The Energy Water Nexus

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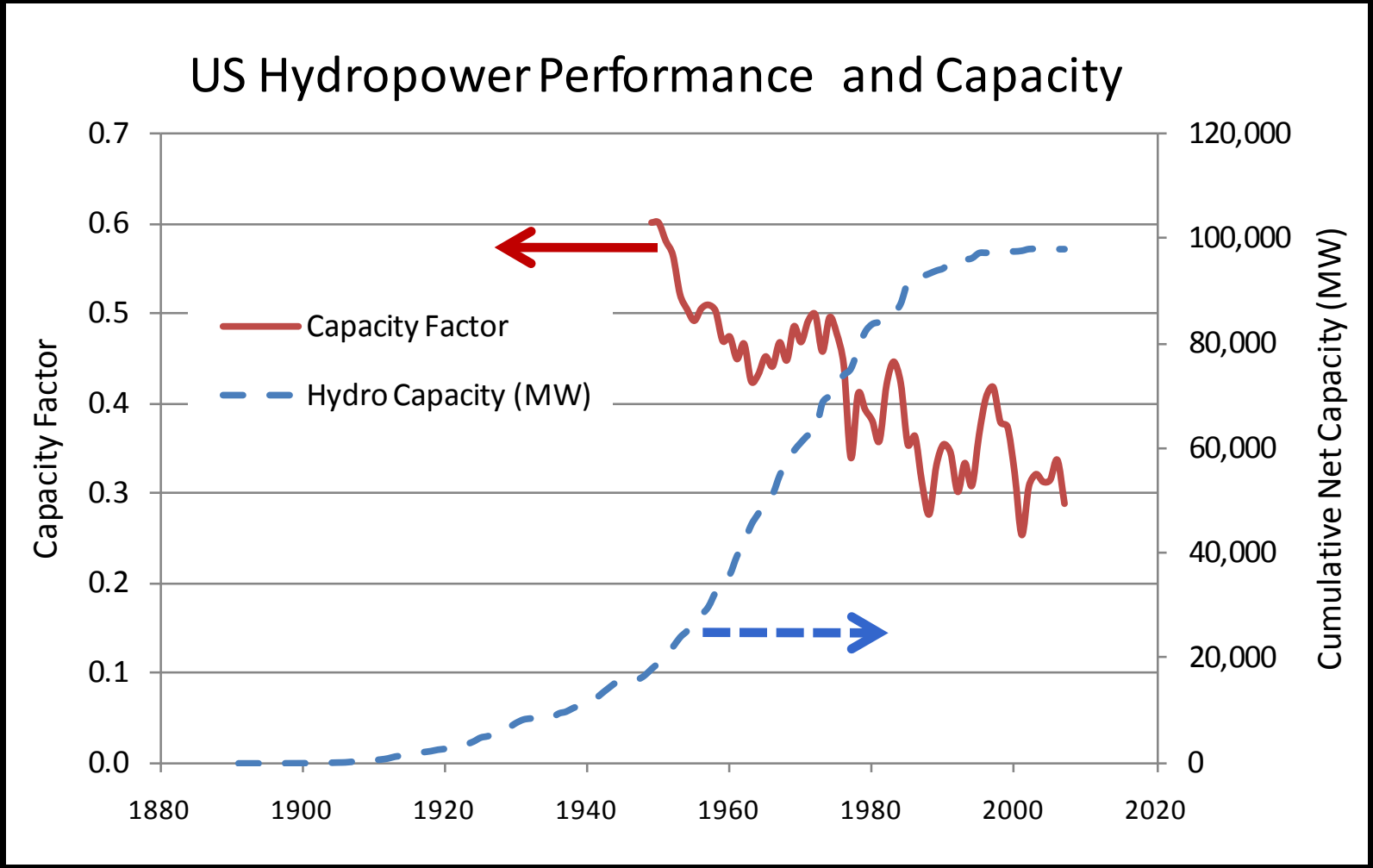
April 21, 2011

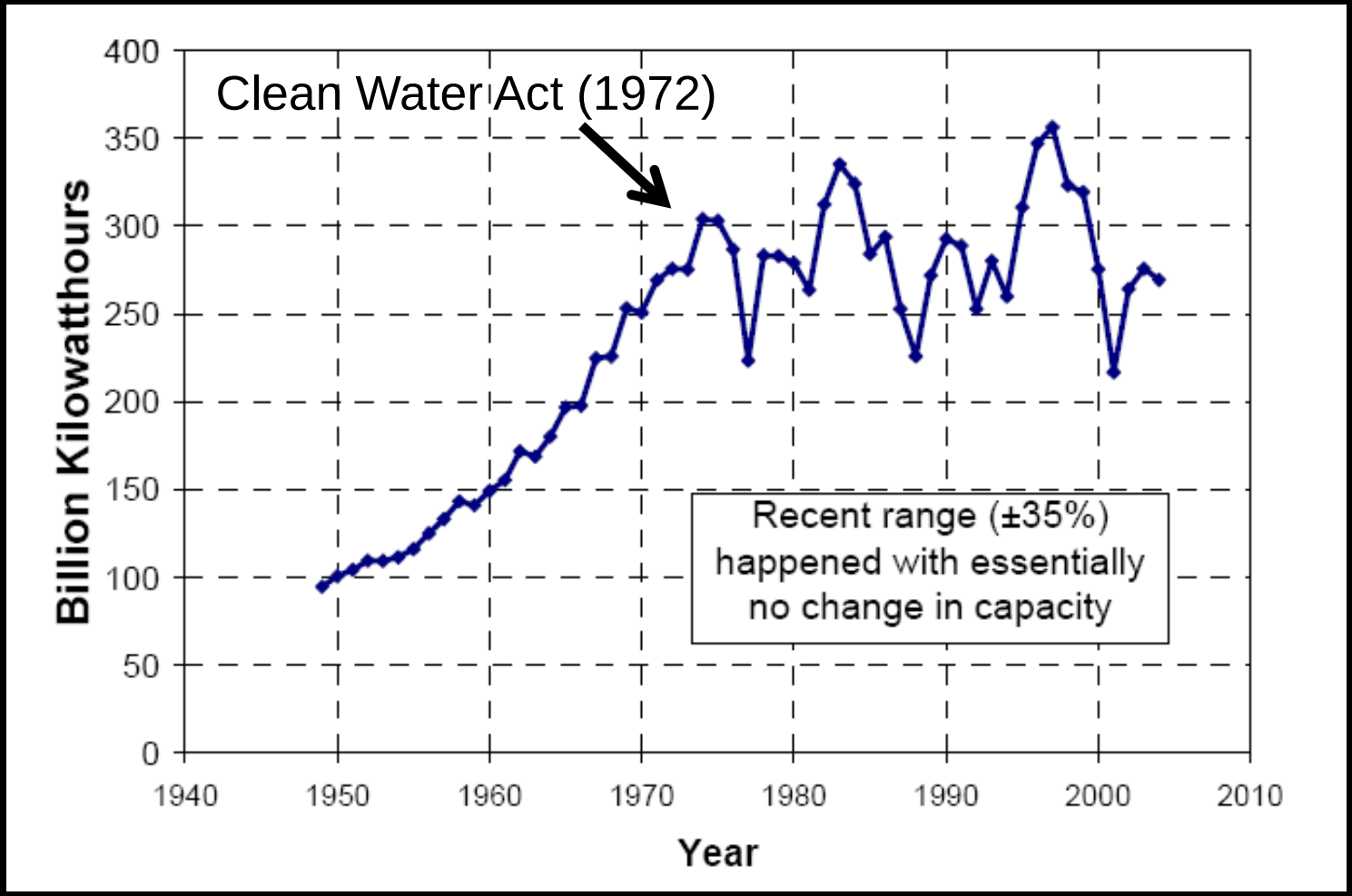
Water for Energy: Electricity

US hydropower exemplifies water limiting an energy resource



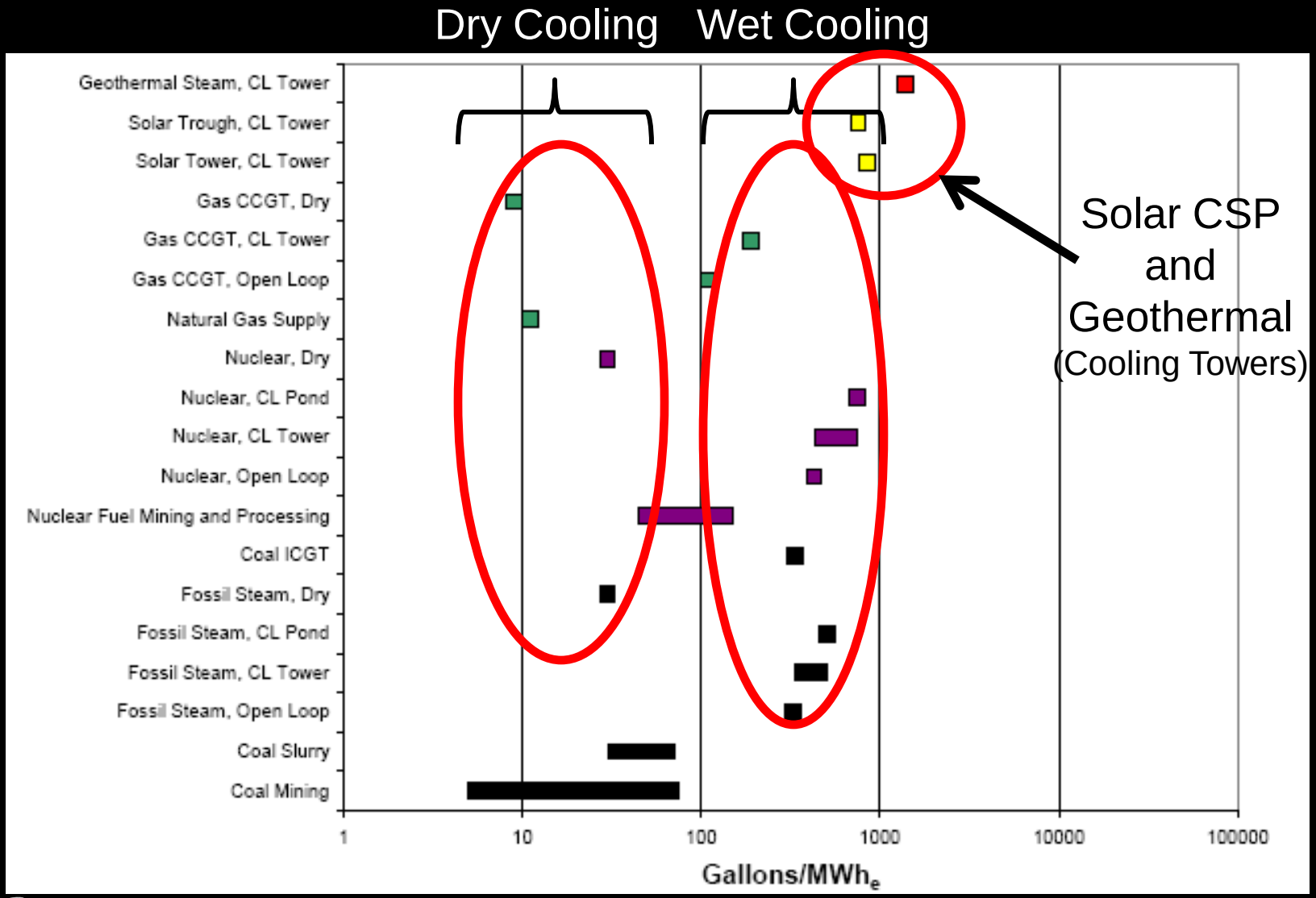
EIA Annual Energy Review 2008.

Hydropower is very direct link of water and energy



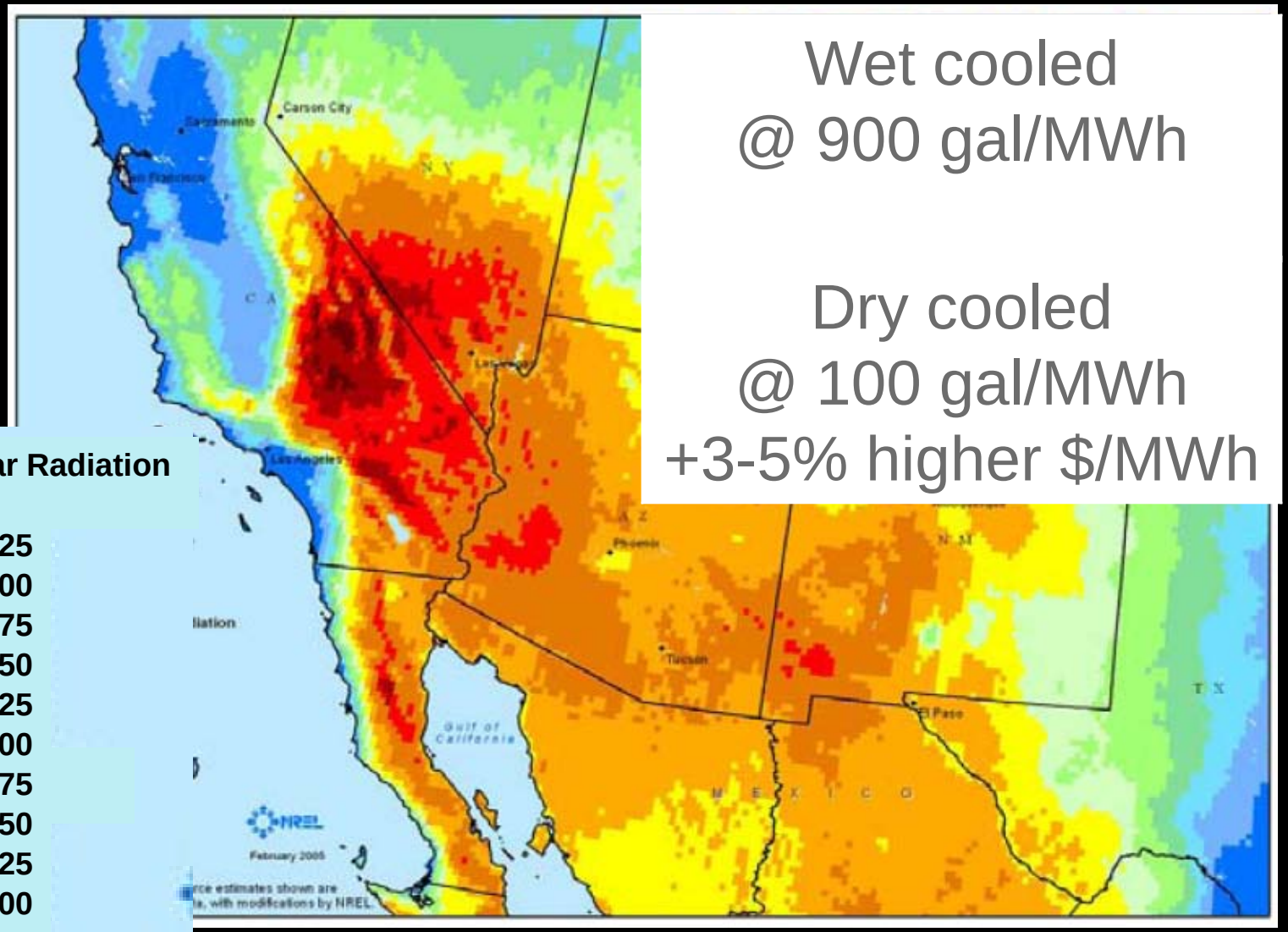
DOE (2006). Energy Demands on Water Resources. Report to Congress .

Cooling systems for Thermoelectric Power Can have vastly different Water Consumption



DOE (2006). Energy Demands on Water Resources. Report to Congress.

Map shows the water and concentrating solar power (CSP) conundrum



Wet cooled
@ 900 gal/MWh

Dry cooled
@ 100 gal/MWh
+3-5% higher $/MWh

Direct Normal Solar Radiation
kWh/m²/day

- 8.00-8.25
- 7.75-8.00
- 7.50-7.75
- 7.25-7.50
- 7.00-7.25
- 6.75-7.00
- 6.50-6.75
- 6.25-6.50
- 6.00-6.25
- 5.75-6.00
- 5.50-5.75
- 2.75-5.50

NREL (2007) DOE/GO-102007-2400.

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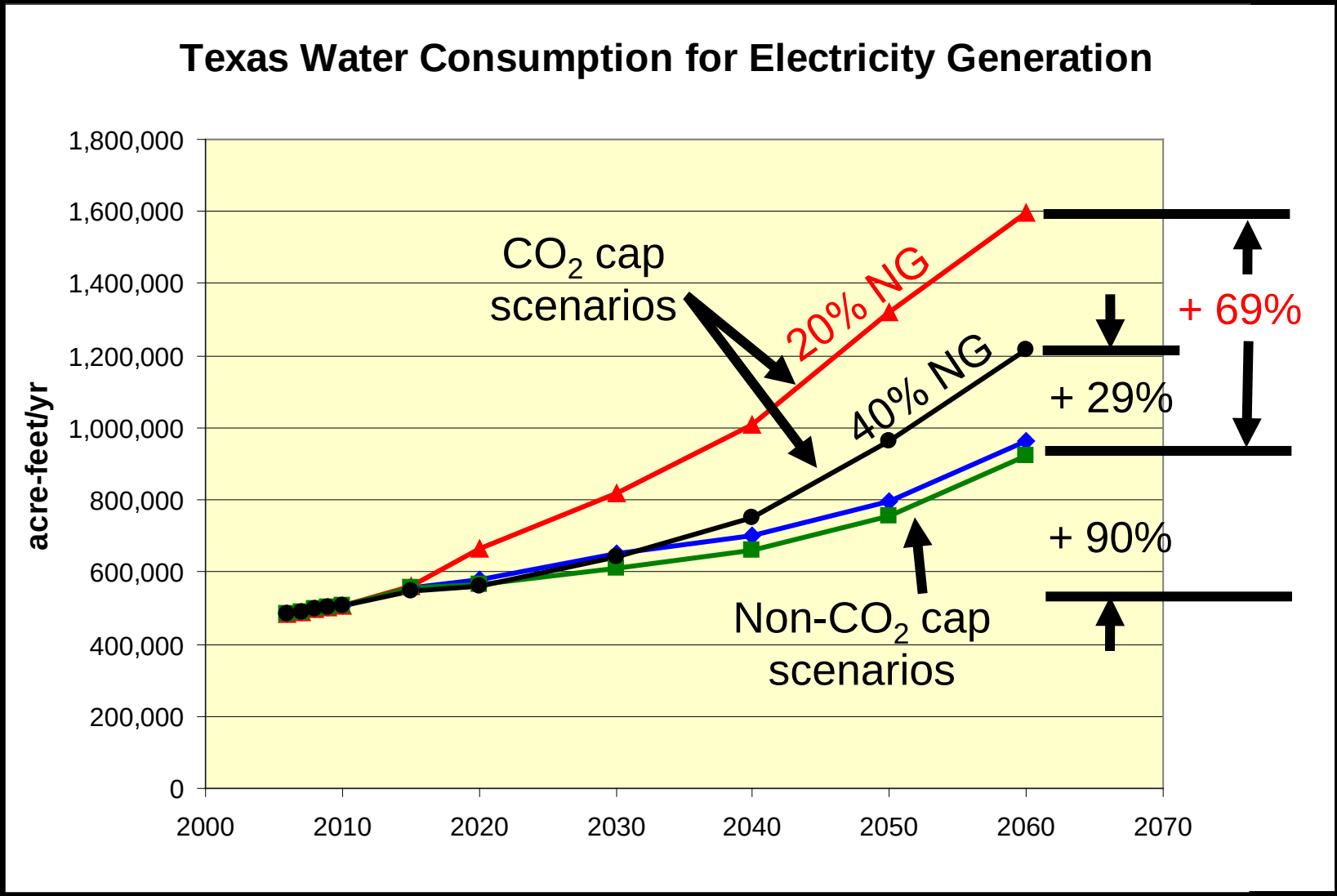
Water Consumption depends heavily upon fuel + cooling system *and* carbon capture *choices*



King, Duncan, & Webber (2008). TWDB Report. Water Demand Projections for Power Generation in Texas

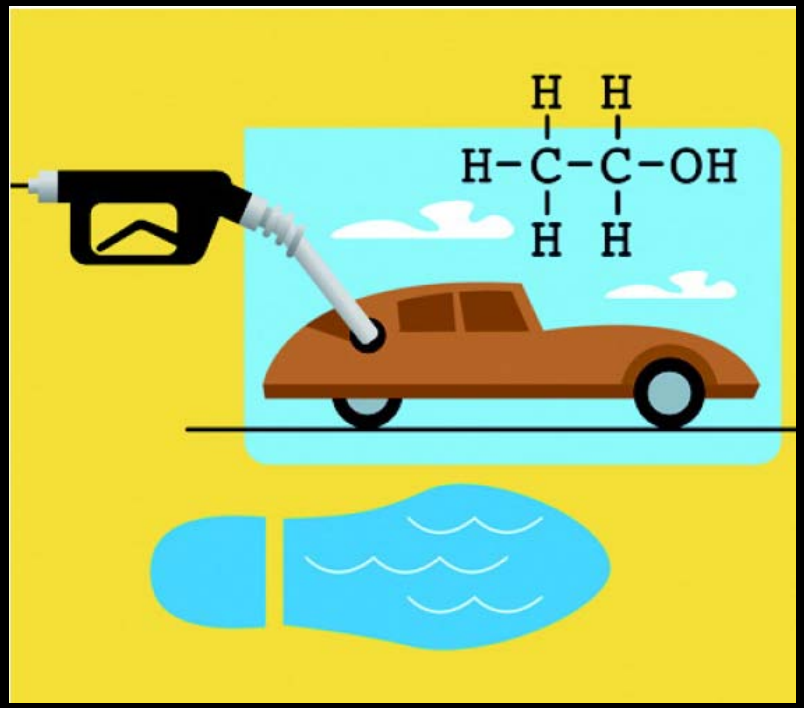
Withdrawal vs. Consumption: Which is more important?

- **Thermoelectric "use" of water**
  - **Withdrawal ~ 48% of US total** (USGS, 2004)
  - **Consumption ~ 3% of US total** (USGS, 1998)

- **Avoid *using* the term "use" to describe water**
  - **Are you "using" a LOT or a LITTLE?**

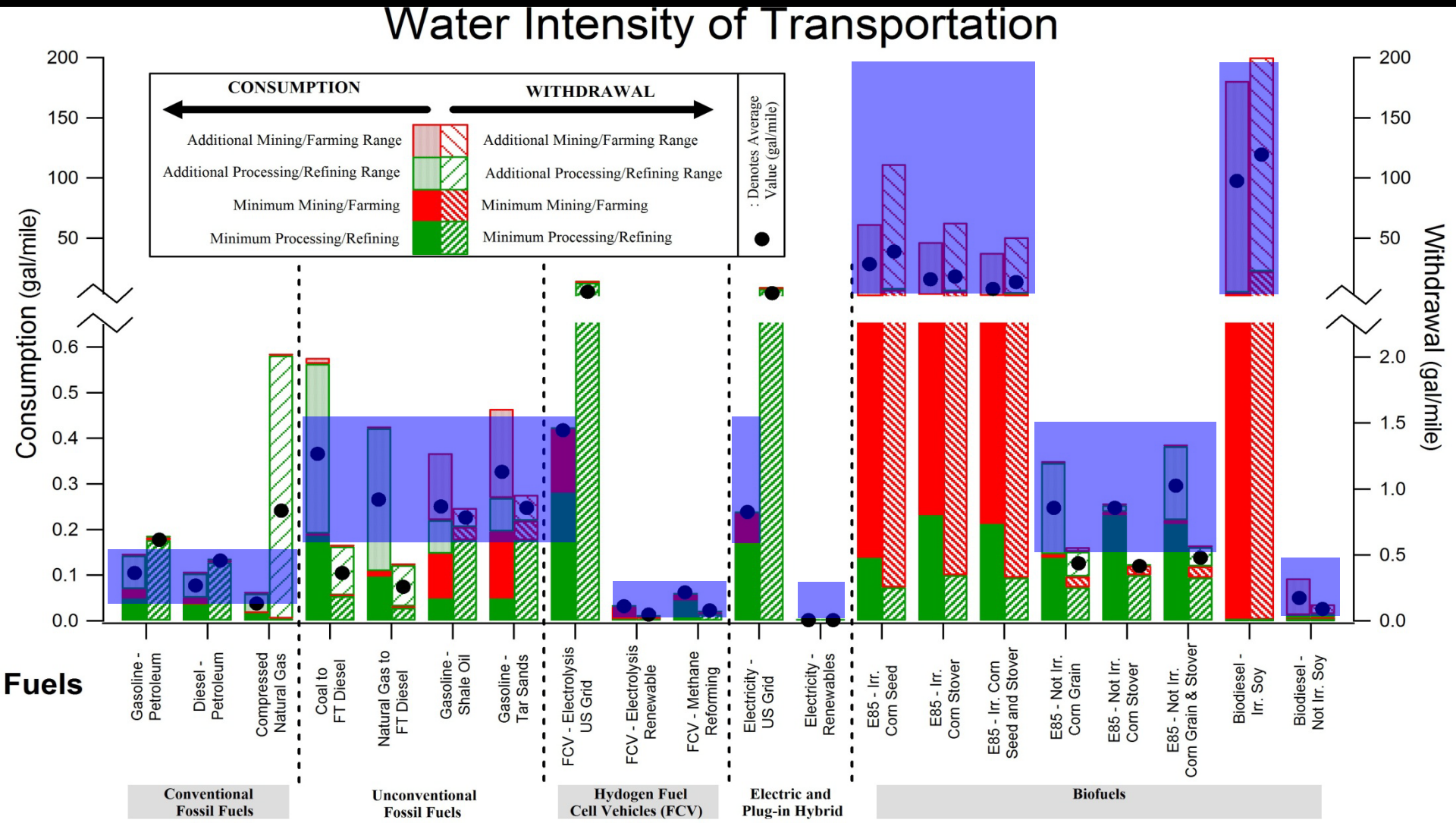
- **A power plant diverting water from a river versus a cooling reservoir has different**
  - **Operational risks**
  - **Environmental impacts**

Water for Energy: Transportation Fuels



Dominguez-Faus et al. *Environ. Sci. & Technol.* **2009 43** (9), 3005-3010.

Water Consumption Intensity from Near Zero to > 100 gal/mile



King & Webber (2008). *Env. Sci. & Tech. 42* (21), 7866-7872.

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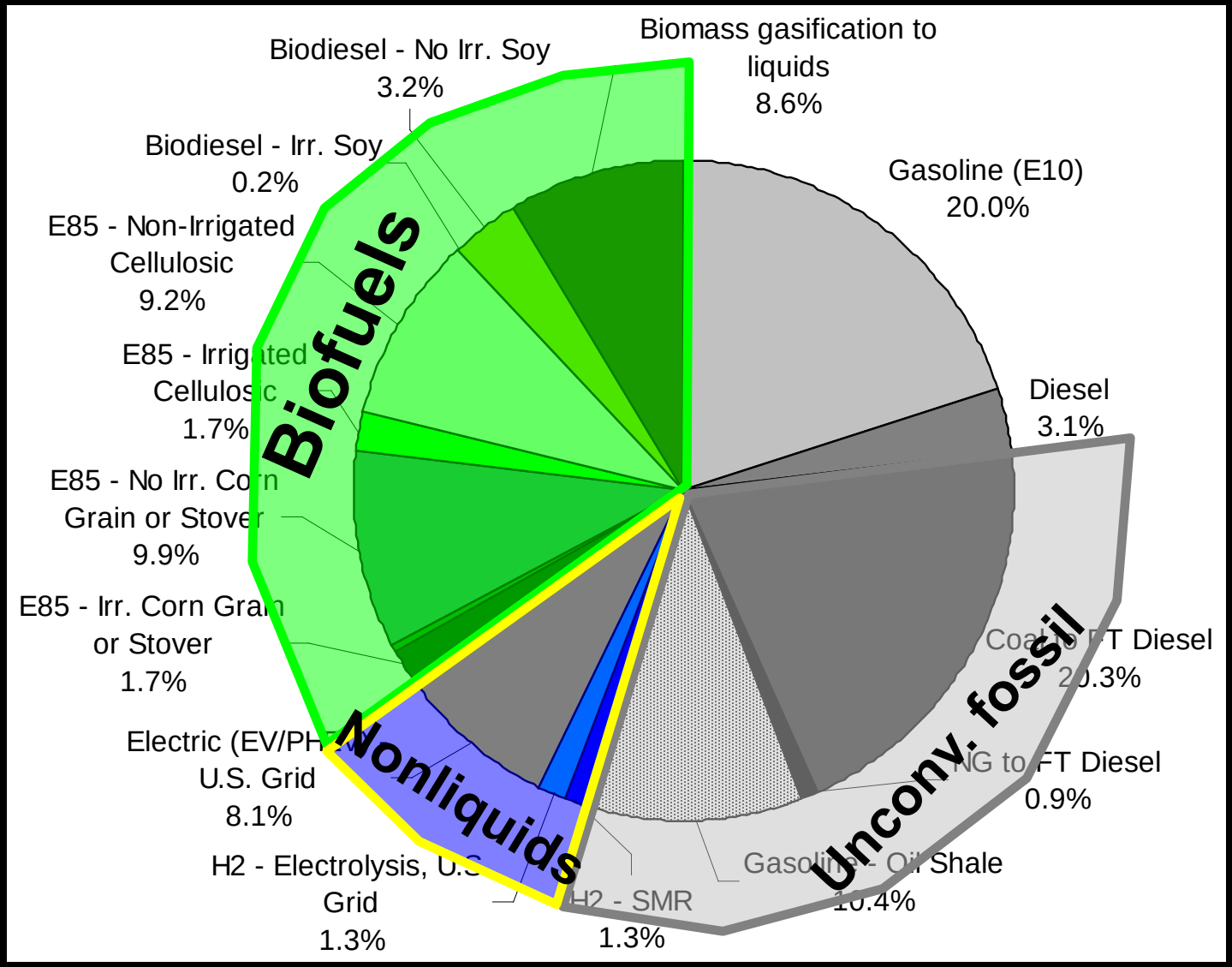
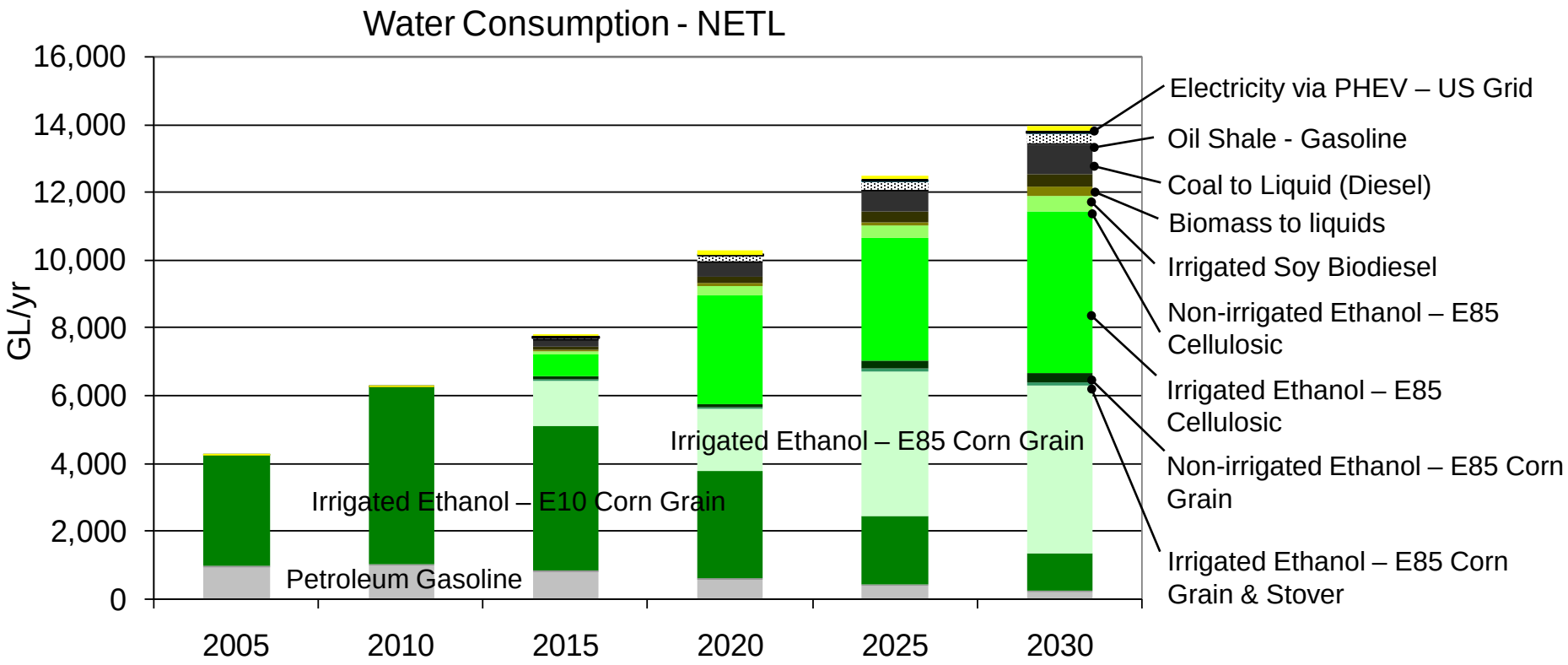
"High Diversity Scenario for 2030": ~ 20% conventional petroleum (4.1 trillion miles)



King, Webber, Duncan (2010) *Energy Policy,* **38** (2), 1157-1167.

"High Diversity Scenario" also shows consumption of 14,000 Billion Liters in 2030

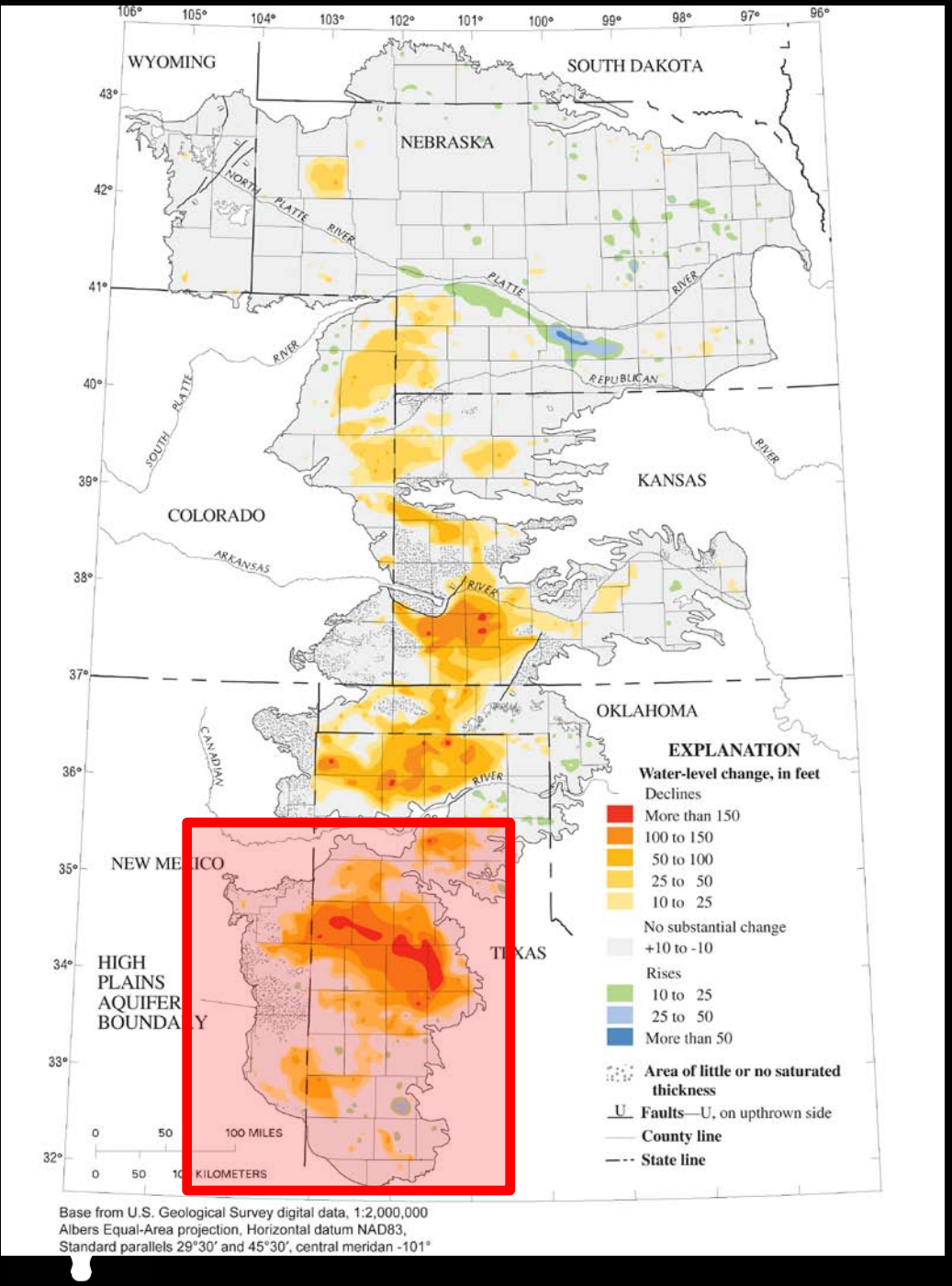


Are we inherently trading "domestic water" for "foreign oil"?

- **Water for LDVs**
  - **2010 ~ 6,000 GL/yr (4% US total)**
  - **2030 ~ 14,000 GL/yr (10% US total)**
- **US Total water consumption**
  - **140,000 billion liters in 1995 (USGS, 1998)**
- **Comparisons for *consumption***
  - **Thermoelectric sector ~ 3% – 4%**
  - **Irrigation ~ 80%**
    - ***Biofuels are now a subset of irrigation***

King, Webber, Duncan (2010) *Energy Policy,* **38** (2), 1157-1167.

Impact of Land Use Change on Groundwater Levels (Ogallala Aquifer)



> 150 ft
100 to 150
50 to 100
25 to 50
10 to 25

Declines

-10 to 10

No change

10 to 25
25 to 50
50 to 100

Rises

9,200 wells
Average decline: 3.8 m (12.6 ft)
Decline Texas: 10.7 m (35 ft)

McGuire, 2004

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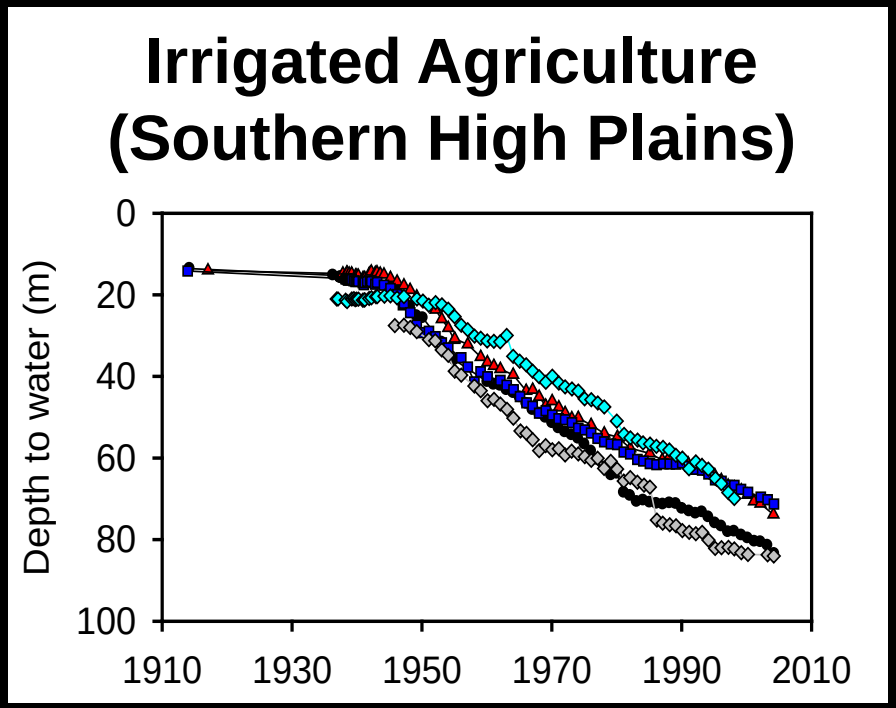
Biofuels or not: Land-use change and irrigation affect groundwater storage



Scanlon, Bridget (UT-BEG)

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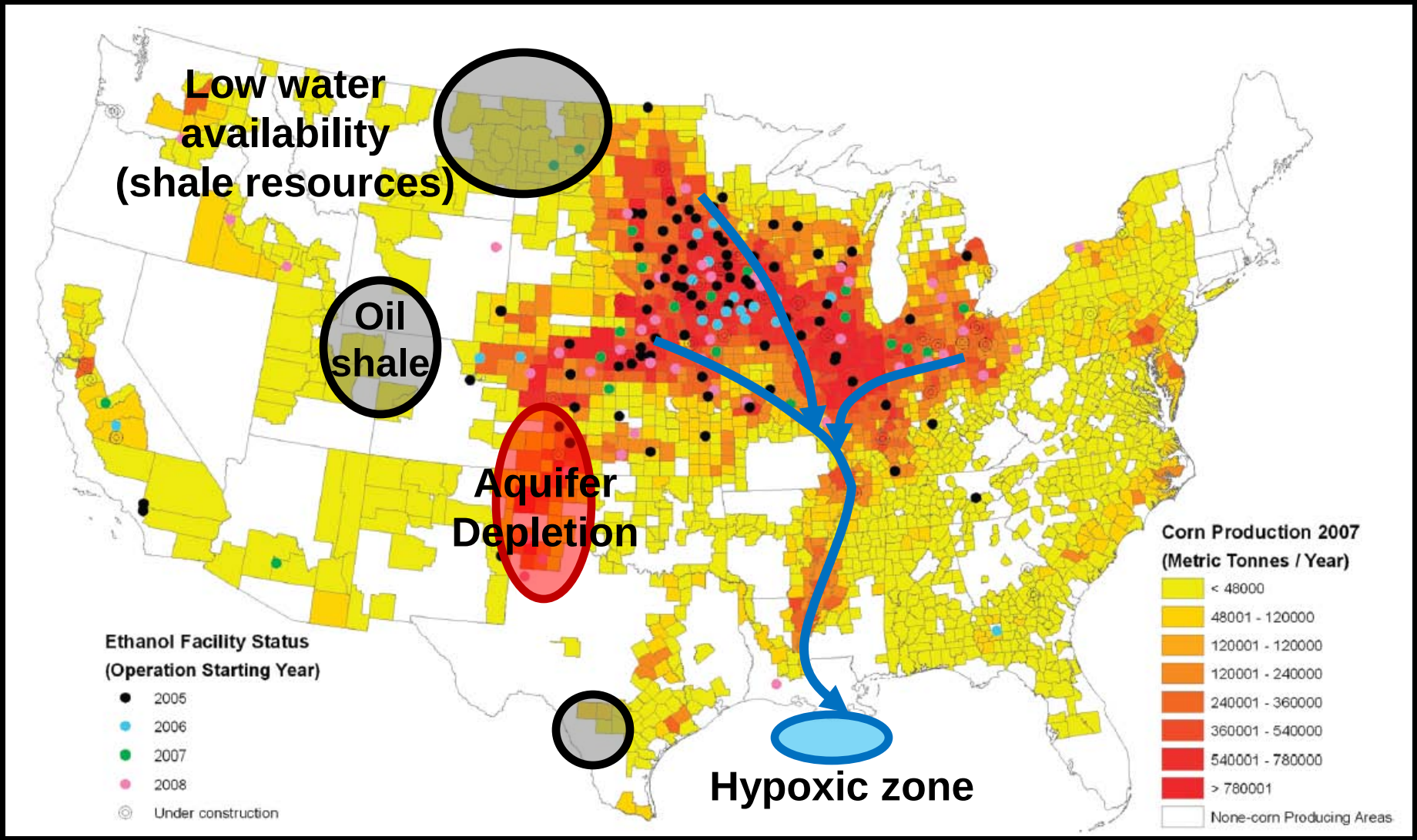
Location of energy resource and water basins are important to understand impacts



Chiu, et al. Water embodied in bioethanol in the U.S. *Environ. Sci. and Technol.* **2009** 43 (8), 2688-2692.

Treating, transporting, and reusing marginal water resources takes energy

Table 3. National average electricity use for water collection and treatment using different water treatment technologies (Goldstein and Smith 2002b, California Energy Commission 2005). Distribution represents additional energy use.

Water Collection and Treatment	kWh/ML†
Surface water treatment	60
Groundwater treatment	160
Brackish groundwater treatment	1000–2600
Seawater desalination	2600–4400

15-70 X higher

†kWh/ML: kilowatt-hours per megaliter

Stillwell, et al. (2010) *Ecology and Society*.

Water and Energy are Becoming Important in Policy and Environment

Future Water and Energy Policy: How does Water influence Energy?

- **Energy and Water Integration Act (in committee)**

  "… include a lifecycle assessment of the quantity of water withdrawn and consumed in the production of transportation fuels …"

  – **i.e. calculate as gal H_2O/mile**

  King & Webber (2008) *Env. Sci. and Tech.*

- **"To mitigate water resource impact, perhaps the next energy policy act should also insist on a water footprint analysis of all biofuels."**

  Keeny (2008) *Env. Sci. and Tech.*

- **Contention over EPA ruling on open-loop power plant cooling (existing vs. new thermoelectric plants)**

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1 Bgal of coal ash breaches Tennessee Valley Authority earthen dam in TN (Dec 2008)

- **26 homes damaged**
- **49/431 coal-ash storage facilities as “high hazard”**

http://carbonfreeeconomy.com/energy/tva-coal-ash-spill-video-pictures

Hydraulic fracturing for gas/oil from shale becoming more extensive in practice … and debate

- **2005 law exempted shale gas hydraulic fracturing from the federal Safe Drinking Water Act**
  - **Ruling under review**
  - **EPA looking further into drinking water impacts**
- **A lot of water or a little?**
  - **Millions of gallons per well, many wells per pad**
  - **1e-5 gallons of water/Btu of Barnett Shale NG (2005)[1]**

1. Bene´, J.; Harden, B.; Griffin, S.; Nicot, J. P. Assessment of groundwater use in the Northern Trinity Aquifer due to urban growth and Barnett Shale development.; King and Webber (2008) *Env. Sci. & Tech*.

Don’t just frac it

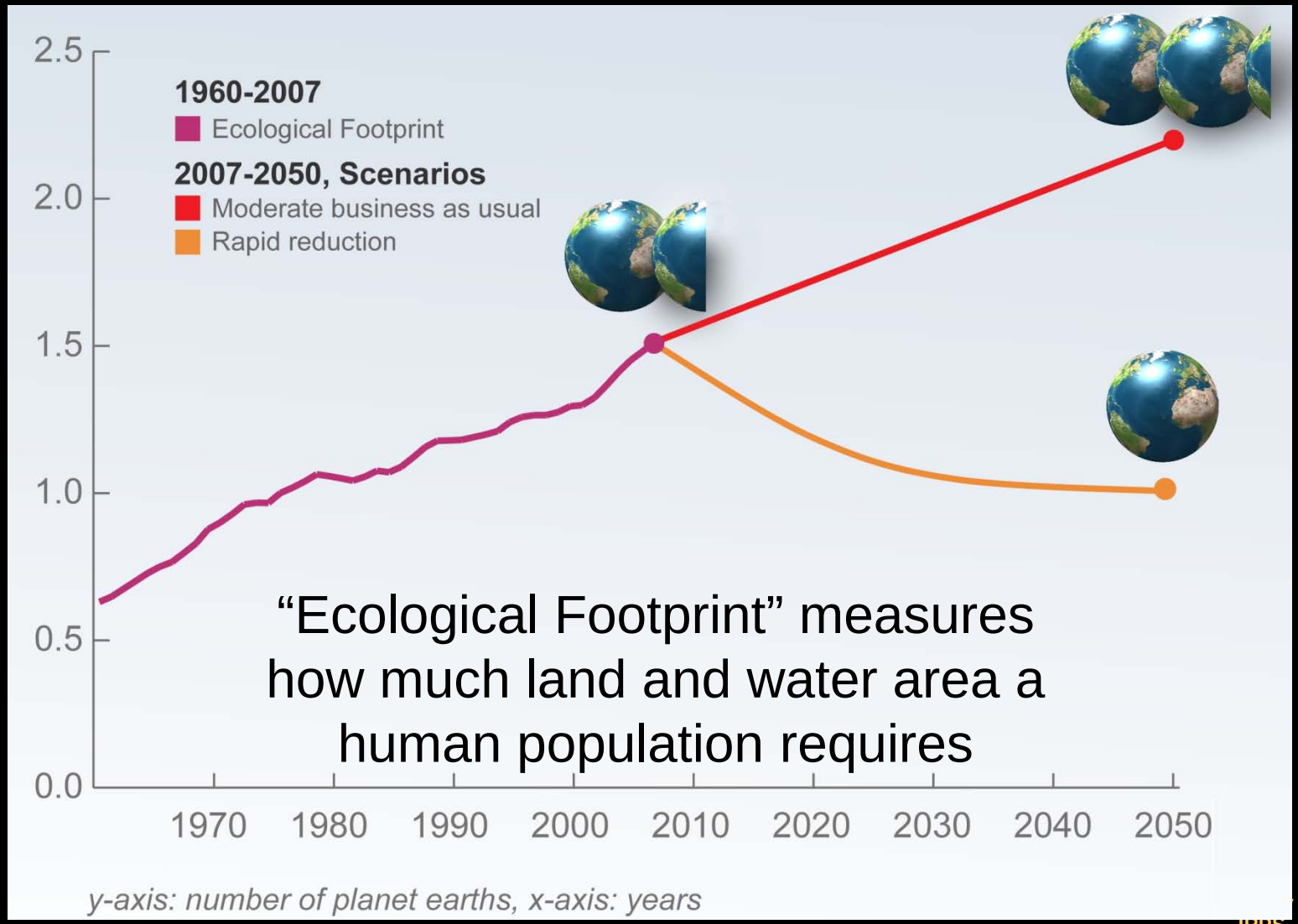
http://gaslandthemovie.com/

Texas license plate

“FRAC IT”

The global view:
Water as a constraint on global energy

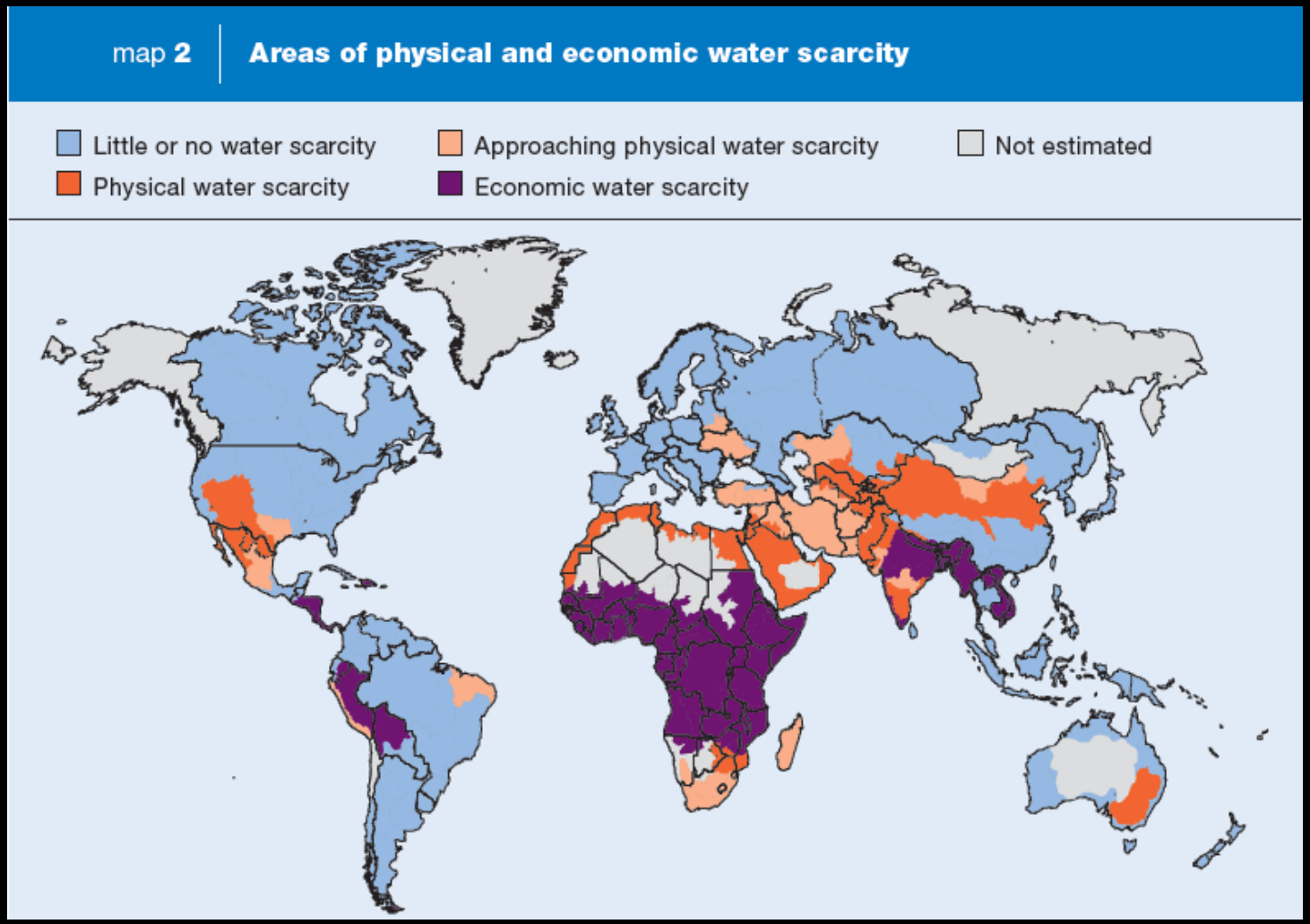
Policies for alternative measures to GDP focus on environmental limits



"Ecological Footprint" measures how much land and water area a human population requires

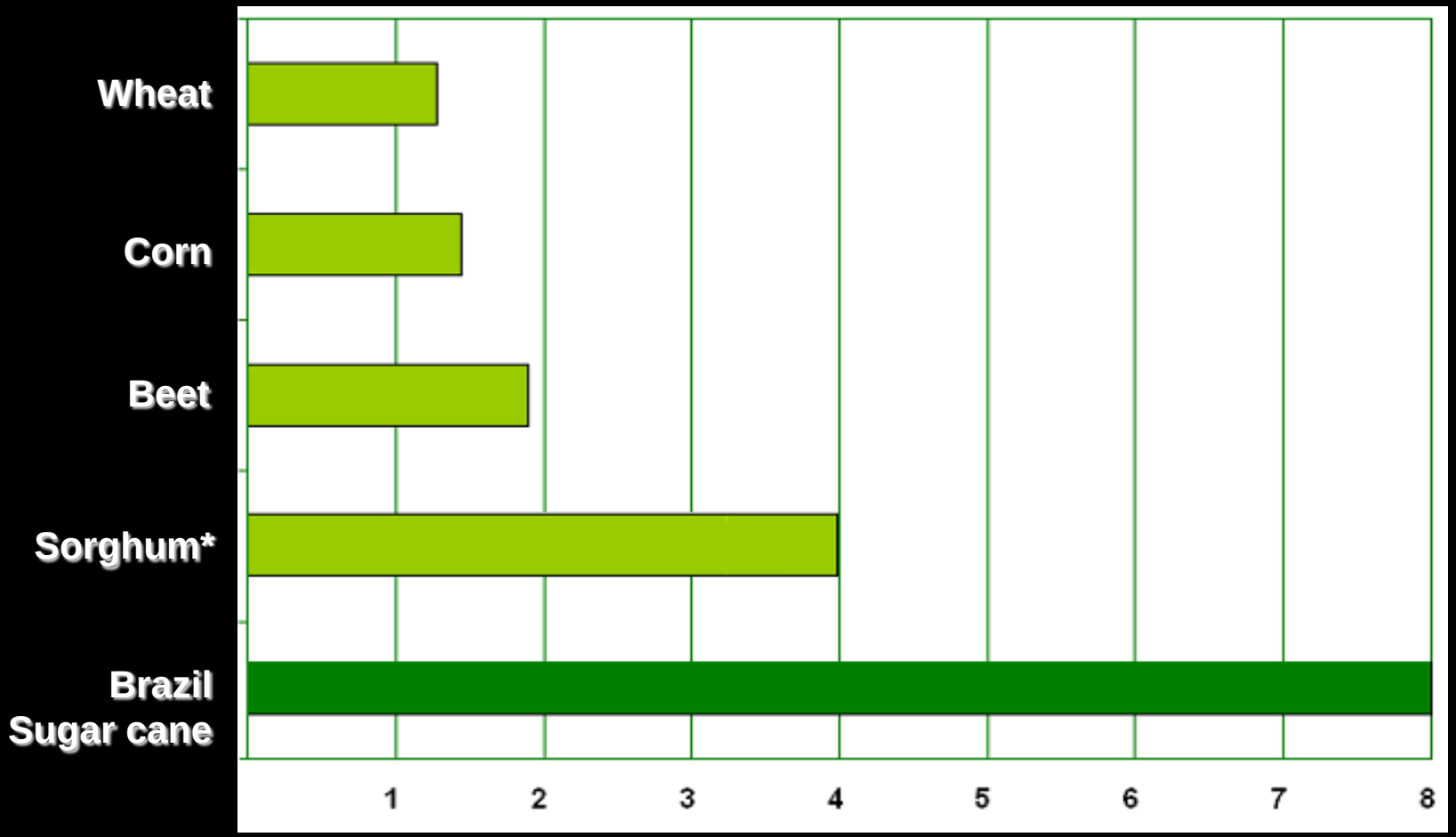
http://www.footprintnetwork.org/en/index.php/GFN/page/world_footprint/

Who has water resources and who doesn't? Who has energy resources and who doesn't?



Comprehensive Assessment of Water Management in Agriculture. 2007. *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture. London:* Earthscan, and Colombo: International Water Management Institute.

For biofuels, sugar cane to ethanol has measurably better energy characteristics



EROI = Energy output/Energy input

Source: LICHT, 2006.

* Source: WORLD WATCH INSTITUTE.

Water quantity is a physical constraint restricting scale of many energy resources

- **Coal-to-liquids in China (inner Mongolia)**
  - **The National Development and Reform Commission said the technology used too much water in already arid regions**

"… we have adopted measures to use water used in agriculture and transfer it to industry."

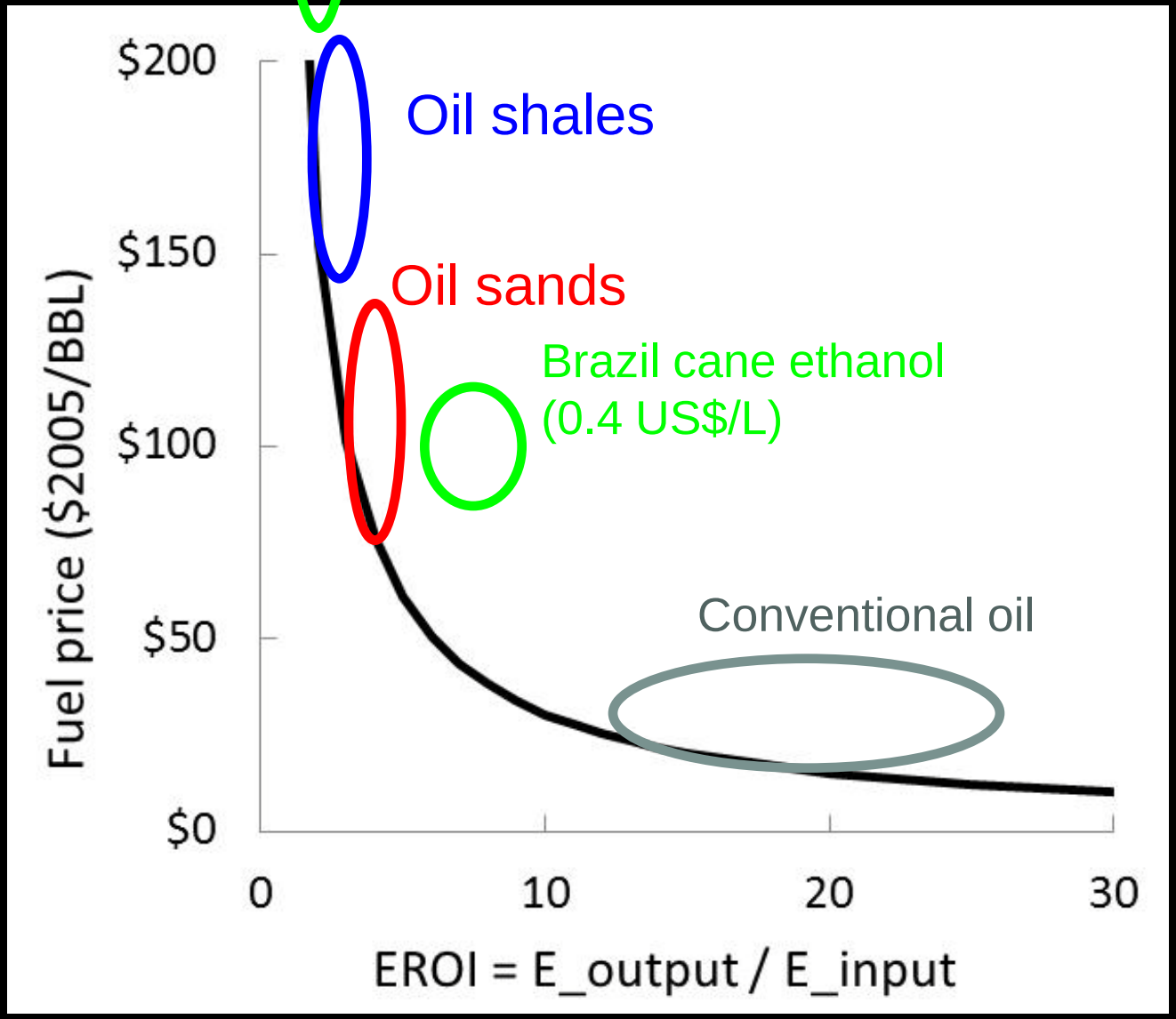
ttp://www.miningmx.com/news/energy/China-yet-to-approve-sasol-coal-oil-scheme.htm

- **Oil shale in United States (Colorado, Utah, Wyoming)**

http://www.chinadaily.com.cn/business/2009-01/22/content_7419616.htm

Many alternative fuels have net energy affected by water

Corn Ethanol?



[illegible]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