HYDRAULIC FRACTURING
GOOD FOR CARBON, BAD FOR WATER?

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US Natural Gas Production by Source

Figure 1. U.S. domestic crude oil production by source, 1990-2040

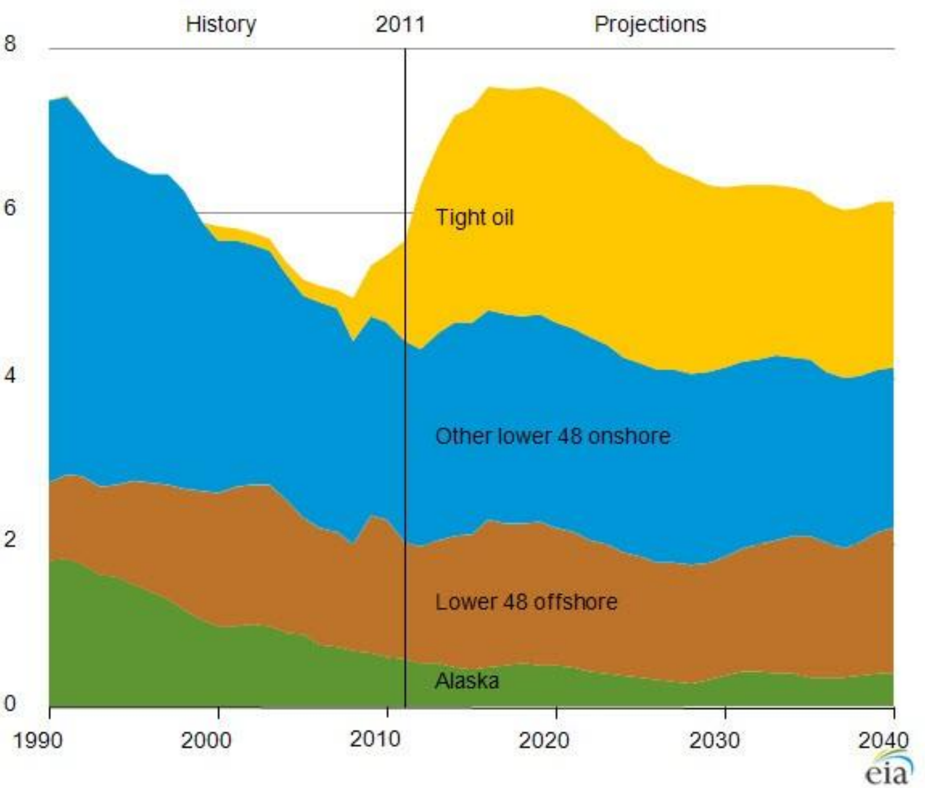
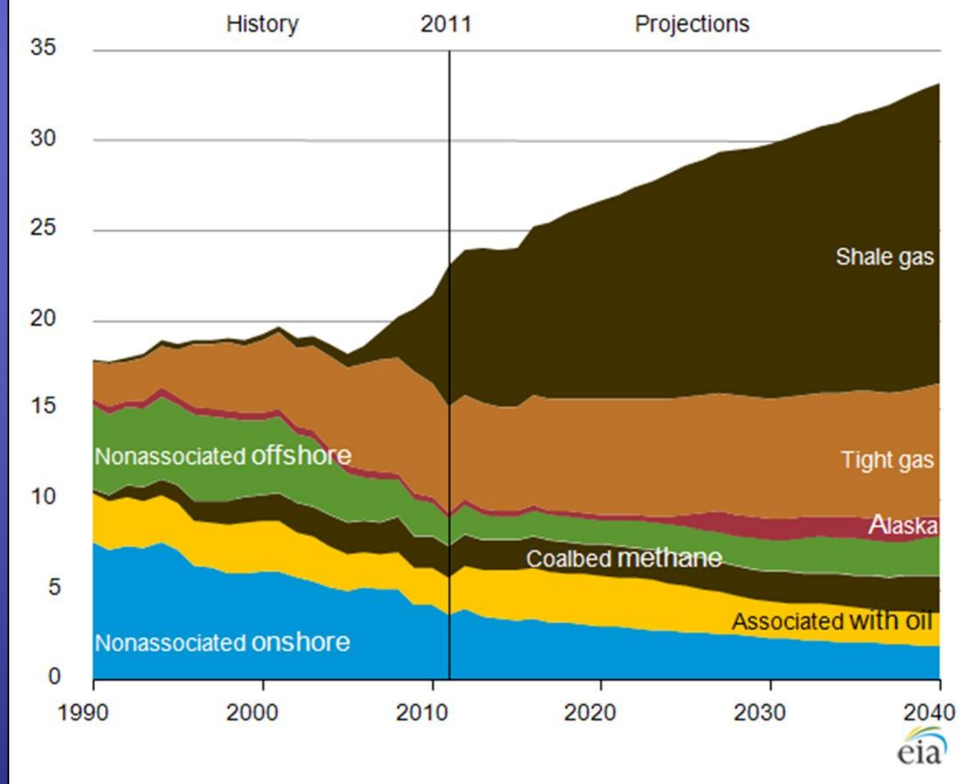
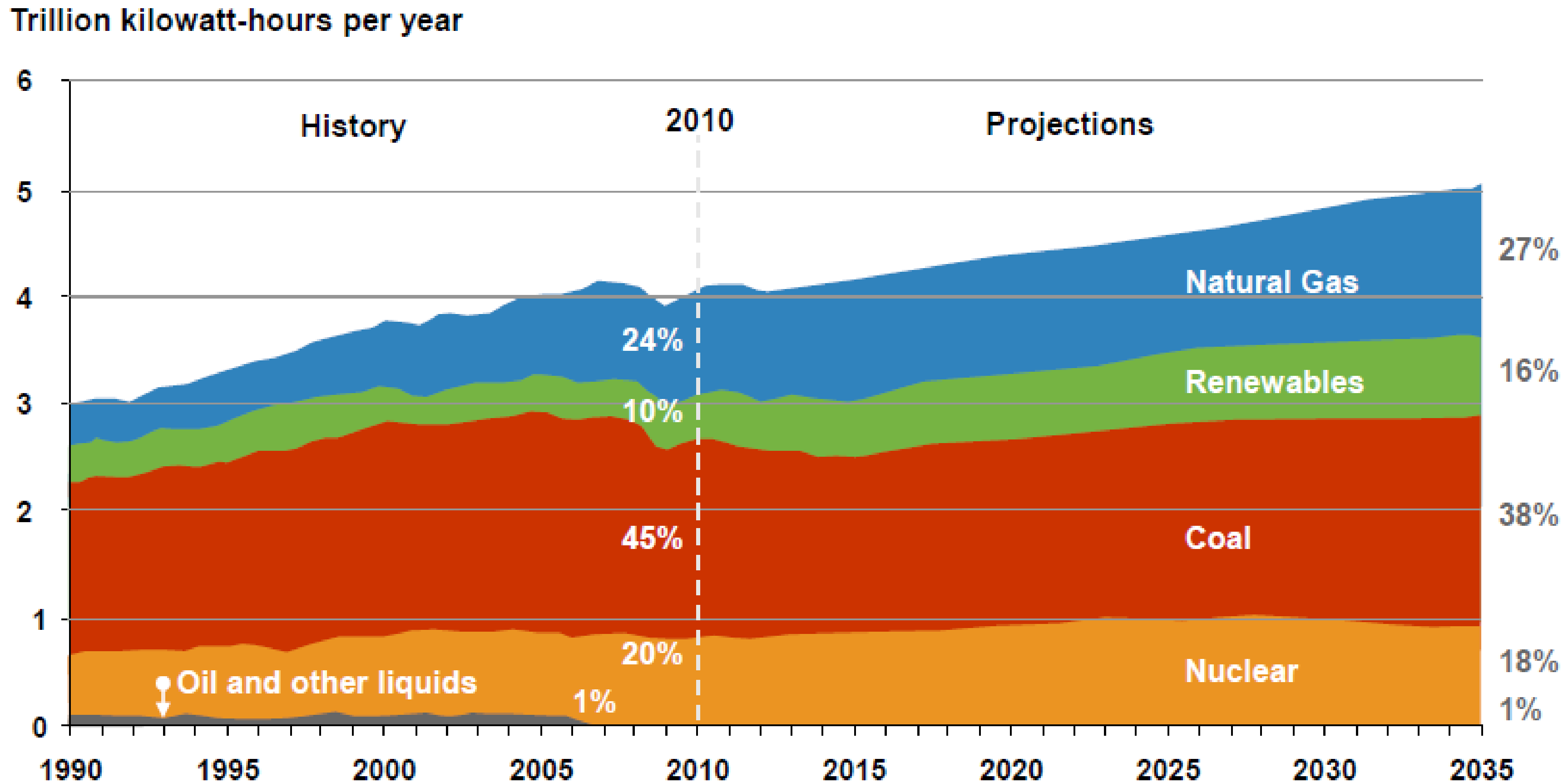


Figure 3. U.S. dry natural gas production by source, 1990-2040

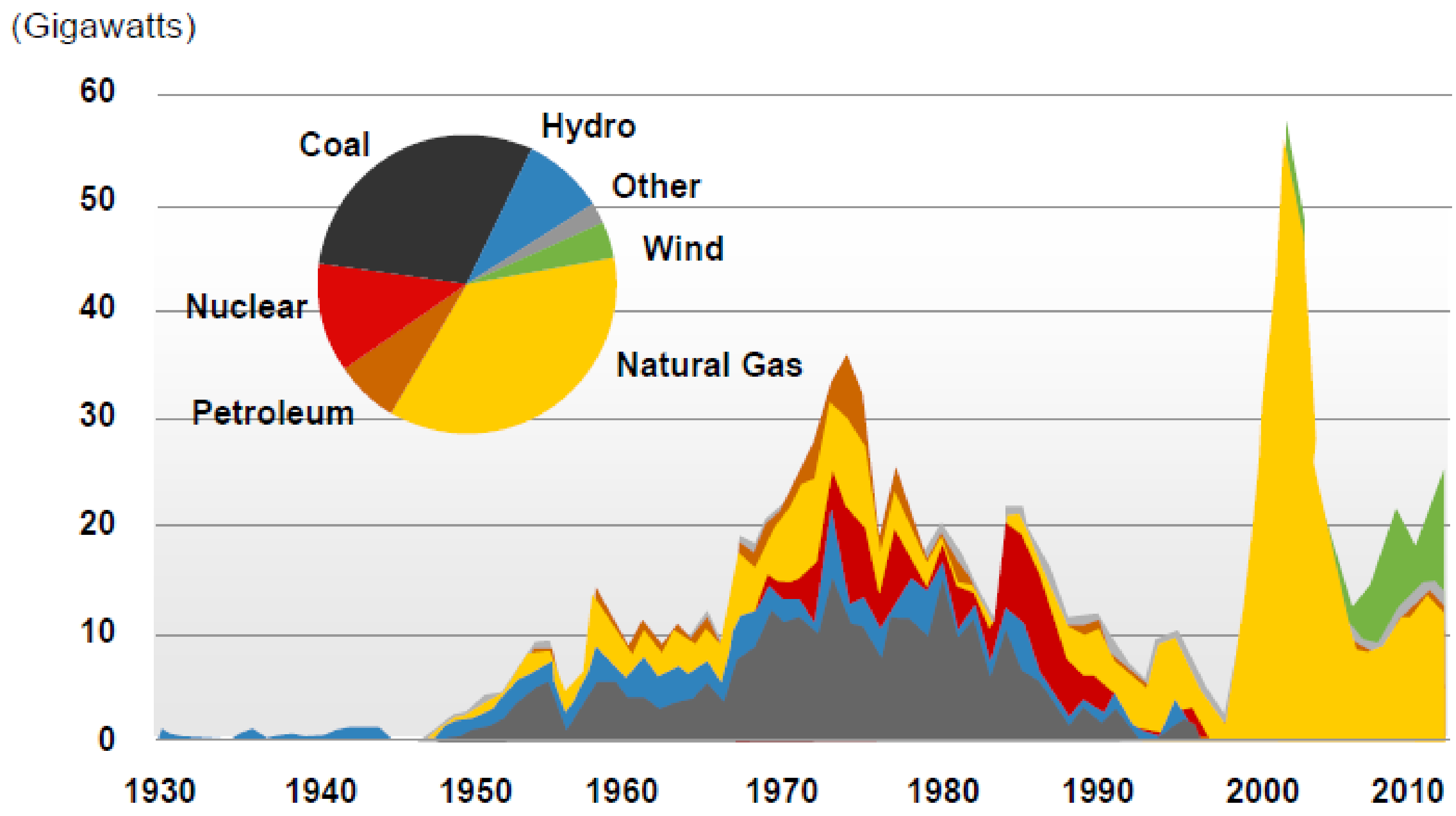


US Electricity Net Generation by Fuel 1990-2035



Source: U.S. Energy Information Administration, Annual Energy Outlook 2012 Early Release

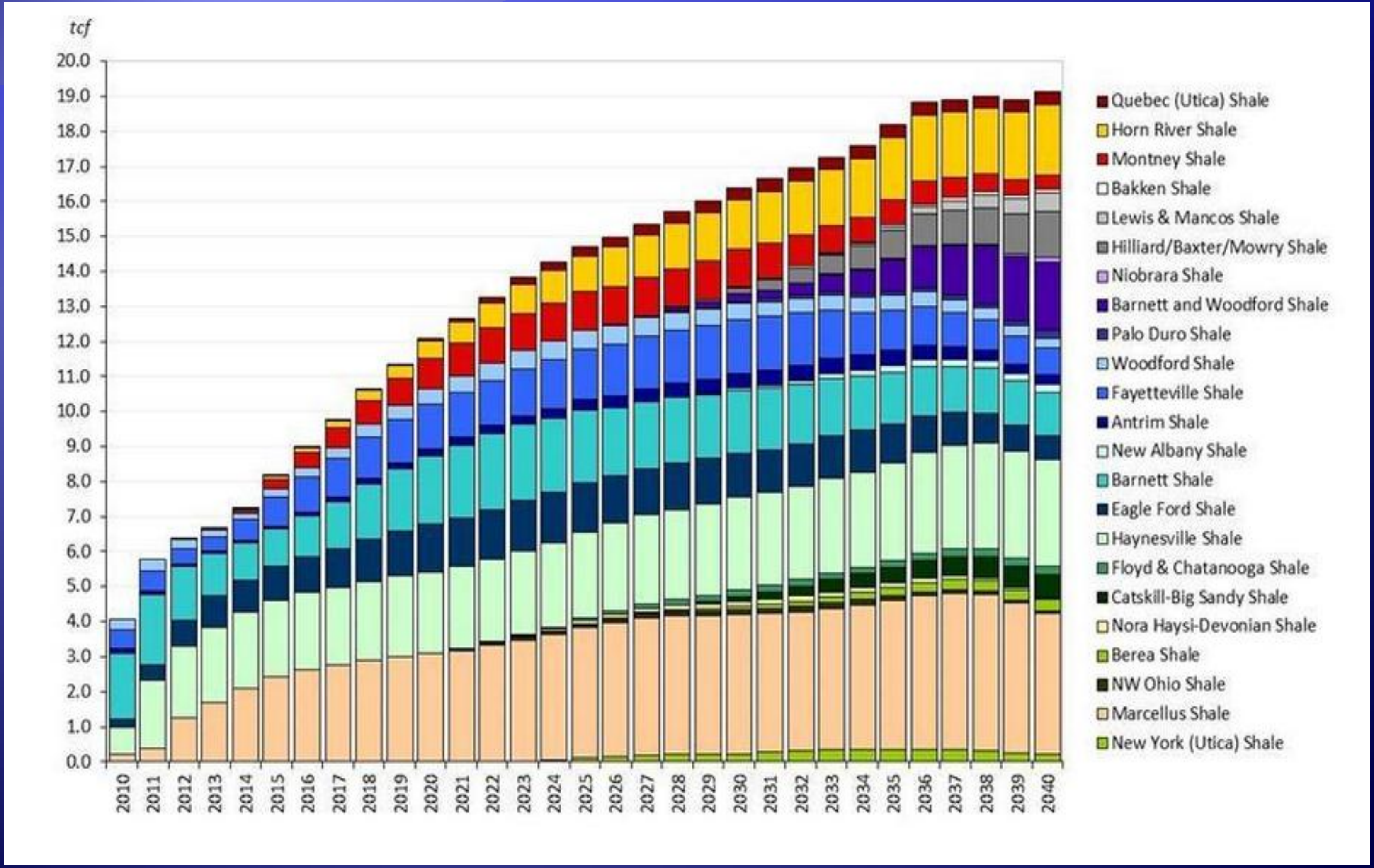
Power Generation Capacity by Startup Year



Source: U.S. Energy Information Administration, Form EIA-860 Annual Electric Generator Report, and Form EIA-860M (see Tables ES3 and ES4 in the January 2013 Electric Power Monthly)

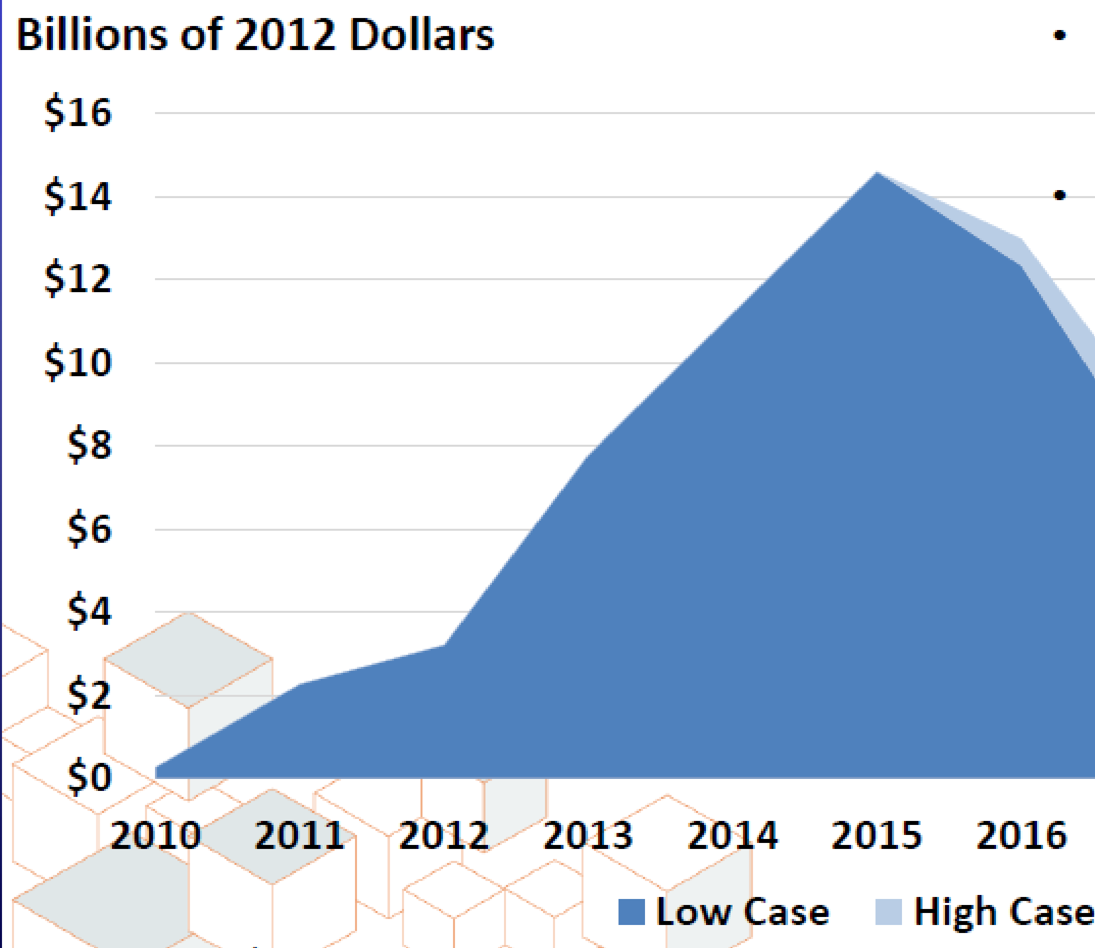
Leidich, 2013

US Shale Gas Production



Jaffe 2011

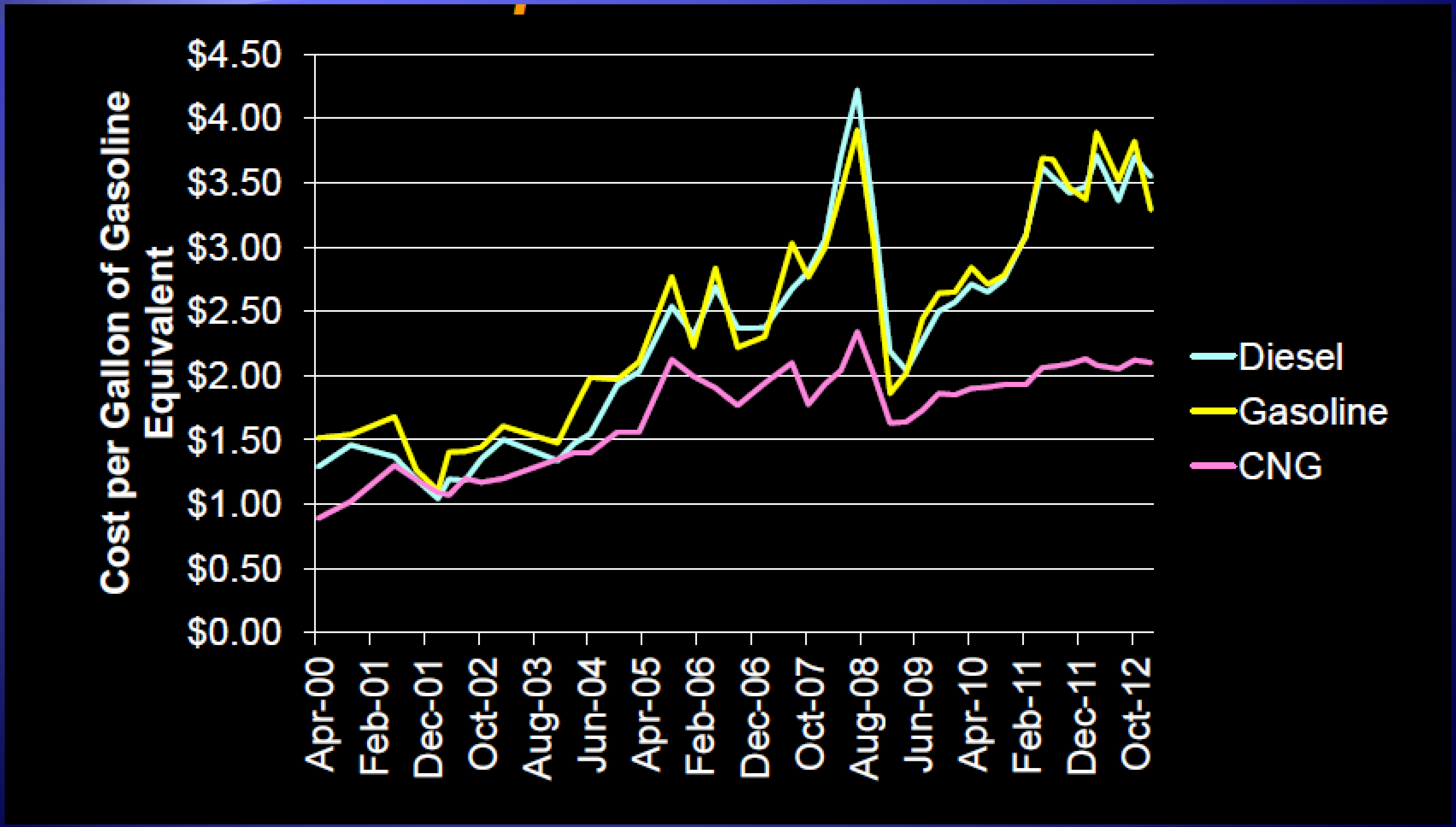
US Petrochemical Incremental Investment due to Shale Gas



- The $72-82 billion total investment is spread over 10 years
- The peak year for investment spending is 2015

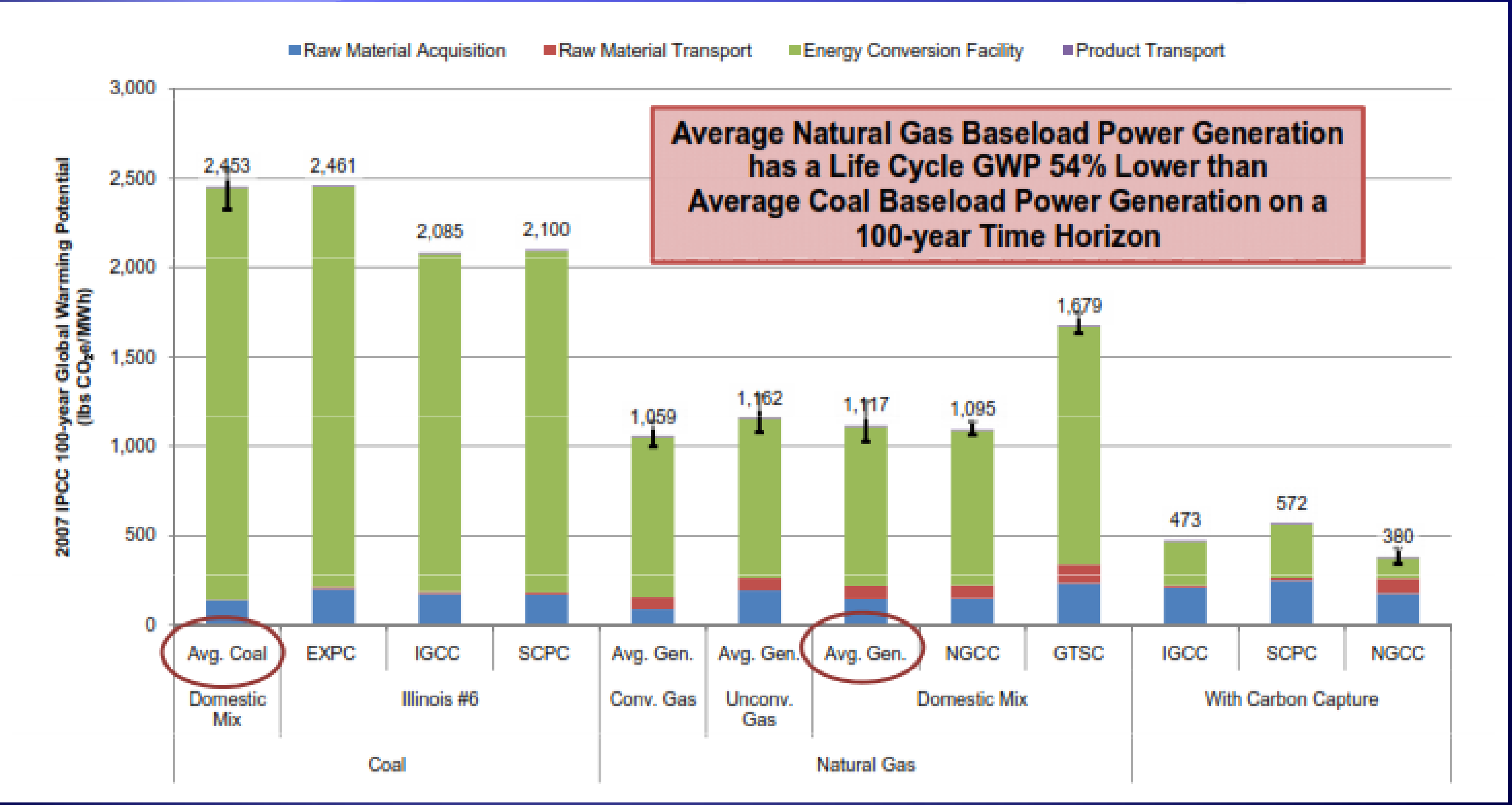
TK Smith ACC (2013)

Compressed Natural Gas as Transportation Fuel



K. Crane, Rand Corp. (2013)

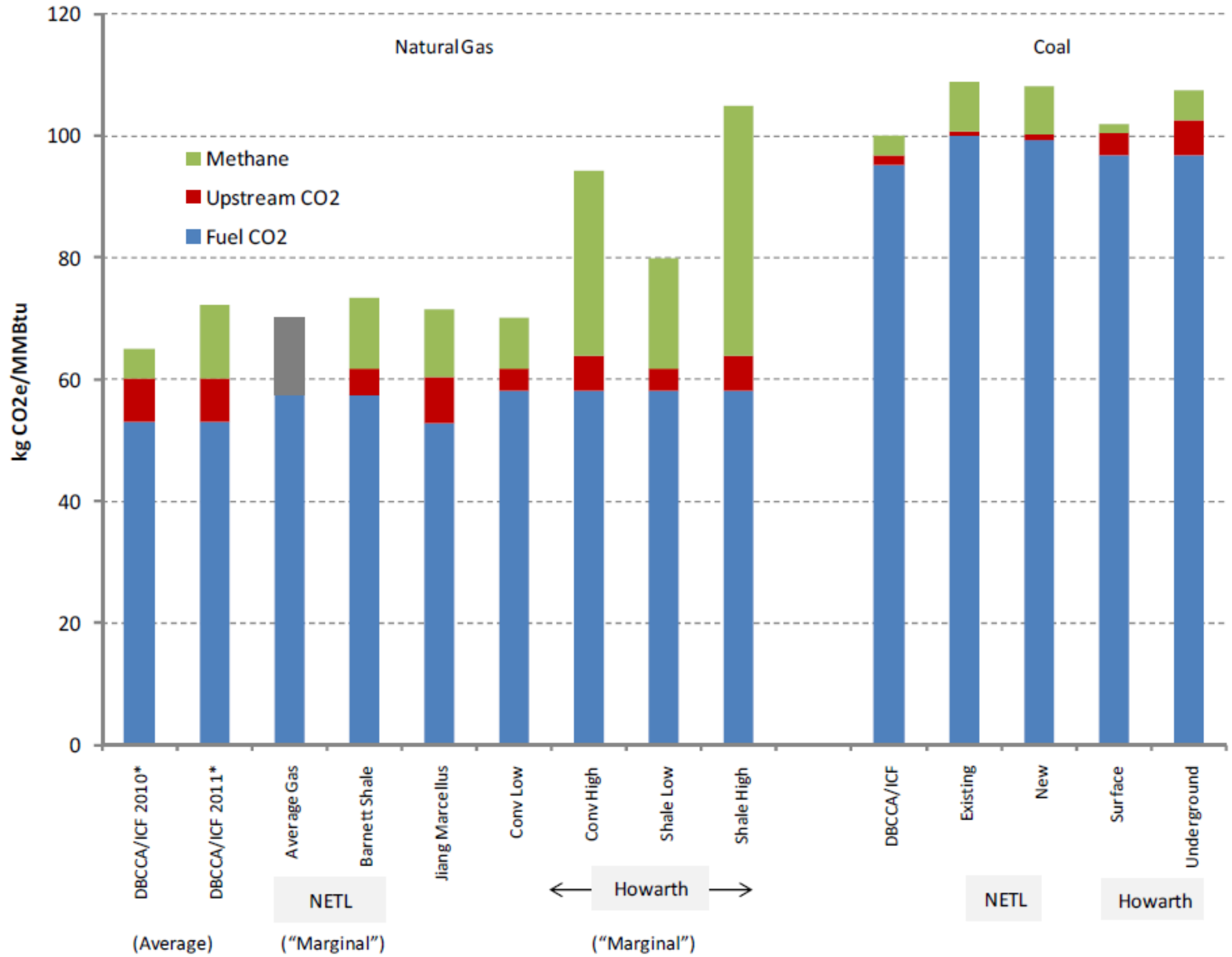
Life Cycle GHG Emissions



NETL, 2013

Worldwatch Institute, 2011

GHG Potential

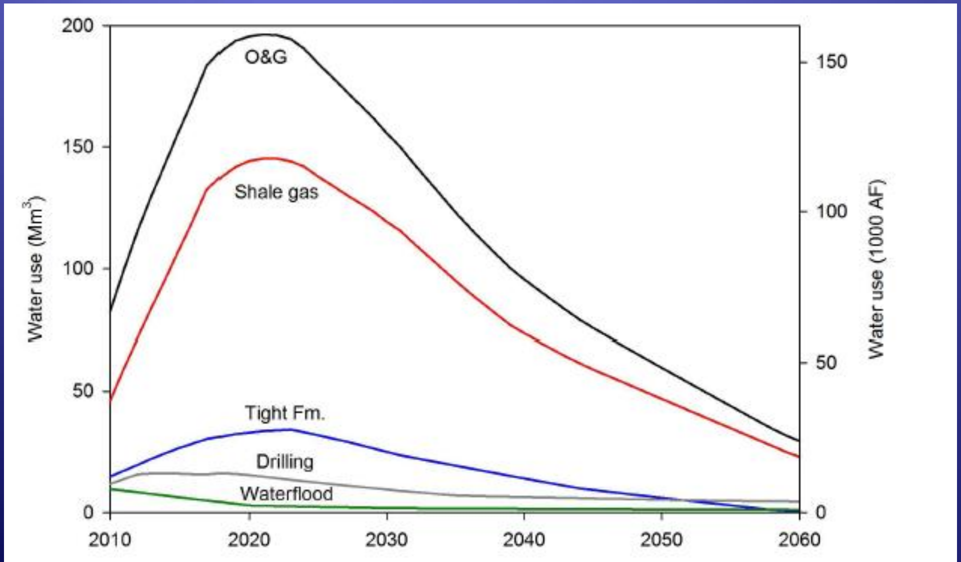


Source: DBCCA Analysis 2011; NETL 2011; Jiang 2011; Howarth 2011. Note: NETL Average Gas study includes bar shaded grey due to inability to segregate upstream CO2 and methane values, which were both accounted for in the study. See page 10 for more information. *2011 EPA methodology compared to 2010.

WATER AVAILABILITY

Water Demand Hydraulic Fracturing

- Barnett – 3 MM gal/well
- Haynesville – 6 MM gal/well
- Eagle Ford – 4 MM gal/well
- All approximately 1000 gallons/lateral ft of horizontal wells (80% between 500 and 1500 gal/ft)



Nicot and Scanlan, 2012

Water Intensity

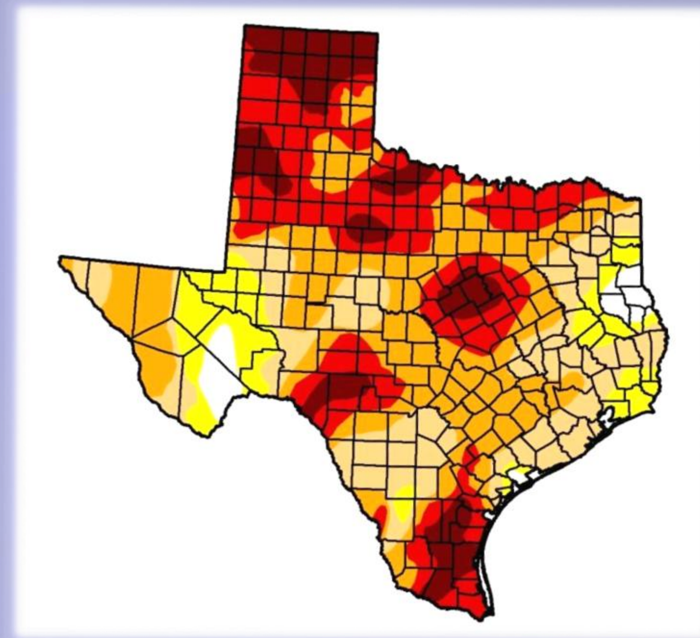
Table 3: Water requirements for various energy resources

Energy resource	Range of gallons of water used per MMBTU of energy produced
Barnett shale natural gas	1.47
Coal (no slurry transport)	2–8
Coal (with slurry transport)	13–32
Nuclear (uranium ready to use in a power plant)	8–14
Conventional oil	8–20
Syngas—coal gasification	11–26
Oil shale	22–56
Tar sands	27–68
Synfuel—Fisher Tropsch (from coal)	41–60
Enhanced oil recovery	21–2,500
Biofuels (irrigated corn ethanol, irrigates soy biodiesel)	$>$2,500

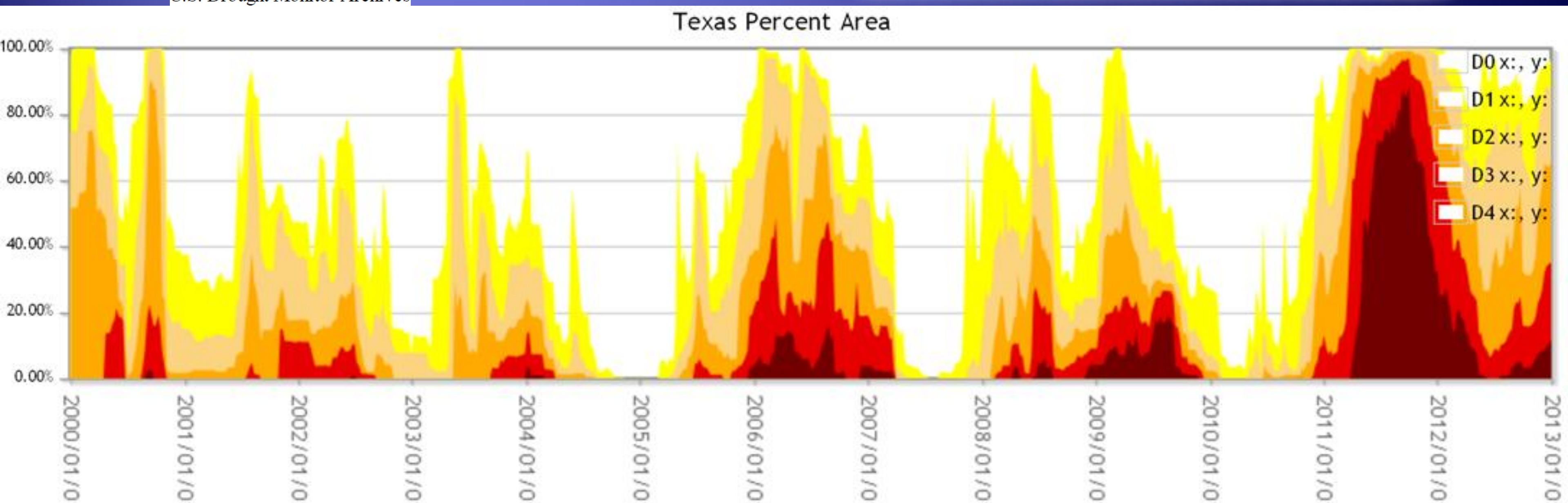
Source: Chesapeake Energy.

Texas – Perennial Drought Separated by Floods

- 2011 most severe one year drought
  - 99+% of Texas in drought
  - 100 km³ of water lost!
- But… its not over
  - Jan 2013 – 97% of Texas in drought!

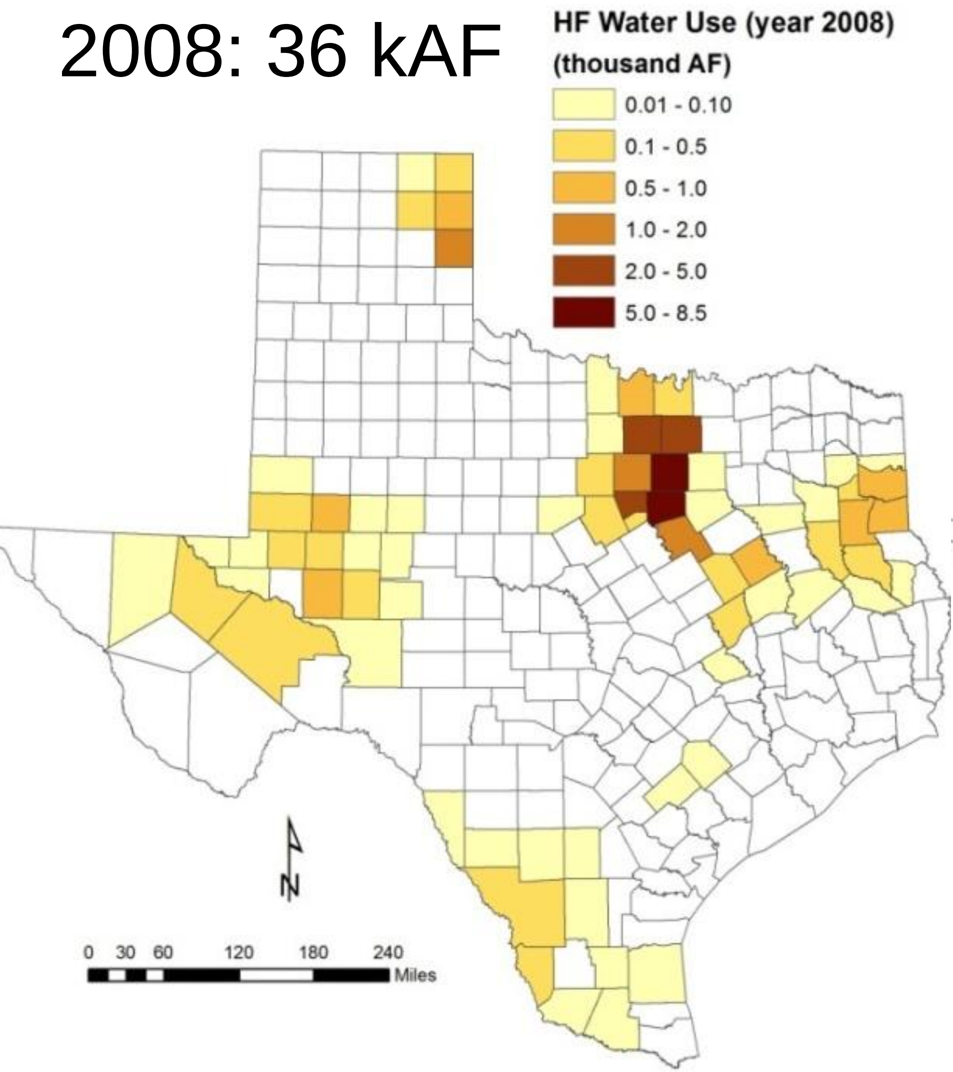


U.S. Drought Monitor Archives

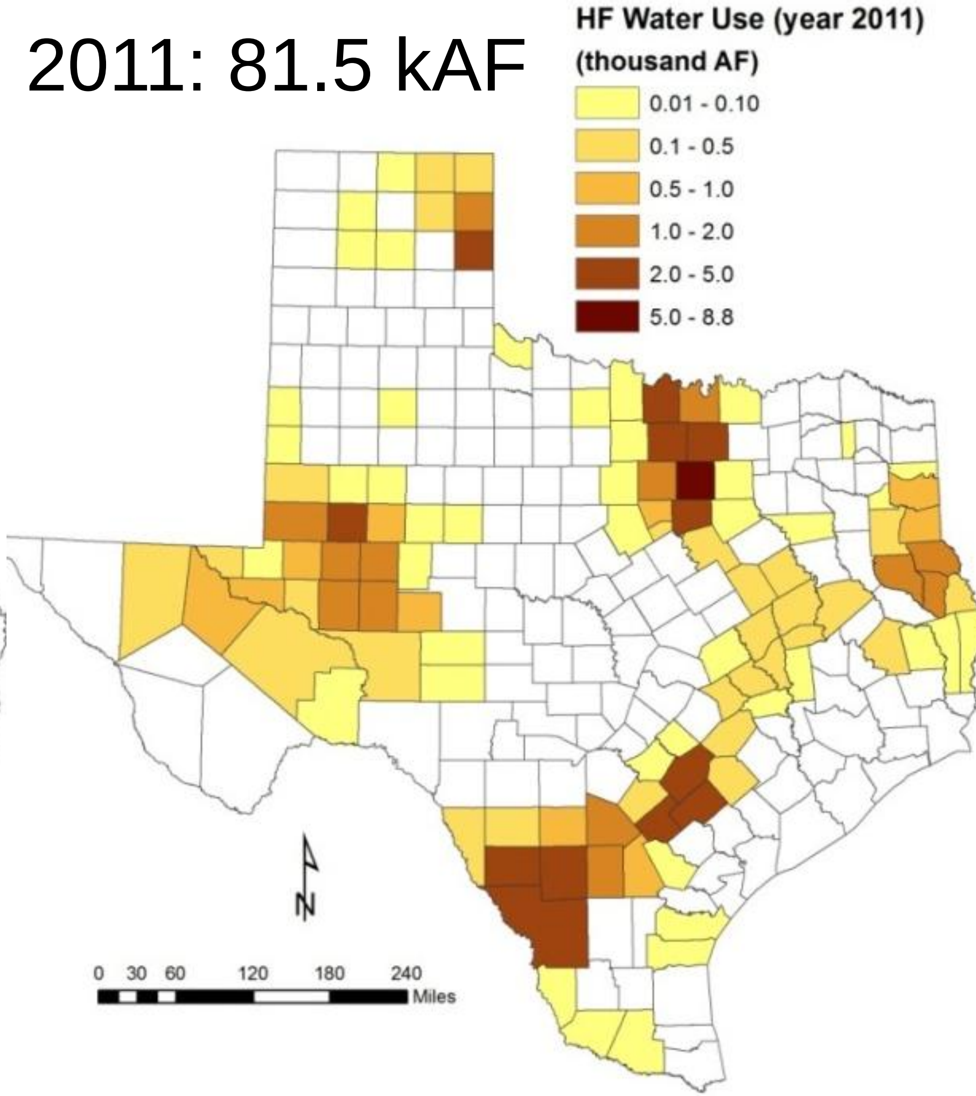


Hydraulic Fracturing Water Use

2008: 36 kAF



2011: 81.5 kAF

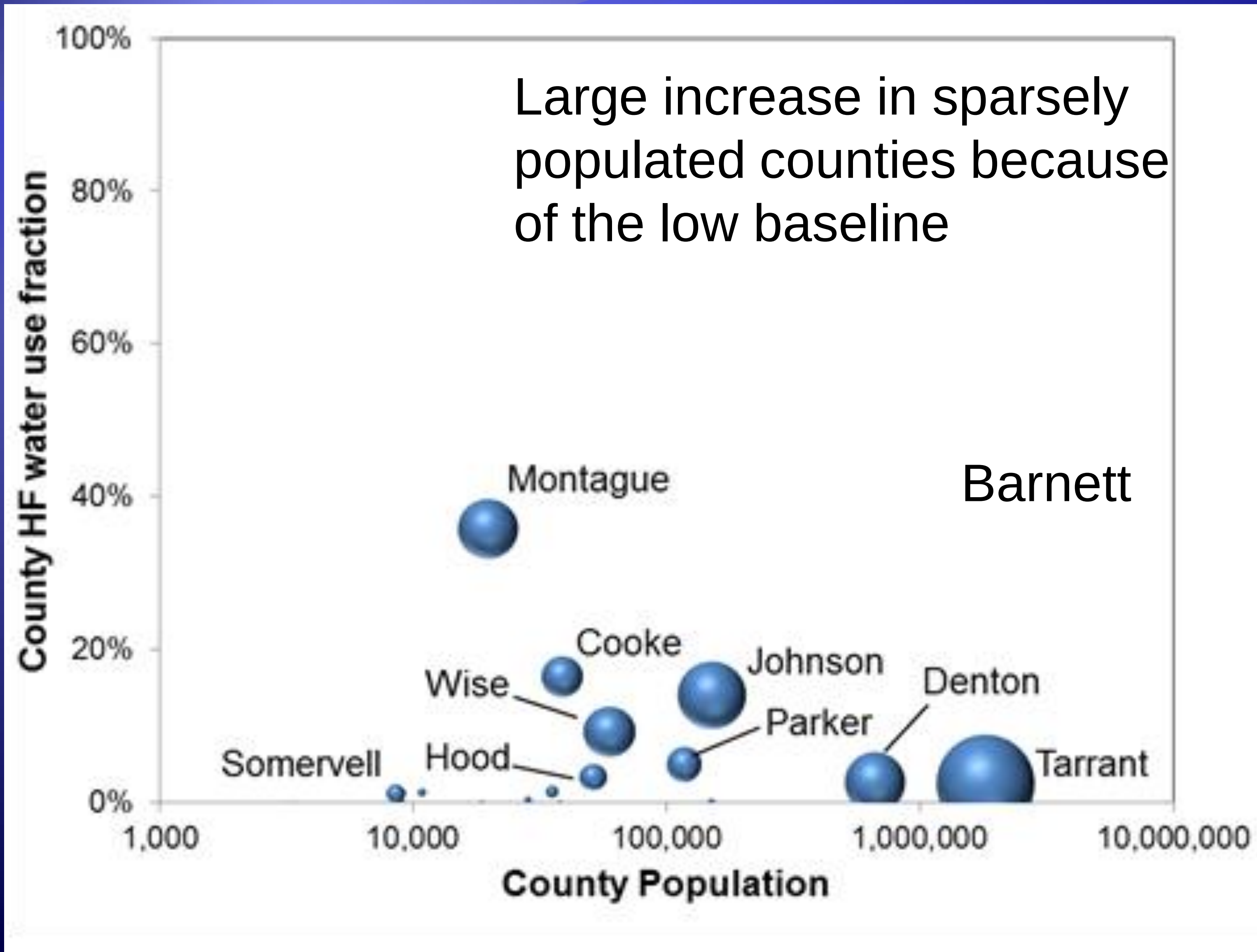


Source of raw data: IHS Enerdeq database

J.P. Nicot, 2013

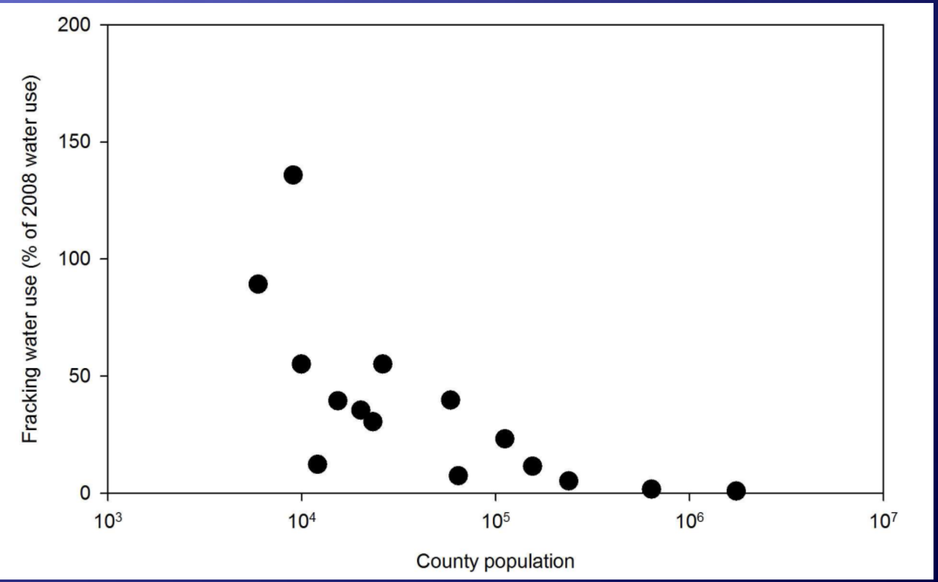
J.P. Nicot, 2013

Baseline water use



Water Availability
Eagle Ford

- Projected water demand – 5-6.7% of total water demand (Jester, 2011)
- Local dislocations possible (Nicot & Scanlon, 2012)
  - Projected water needs as percentage of **desired (sustainable)** pumping rates
    - Live Oak – 3.5%
    - De Witt – 8.3%
    - Karnes – 56.5%
    - La Salle – 66%
    - Dimmit – 130%
    - Webb - 136%



Water Availability

- Hydraulic fracturing generally represents a small demand relative to other demands
  - Possible local dislocations in low population/water demand areas
  - High visibility and unsympathetic public!
- How do we minimize that demand?
  - Reuse and recycling of flowback and produced waters
  - Use of poor quality source waters

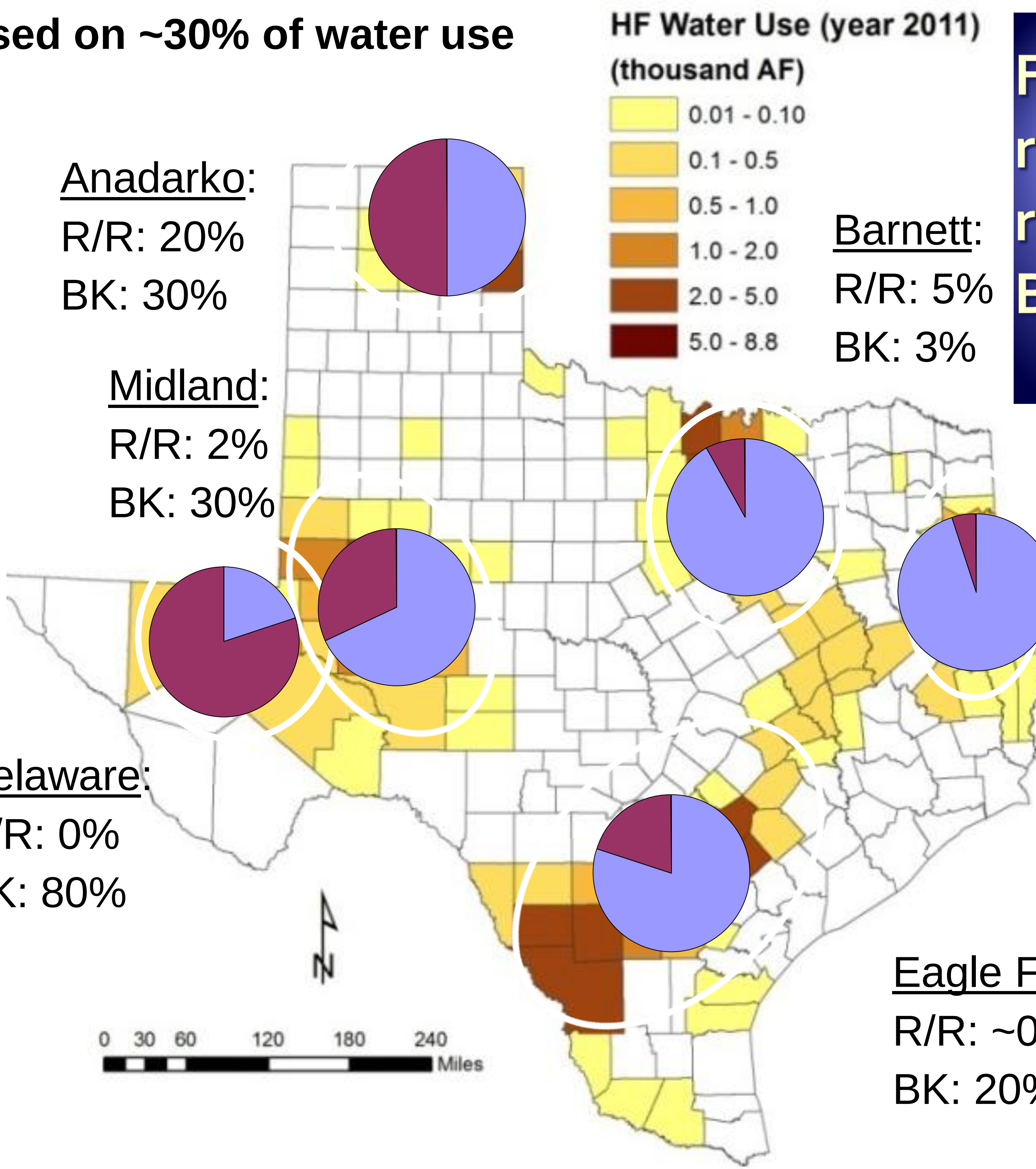
Reuse/Recycling

	PA Marcellus	TX Barnett
Water availability	Abundant	Limited
Drilling water, MM gal	0.085	0.25
Hydraulic fracturing, MM gal	5.5	3.8
New unconventional wells 2012	1365	660
Wells completed 2012 (est)	540	500
Active horizontal wells 2012	3680	>10,000
Salt water disposal wells	7-8	980 (12,000 in TX)
Flowback + produced (WW), MGD (est)	3.1	2
Fraction WW recovered	~0	~0
Fraction WW Reused	0.87	0.13
Fraction WW deep-well injected	0.13	0.87

Silva et al. 2013

Fraction from recycling / reuse (RR) and Brackish (BK)

Based on ~30% of water use



Anadarko:
R/R: 20%
BK: 30%

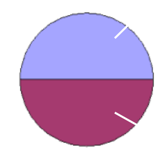
Midland:
R/R: 2%
BK: 30%

Delaware:
R/R: 0%
BK: 80%

Barnett:
R/R: 5%
BK: 3%

East Texas:
R/R: 5%
BK: ~0%

Eagle Ford:
R/R: ~0%
BK: 20%



J.P. Nicot, 2013