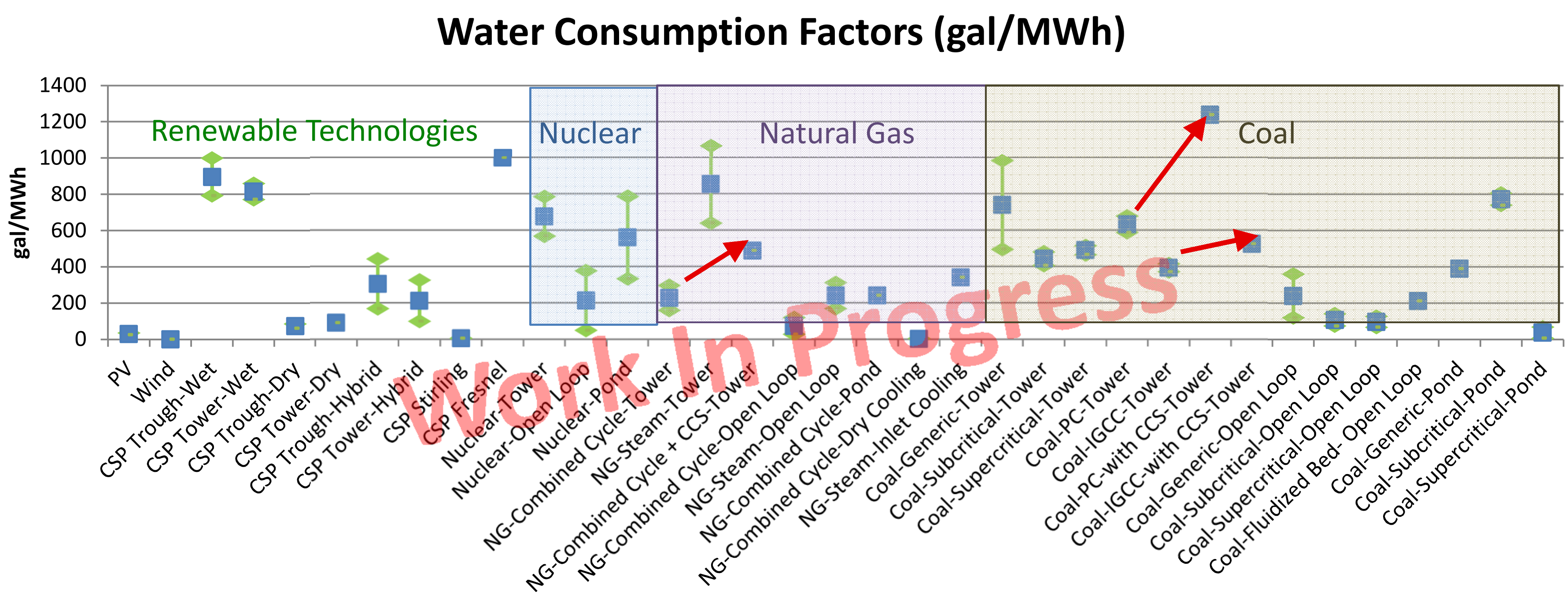
Carbon Capture and Sequestration (CCS) involves multiple processes –

some have water implications



Water requirements for electricity generation technologies

Differences result from both *generation* and *cooling* technologies

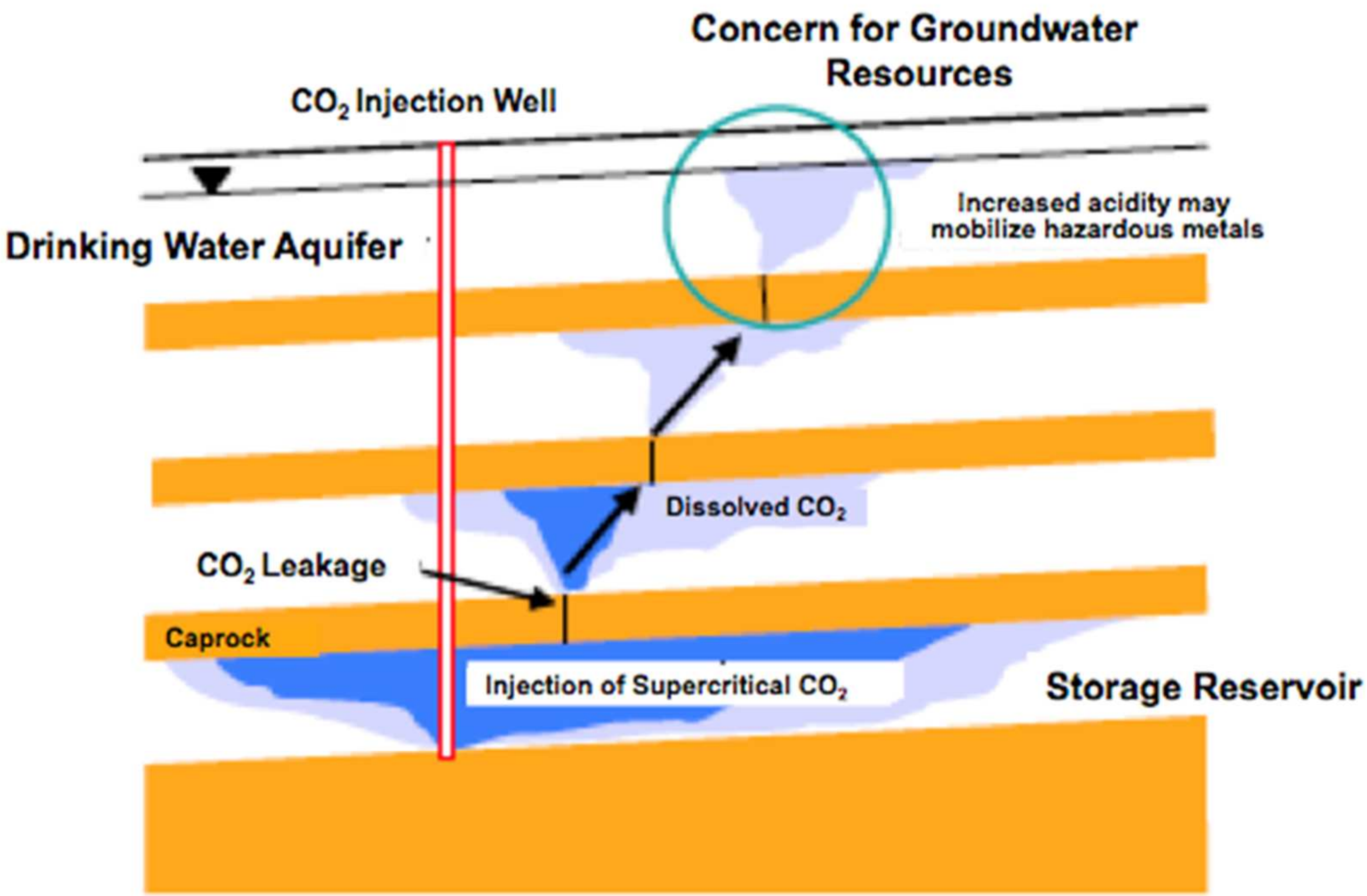


US DOE is supporting research in carbon capture

→ **Adding CCS**

(Macknick et al, in prep)

Groundwater quality can change in response to CO_2 leakage from deep geologic storage



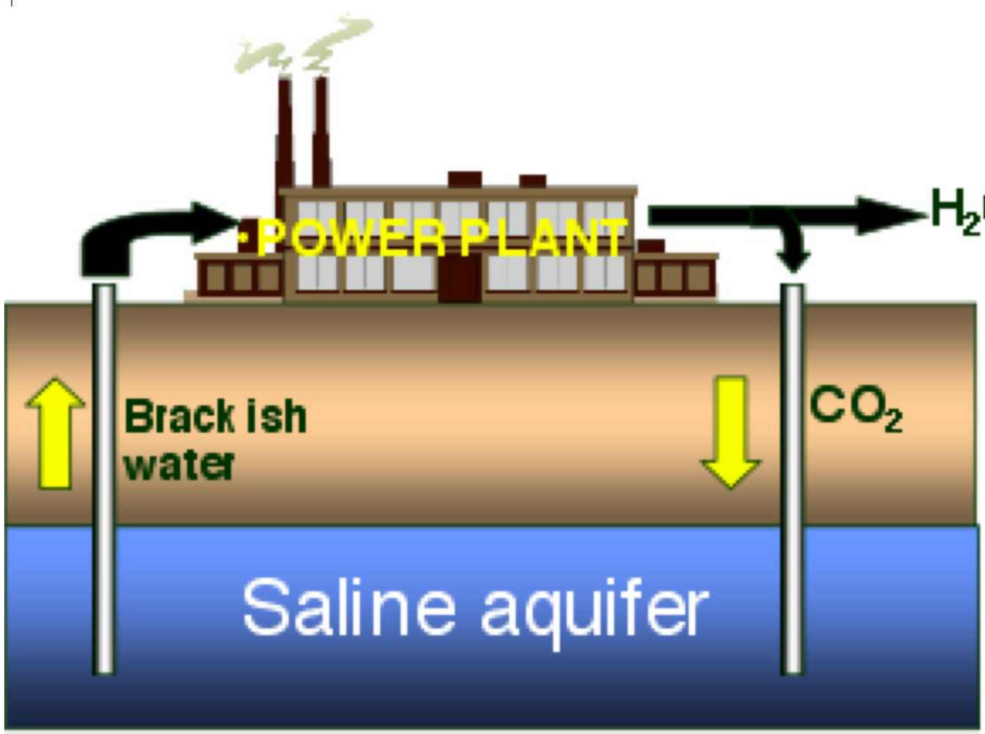
From Xu et al., 2007

Careful management and monitoring is needed

Synergistic opportunities: Simultaneous CO_2 removal and fresh water production (Decarbonation/Desalination)

Separate fresh water along with CO_2 from flue gas - *perform two separations in one operation*

Modern 1 GW IGCC plant's CO_2: 7.5 million m^3 →



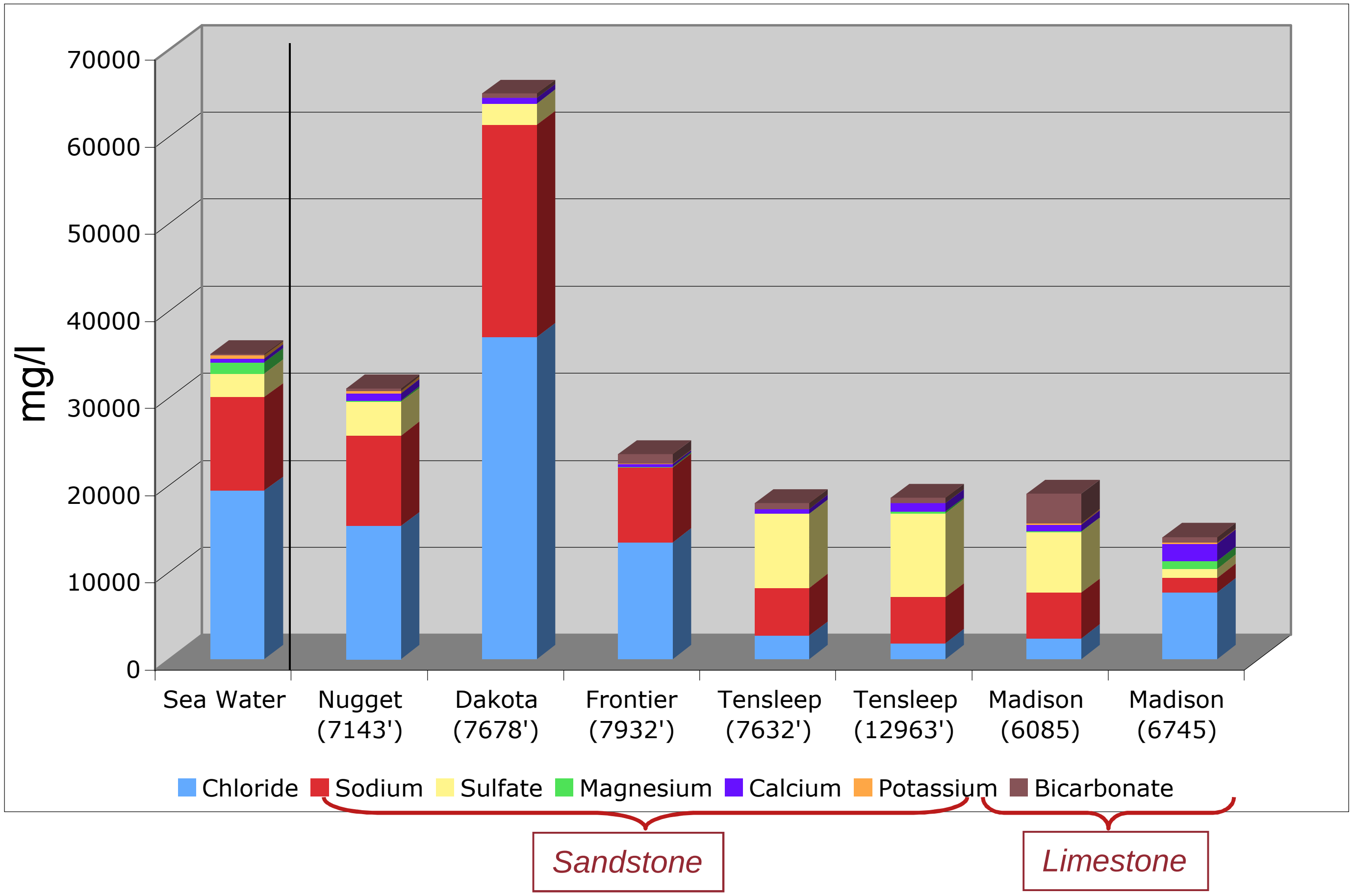
Source: Aines/Bourcier/Wolfe

Treating 7.5 M m^3 of displaced brine to create fresh water could:

- Help manage pressure in the saline aquifer
- Provide <u>half</u> the plant's operating fresh water (includes cooling)

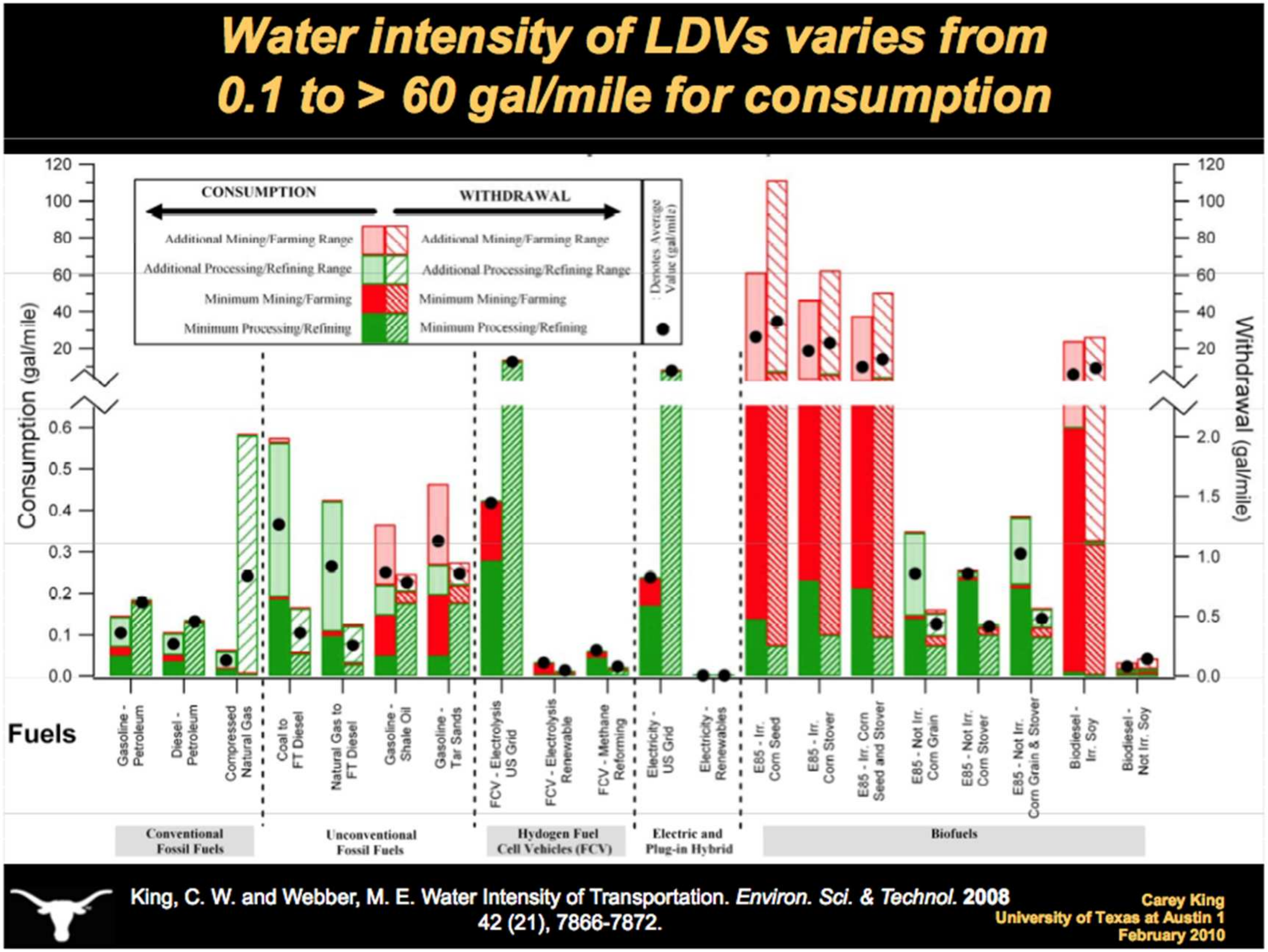
Water chemistries vary widely in potential CCS target formations: *this presents both challenges and opportunities*

Sea Water vs. Various Wyoming Formation Chemistries



Data courtesy of Vicki Stamp, RMOTC and Geoffrey Thyne, University of Wyoming, 2008

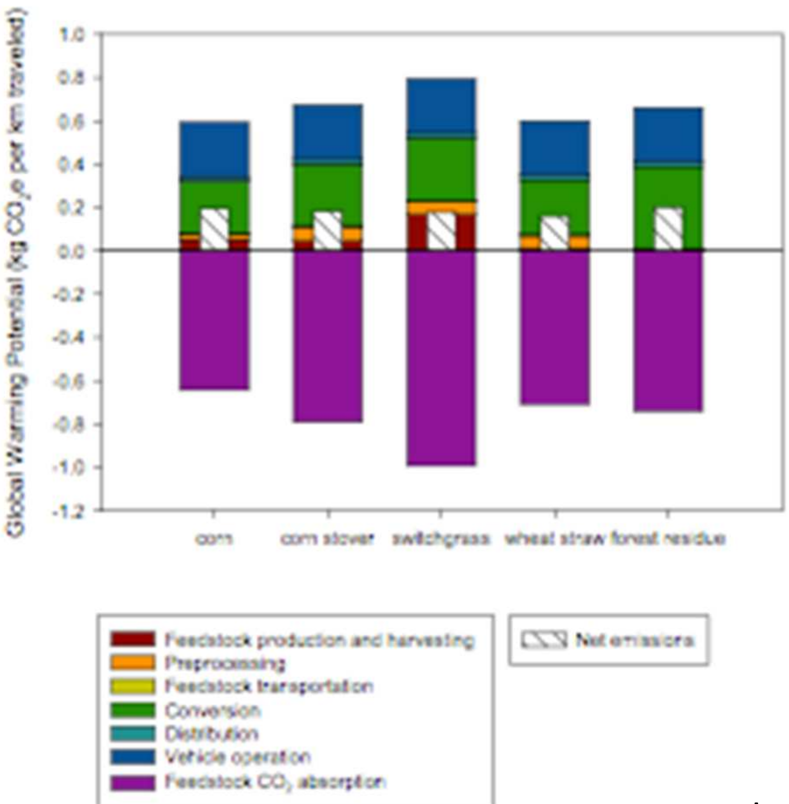
Water intensity of transportation fuels is likely to increase



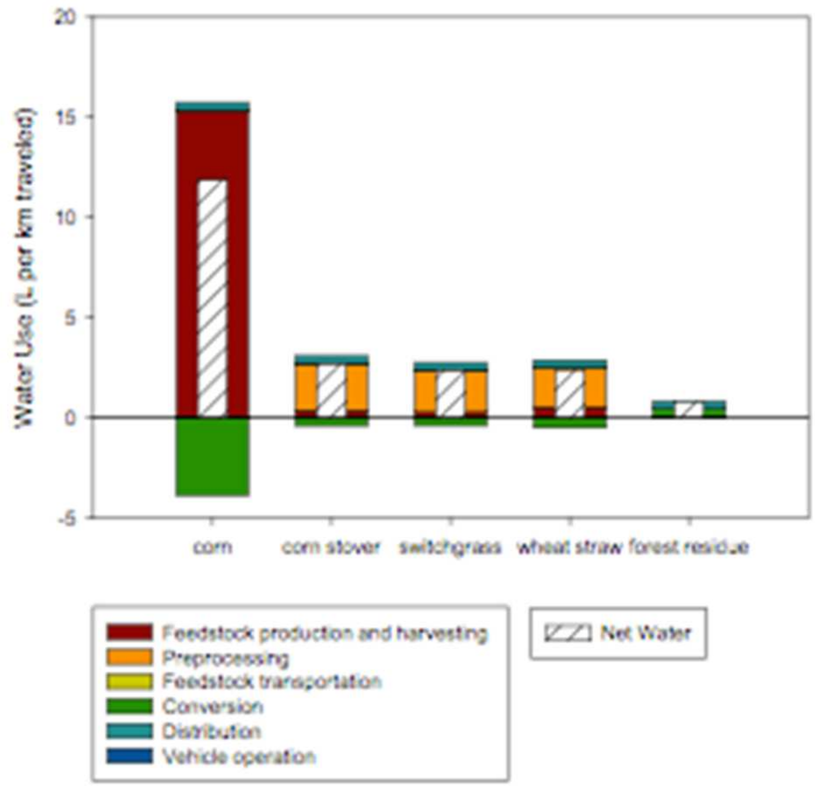
Life cycle assessments: where are the greatest impacts?

Example: LCA of Energy Independence and Security Act of 2007:
Ethanol-global warming potential and environmental emissions

GWP FOR 2022 E85 ACROSS FEEDSTOCKS

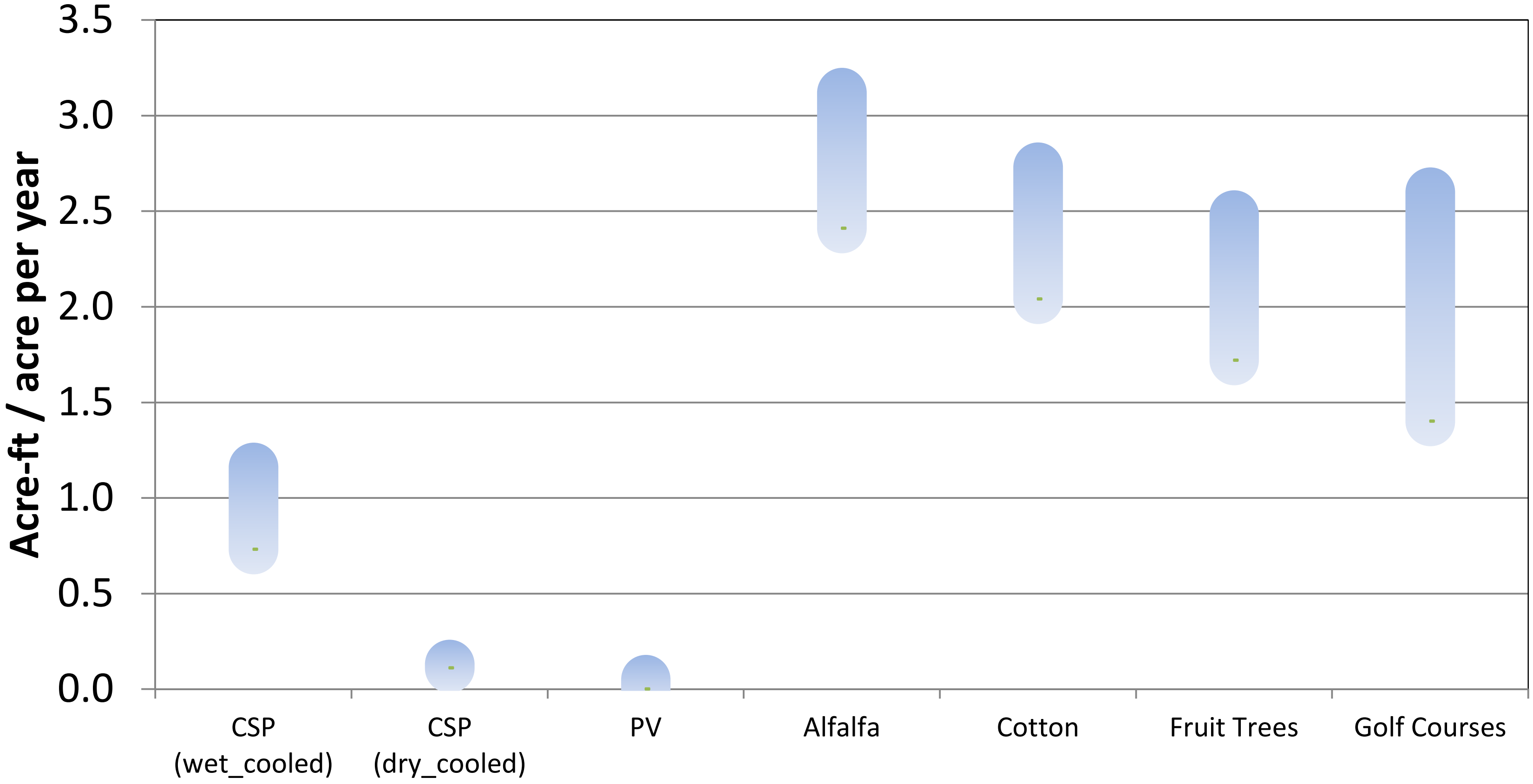


TOTAL LIFE CYCLE WATER USE FOR 2022 E85



Source: Heath et al., 2009

Considerations for decision makers:
water use per land area

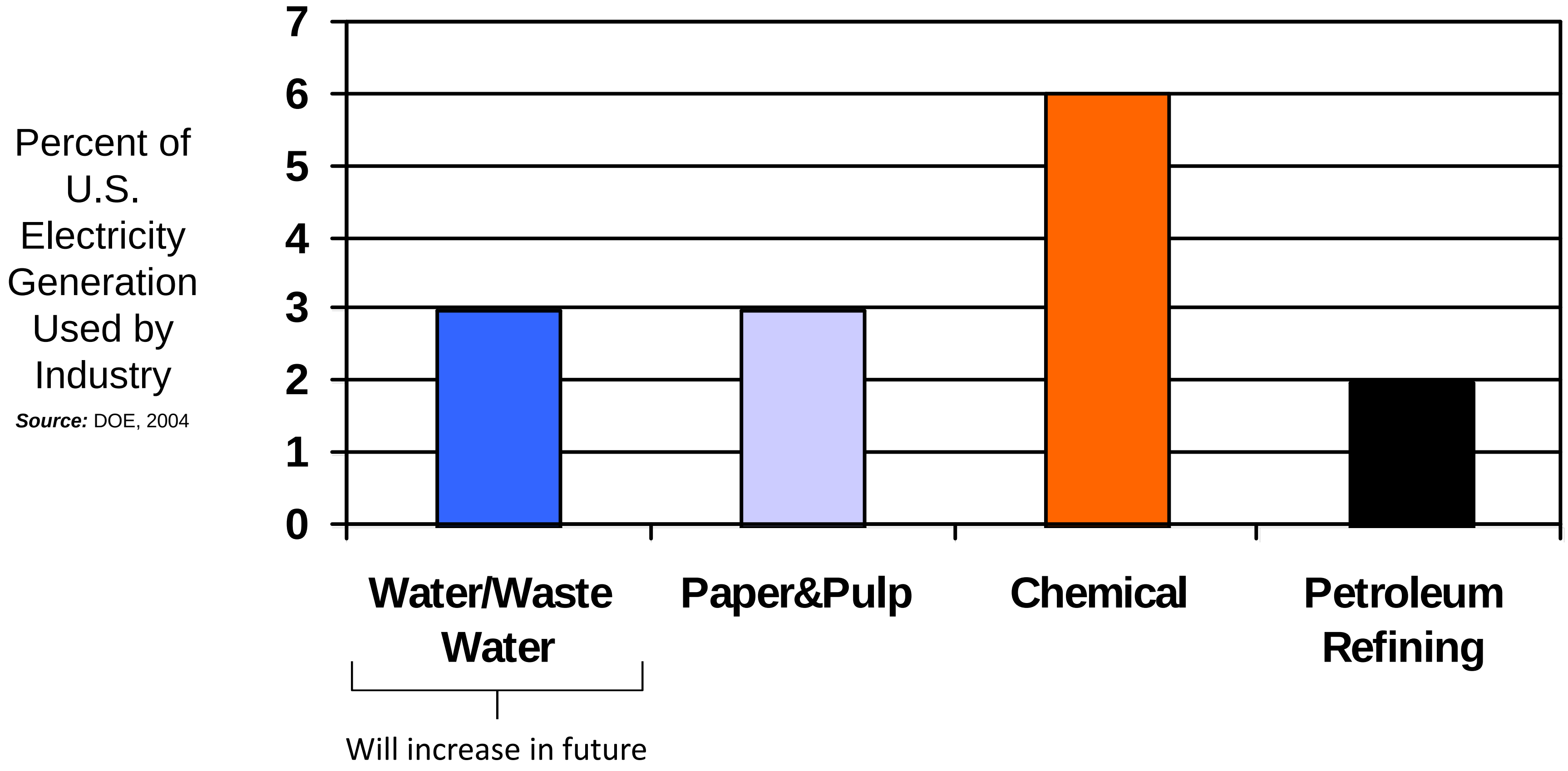


Sources:
CSP: Reducing Water Consumption of CSP Electricity Generation, Report to Congress 2009.
Crops: Blaney, Monthly Consumptive use of Water by Irrigated Crops & Natural Vegetation, 1957.
Golf : Watson et al., The Economic Contributions of Colorado's Golf Industry: Environmental Aspects.

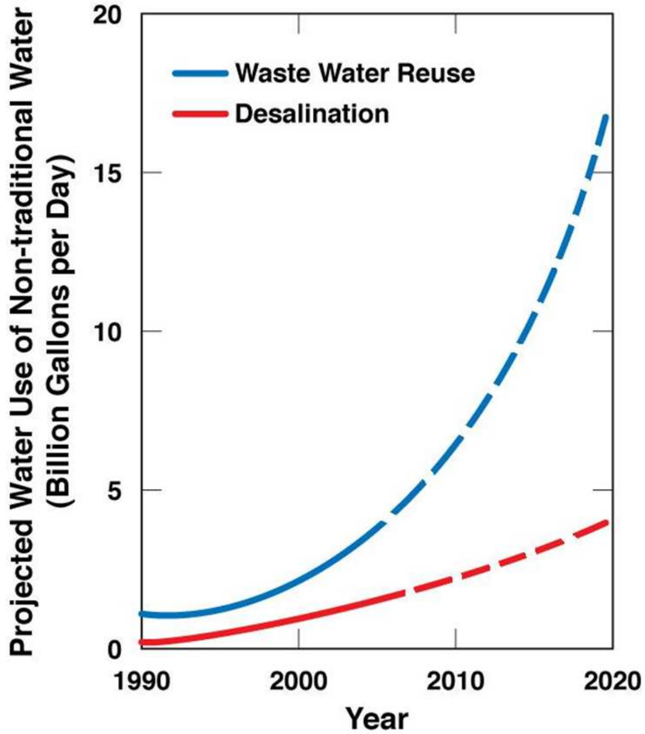
Courtesy: Craig Turchi, NREL

Energy for Water

The Water/Wastewater Sector is already a major user of electricity

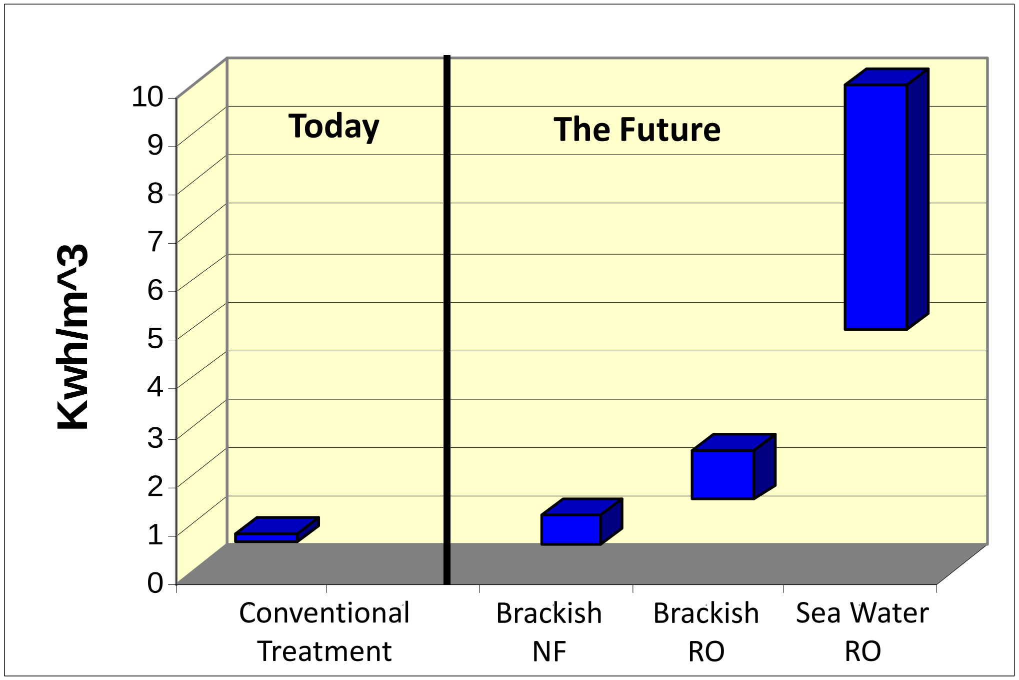


Use of non-traditional water resources is growing



(From EPA 2004, Water Reuse 2007, Mickley 2003)

Power Requirements For Treatment



(Einfeld 2007)

Desal growing at 10% per year, waste water reuse at 15% per year

Reuse not accounted for in USGS assessments

Non-traditional water use is energy intensive

Courtesy, Mike Hightower

New water supplies require energy

Water Supply Options	Energy Demand (kWhr/kgal)
Fresh Water Importation (100-300 miles)	10-18
Seawater Desalination w/Reverse Osmosis	
Brackish Groundwater Desali	
Reverse Osmo	7-9
Pu… …trate management	1-3
	8-12
Aquifer Storage and Recovery	
Pre-treatment (as needed)	3-4
Post-treatment (as needed)	3-4
Pumping	2-3
Total	5-11

Saving water means saving energy*

**CPUC pilot program: efficiency credits for energy imbedded in saving water*

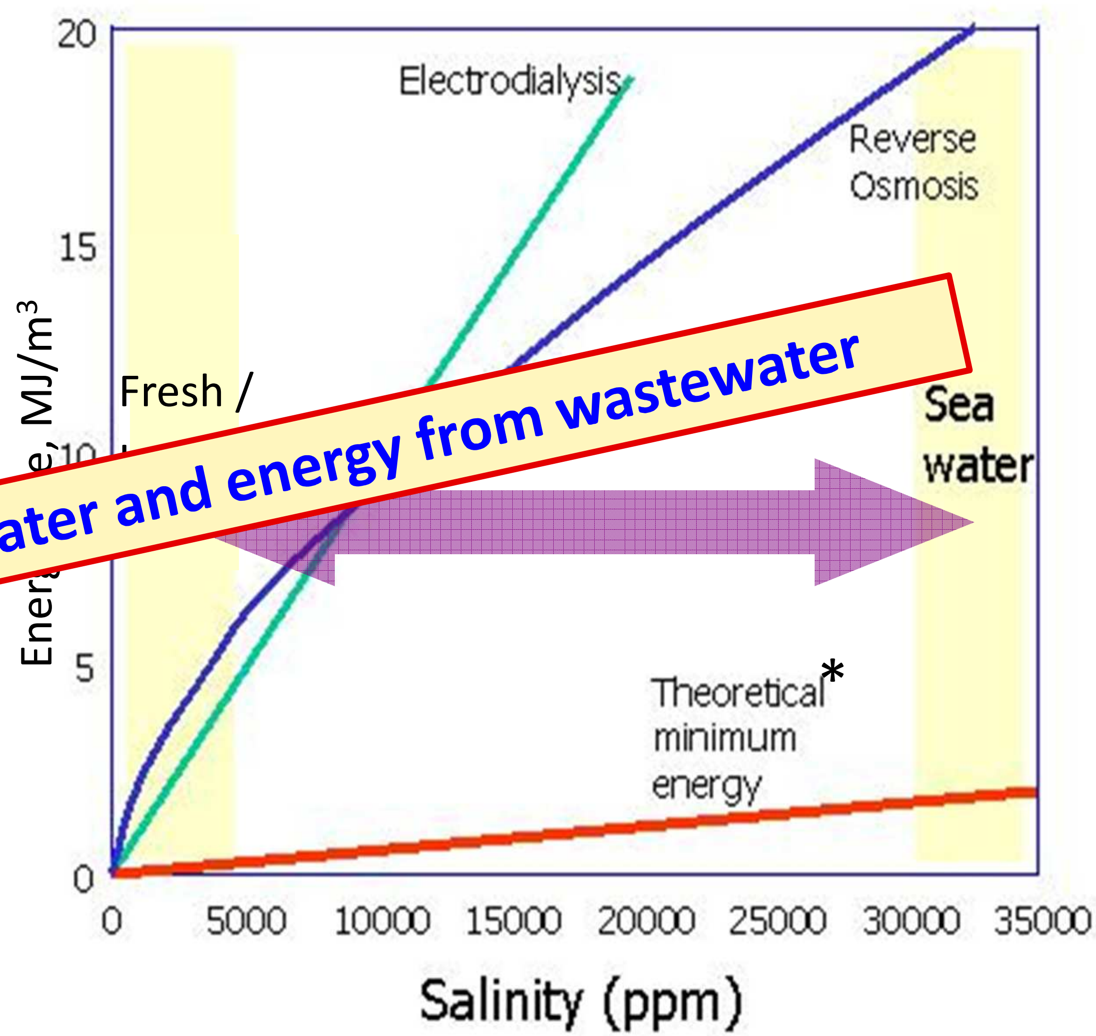
Courtesy, Mike Hightower

Separation science: opportunities to reduce the energy requirements for treatment

Reverse osmosis:

Electrodialysis:

Thermal methods



Opportunity: water and energy from wastewater

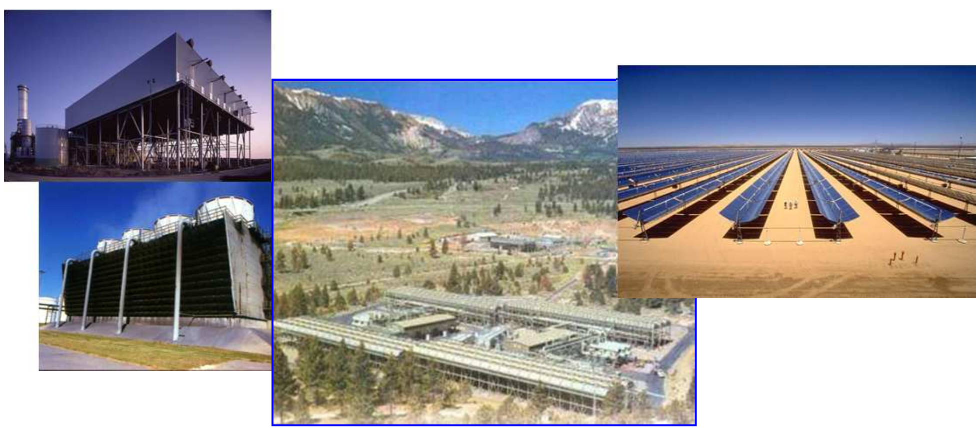
NREL is unique: the only DOE national laboratory dedicated solely to renewable energy and energy efficiency technologies

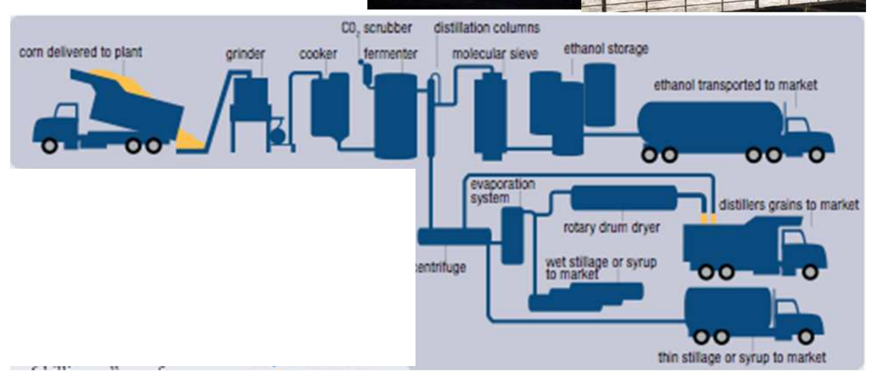
- ***Sustainability*** is a key concept of our energy future
- Energy-water nexus is addressed in many ways:
  - Water **use**

    individual technologies, technology pathways, life cycle assessments
  - Water **savings**

    Efficiency, conservation, technology implementation programs
  - **Integration**

    - RE with water/wastewater/treatment
    - RE in energy system portfolios
    - Energy and water flows in the built environment





Risk and Uncertainty

c Energy Analysis

Integrated Assessments

Analyze energy scenarios and/or the benefits and impacts of energy plans, programs, portfolios, or policy options

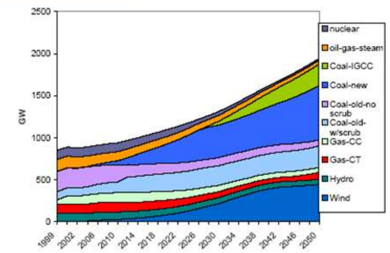
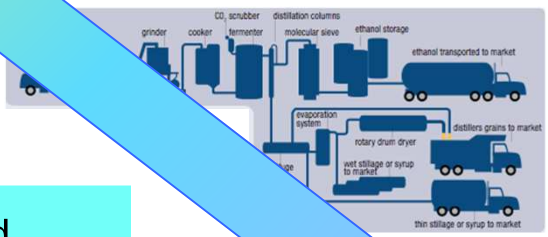
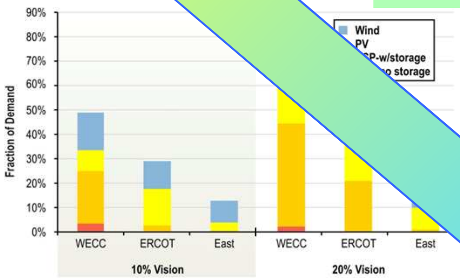


Figure 6: Capacity Expansion in the WinDS PHEV-60 Case

Economics, Markets and Finance

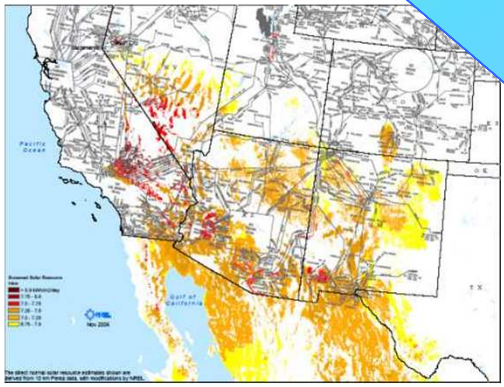
Evaluate implications of markets, financial instruments and economic factors





Systems

Overall system performance and technology interfaces in the context of the overall system



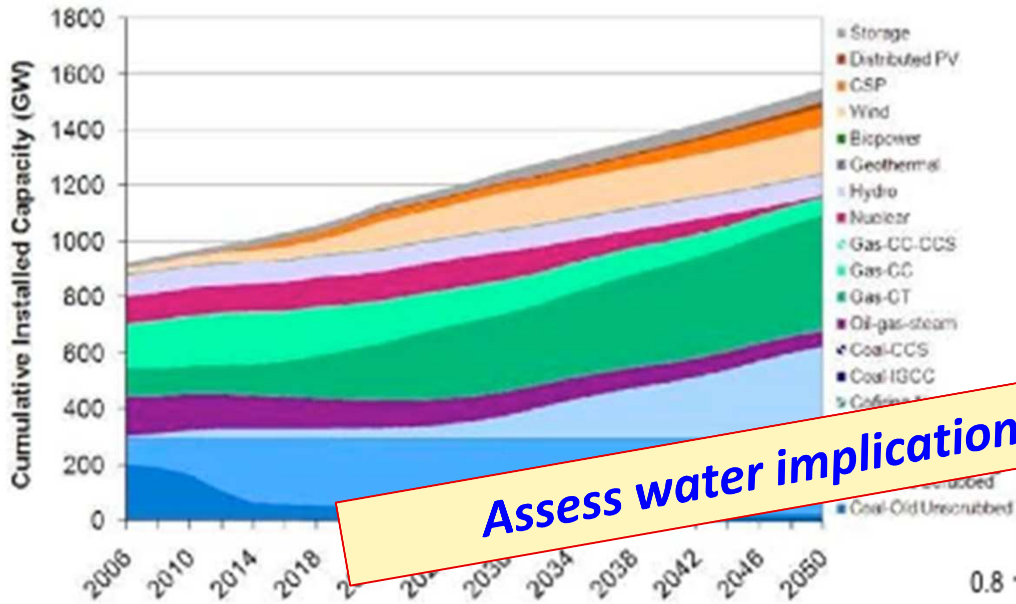
Technology/Components

Analyze technology and component performance and cost

Resources

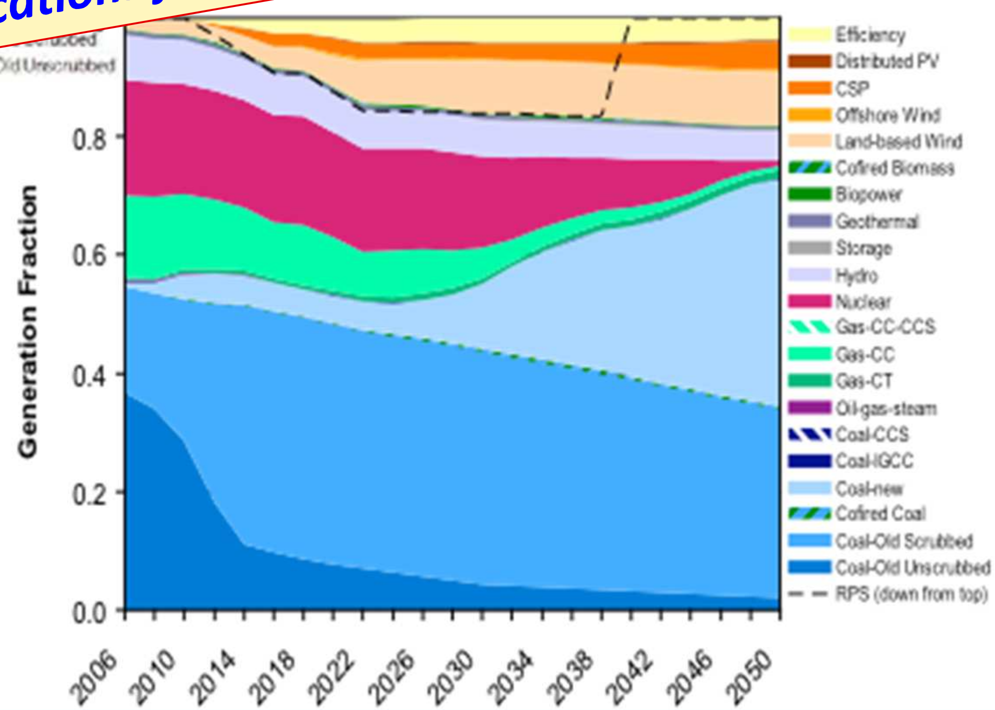
Assess resource availability and characteristics

Analysis: Regional Energy Deployment System (ReEDS) model evaluation of impacts of a proposed 20% Renewable Portfolio Standard (RPS) on the energy sector



Contributions to power generation capacity in a 20% RPS case

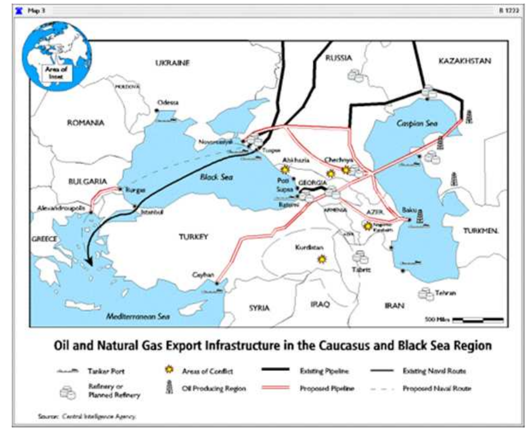
Assess water implications for different scenarios

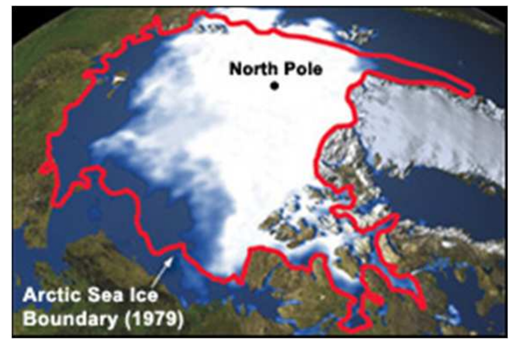


Contributions to meeting total load in the 20% RPS case

Source: Logan et al., 2009

The Times They Are a-Changing…





Energy resources

- Increasing global competition and volatility, energy security issues
- ***New resources needed and deployed:*** conventional, unconventional and renewable

Water resources

- Increasing demands, management challenges
- New resources needed: conventional and unconventional

Climate change/policy change

- Increasing convergence of political and public opinion
- Observable changes, clearer delineation of risks
- Emerging CO_2 markets, finance/insurance interest
- ***Already driving actions***

Sustainable options are desired

These result in tremendous challenges and opportunities!

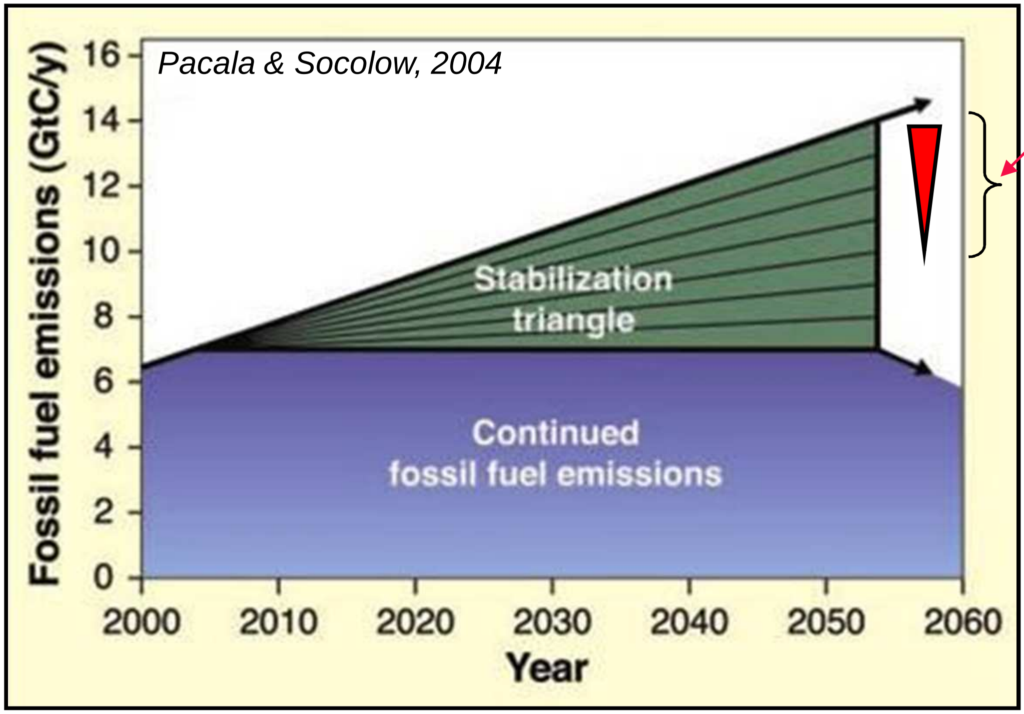
National Renewable Energy Laboratory
Innovation for Our Energy Future

NREL appreciates your assistance in collecting additional data!!

www.nrel.gov

Or contact Robin Newmark
robin.newmark@nrel.gov

Continued use of fossil fuels might require CO_2 Capture & Storage (CCS) as a pathway to substantial GHG reductions



Using CCS can be used to reach 15-50% of abatement needed for stabilization at 500 ppm

CCS may be a key portfolio component (with efficiency, conservation, renewables)

CCS could be an important bridging technology

Hot, Flat and Crowded: Colorado in 2050

Global Warming

Rise of the middle class?

Can this be sustained? Currently receive only 17 inches of precipitation annually

Population growth

- Mean temperature may rise 2.5-5.5^{o}F
- Mountain climates projected to migrate upward in elevation
- Desert Southwest climate to progress up into the valleys of the Western Slope.
- Average annual precipitation may show little change, but a seasonal shift in precipitation emerges.
- Strong decline in lower-elevation snowpack (<8200'), modest for higher elevations
- Earlier spring runoff, reduced late-summer flows

Source: Climate Change in Colorado, Western Water Assessment, 2008

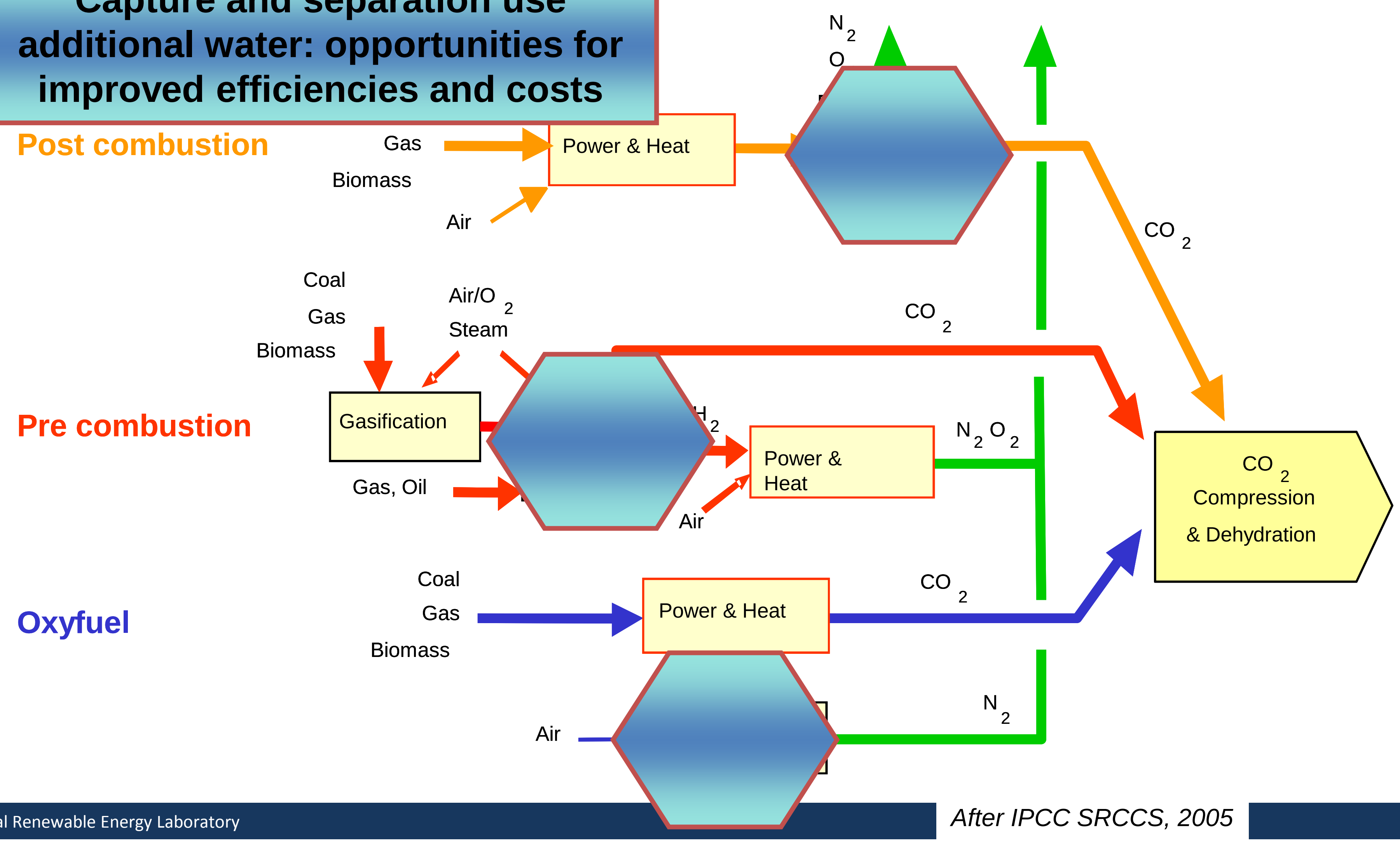
- Population at ~7 million (up from ~5 million today)
- Demographic shifts (urban sprawl?)

Source: Colorado's Population in 2050, NPG, Inc., 2001

Storage requires high purity (>95%) CO_2 streams

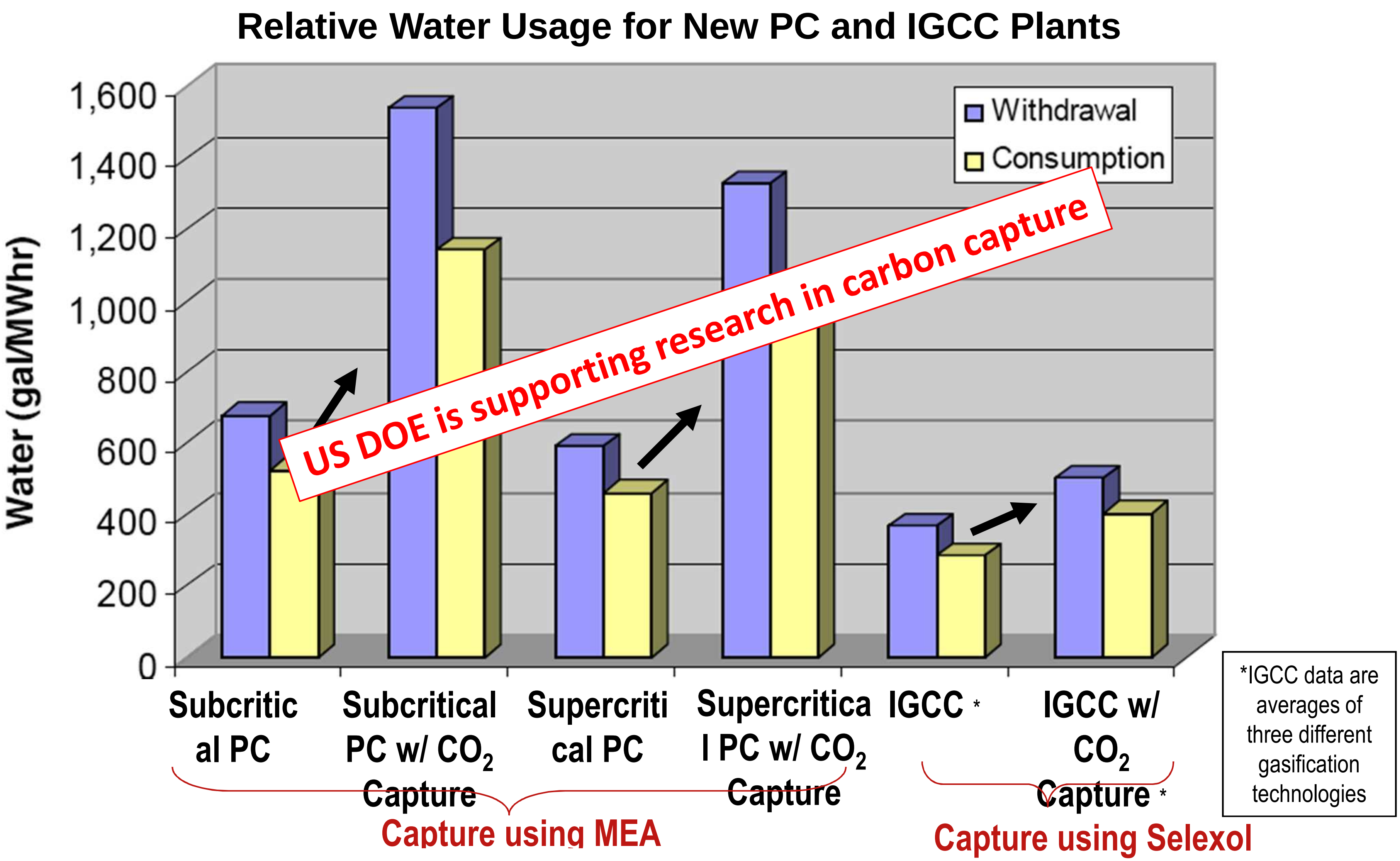
Three technology pathways can capture and separate large volumes of CO_2

Capture and separation use additional water: opportunities for improved efficiencies and costs



After IPCC SRCCS, 2005

Conventional capture technologies increase overall water usage



Source: DOE-NETL *Estimating Freshwater Needs For Thermoelectric Generation*, 2007