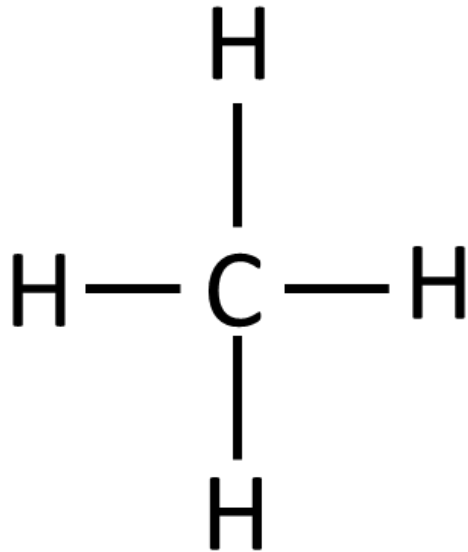




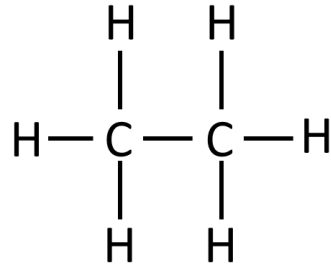
Natural Gas

OLLI: May 6, 2014

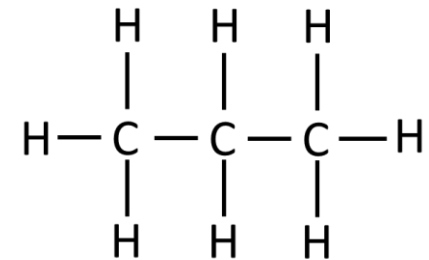
What is natural gas?



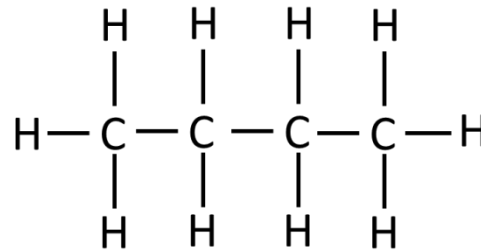
methane



ethane

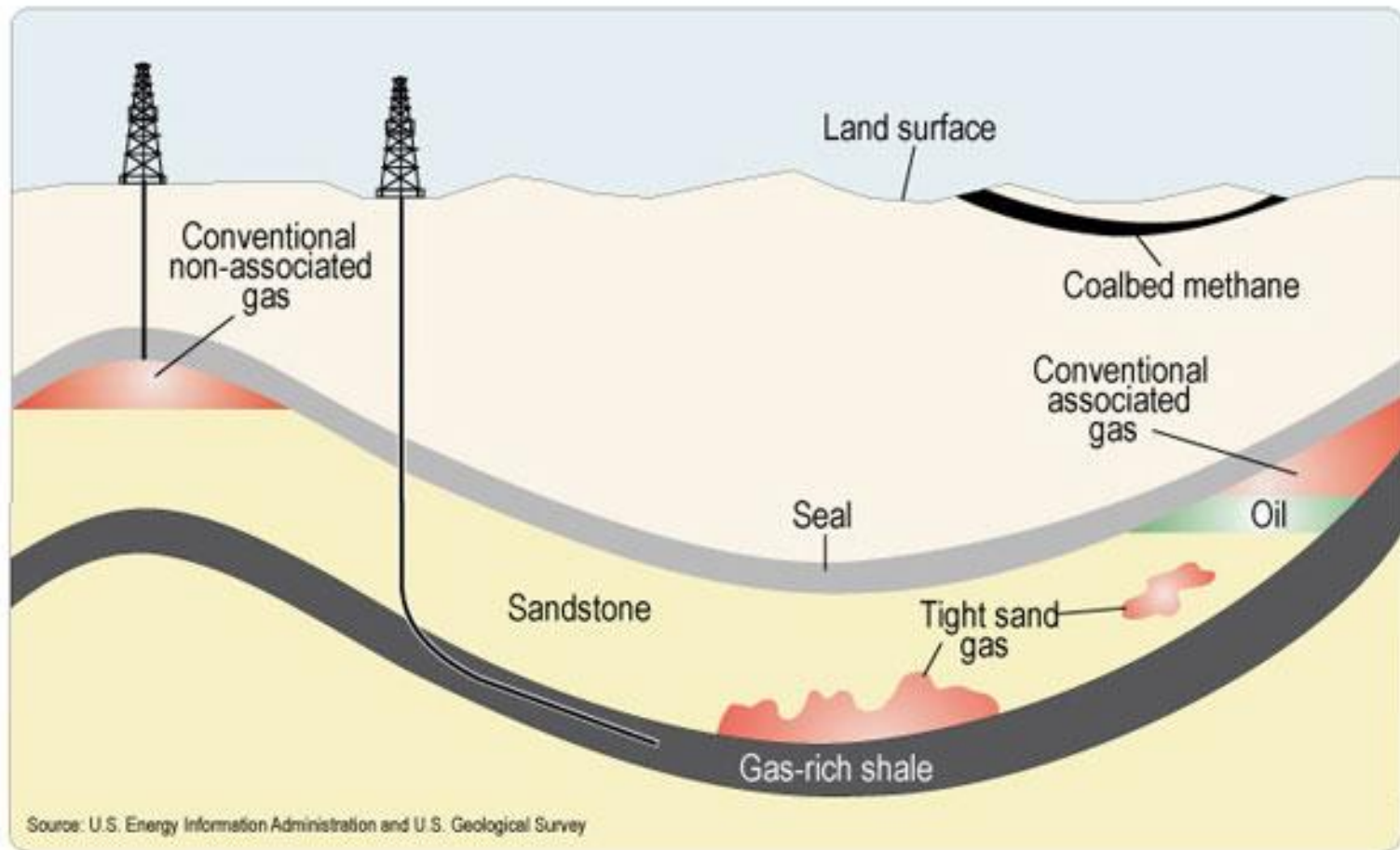


propane



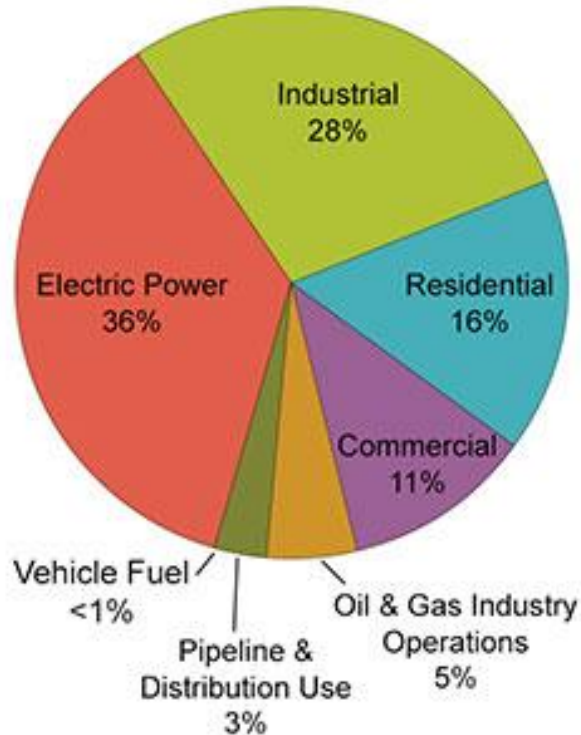
butane

Extraction Process



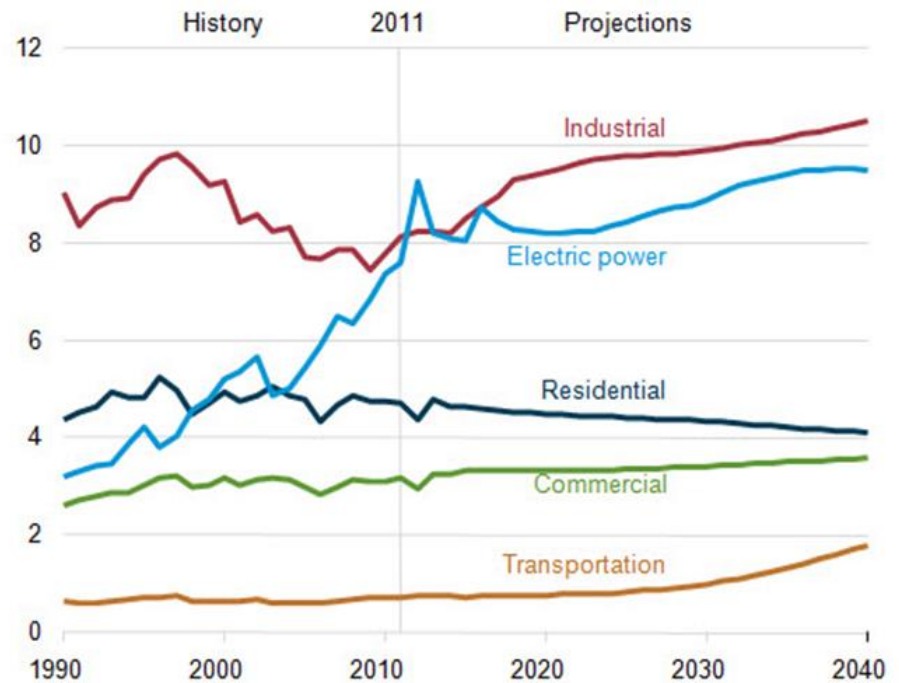
Natural Gas use by Economic Sector

Natural Gas Use, 2012



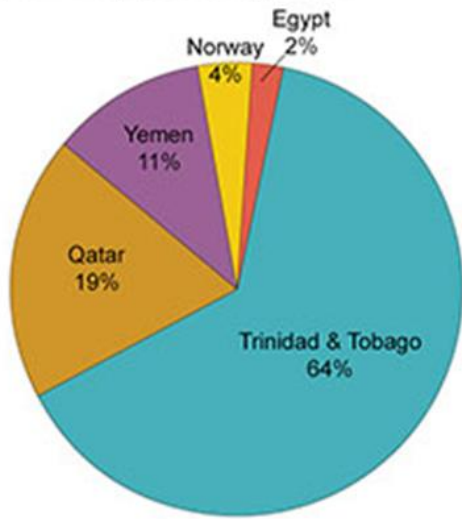
Source: U.S. Energy Information Administration, *Natural Gas Monthly* (March 29, 2013).

Figure 85. Natural gas consumption by sector, 1990-2040 (trillion cubic feet)

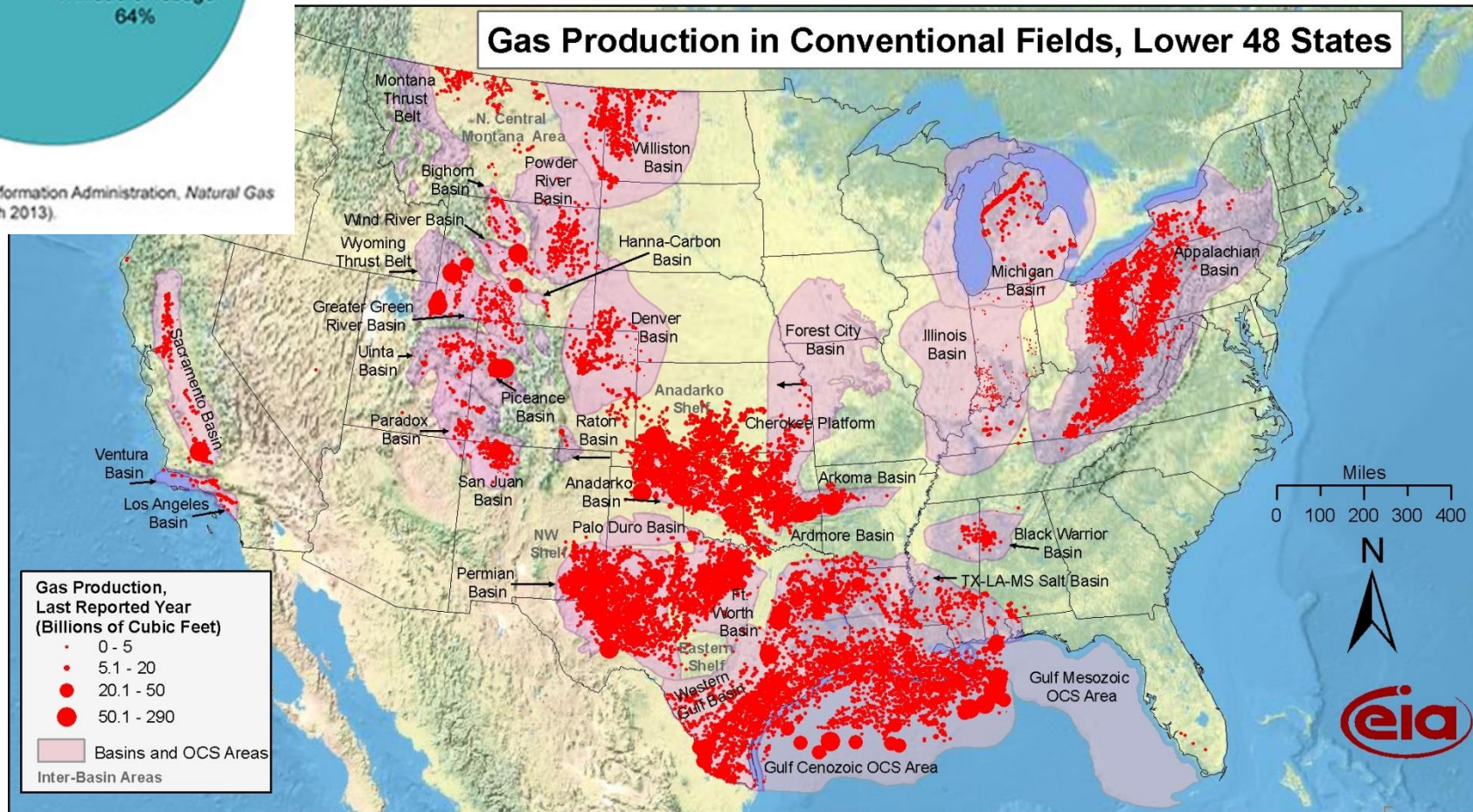


Conventional Natural Gas

U.S. Liquefied Natural Gas Imports by Country (Percent), 2012



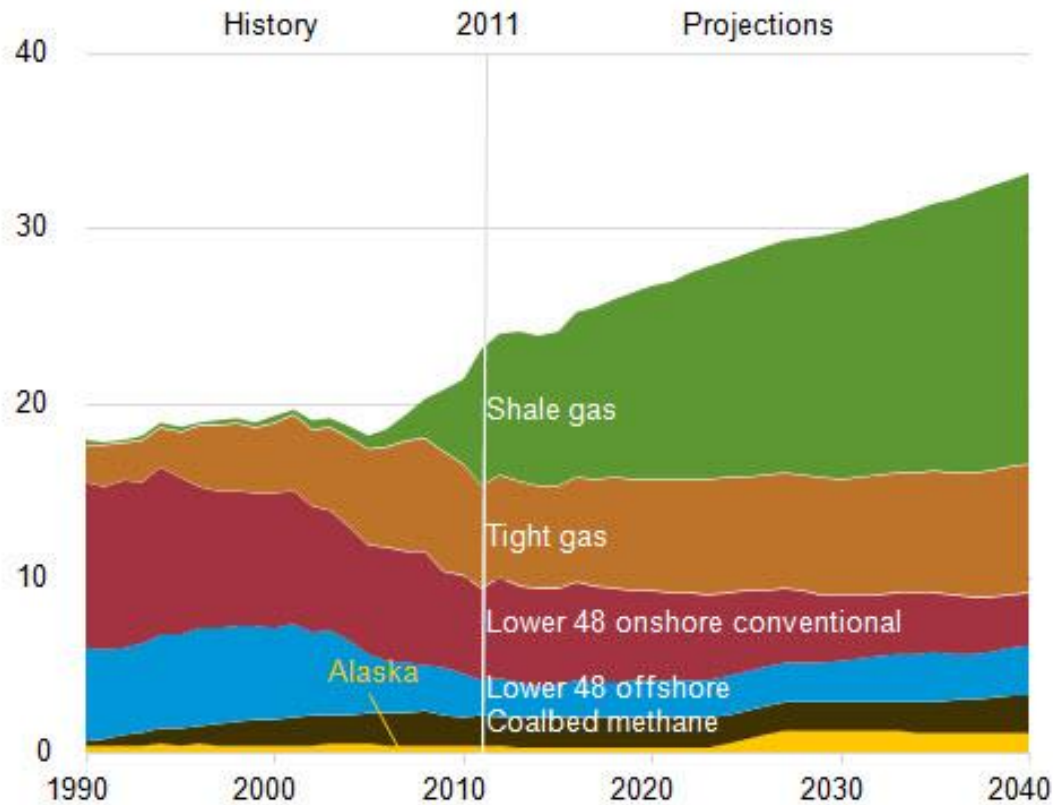
Gas Production in Conventional Fields, Lower 48 States

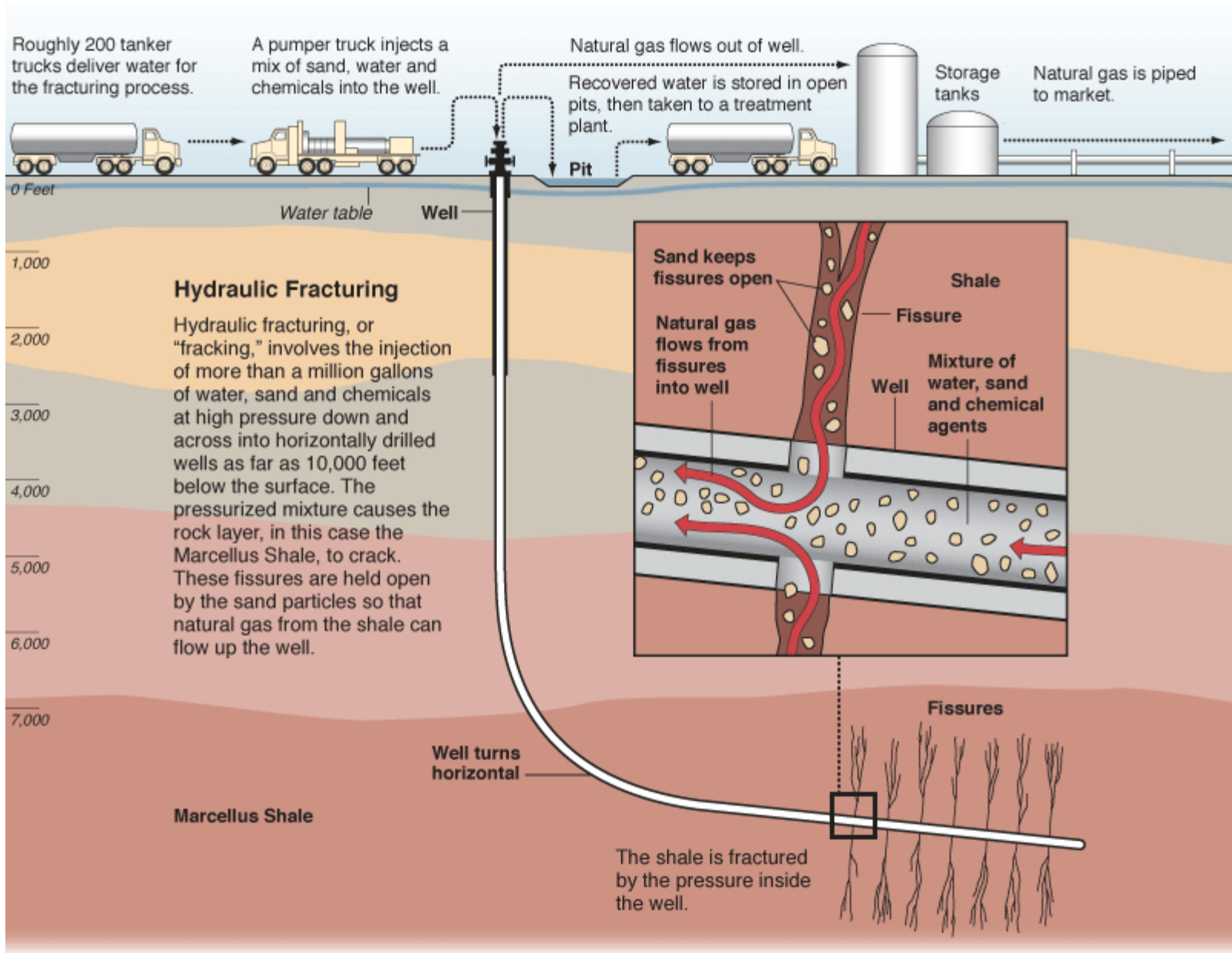


Source: Energy Information Administration based on data from HPDI, IN Geological Survey, USGS
Updated: April 8, 2009

U.S. Natural Gas Production

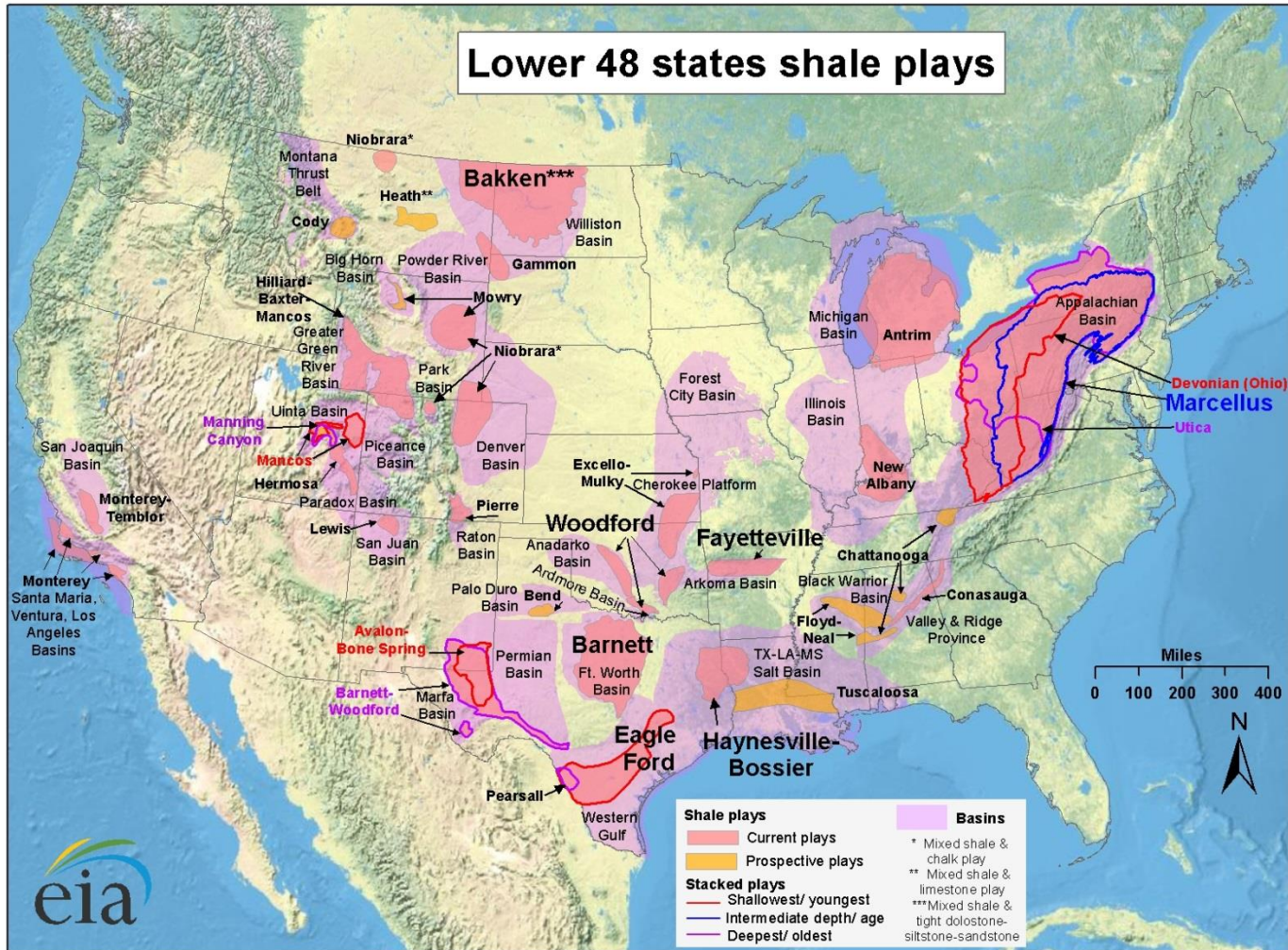
Figure 91. Natural gas production by source, 1990-2040 (trillion cubic feet)





Graphic by Al Granberg

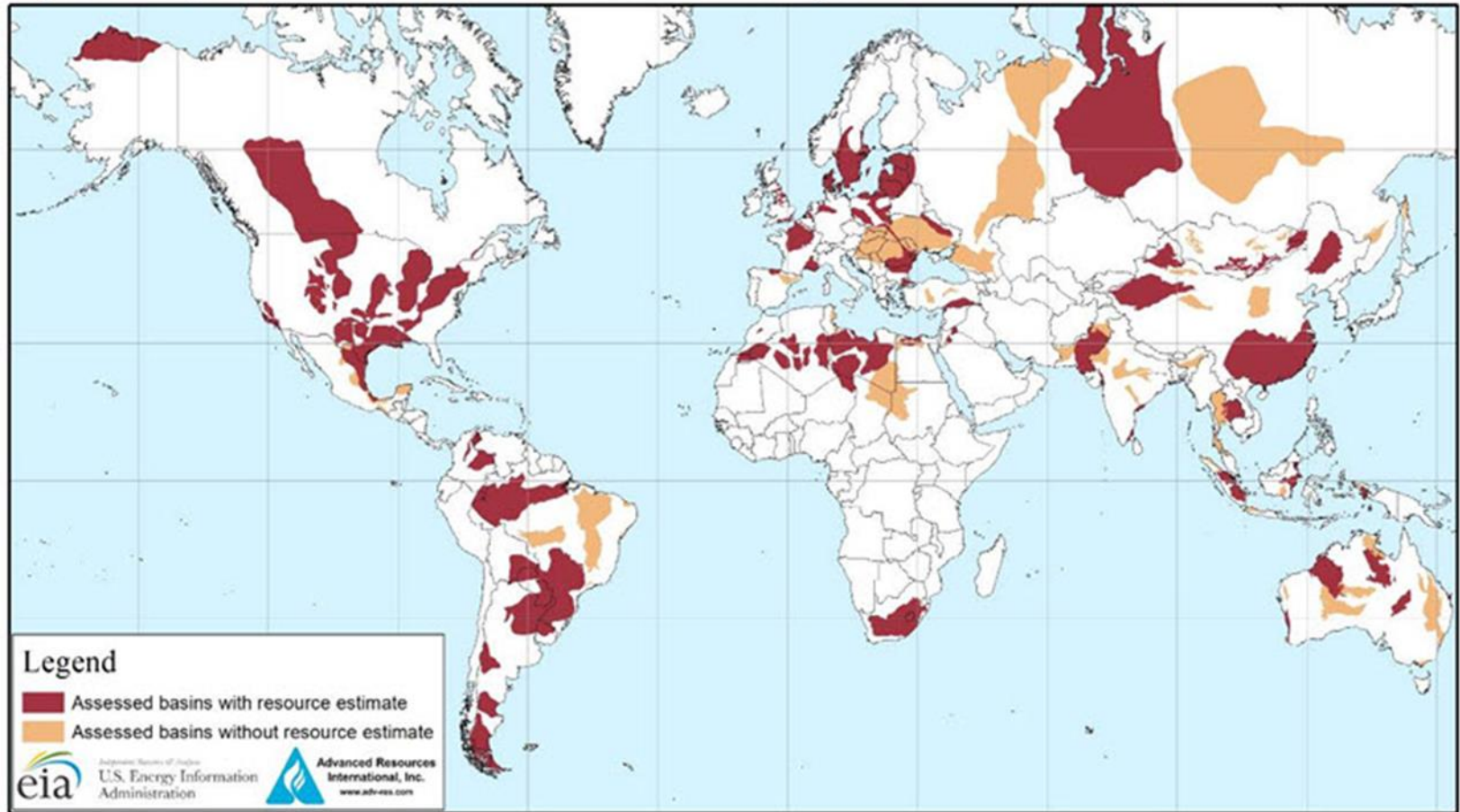
Shale Gas Reserves



Source: Energy Information Administration based on data from various published studies.
Updated: May 9, 2011

Global Shale Gas Reserves

Figure 1. Map of basins with assessed shale oil and shale gas formations, as of May 2013



Source: United States basins from U.S. Energy Information Administration and United States Geological Survey; other basins from ARI based on data from various published studies

Environmental Concerns with Shale Development

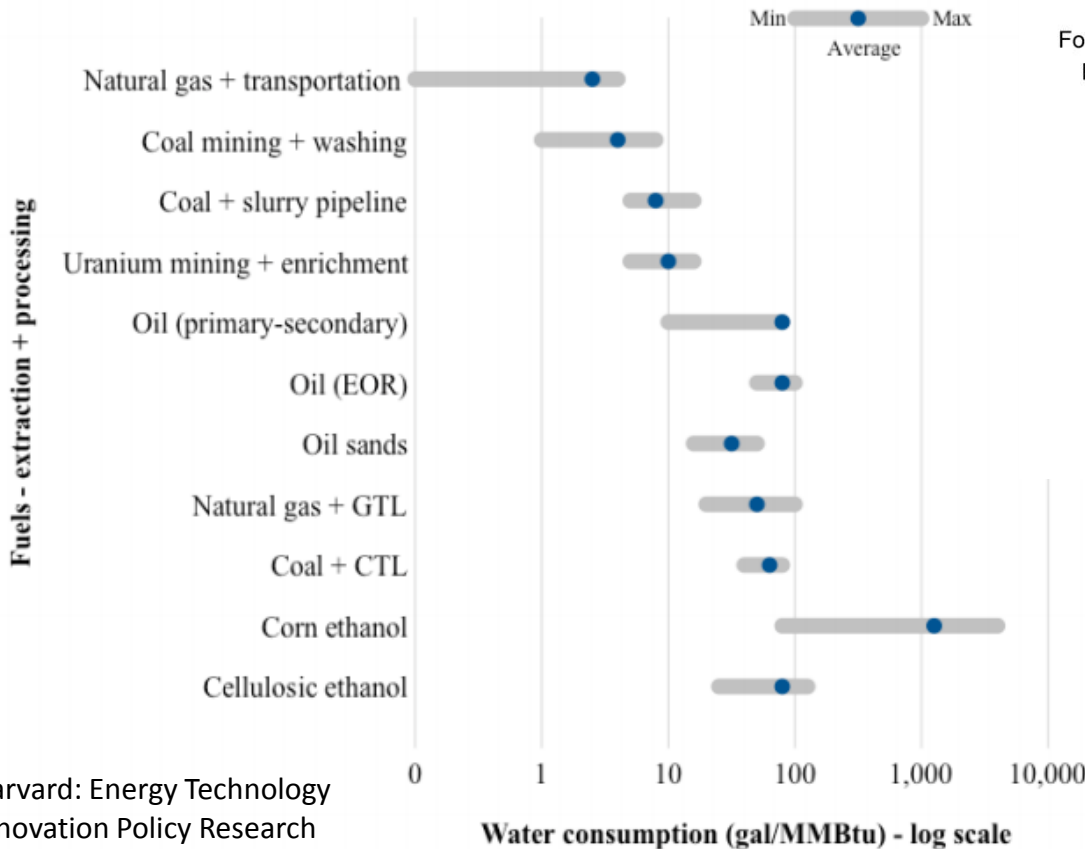
- **Water Use**
- **Aquifer Contamination**
- **Wastewater Management**
- **Methane Emissions**
- **Seismic Activity**

Water Use

- **3-6 million gallons per frack**

➤ 4.5-9 Olympic Swimming pools worth of water

Chart ES-1: Water consumption of extraction and processing of fuels



Water Savings from Fuel Shift

For every gallon of water used to produce natural gas through hydraulic fracturing

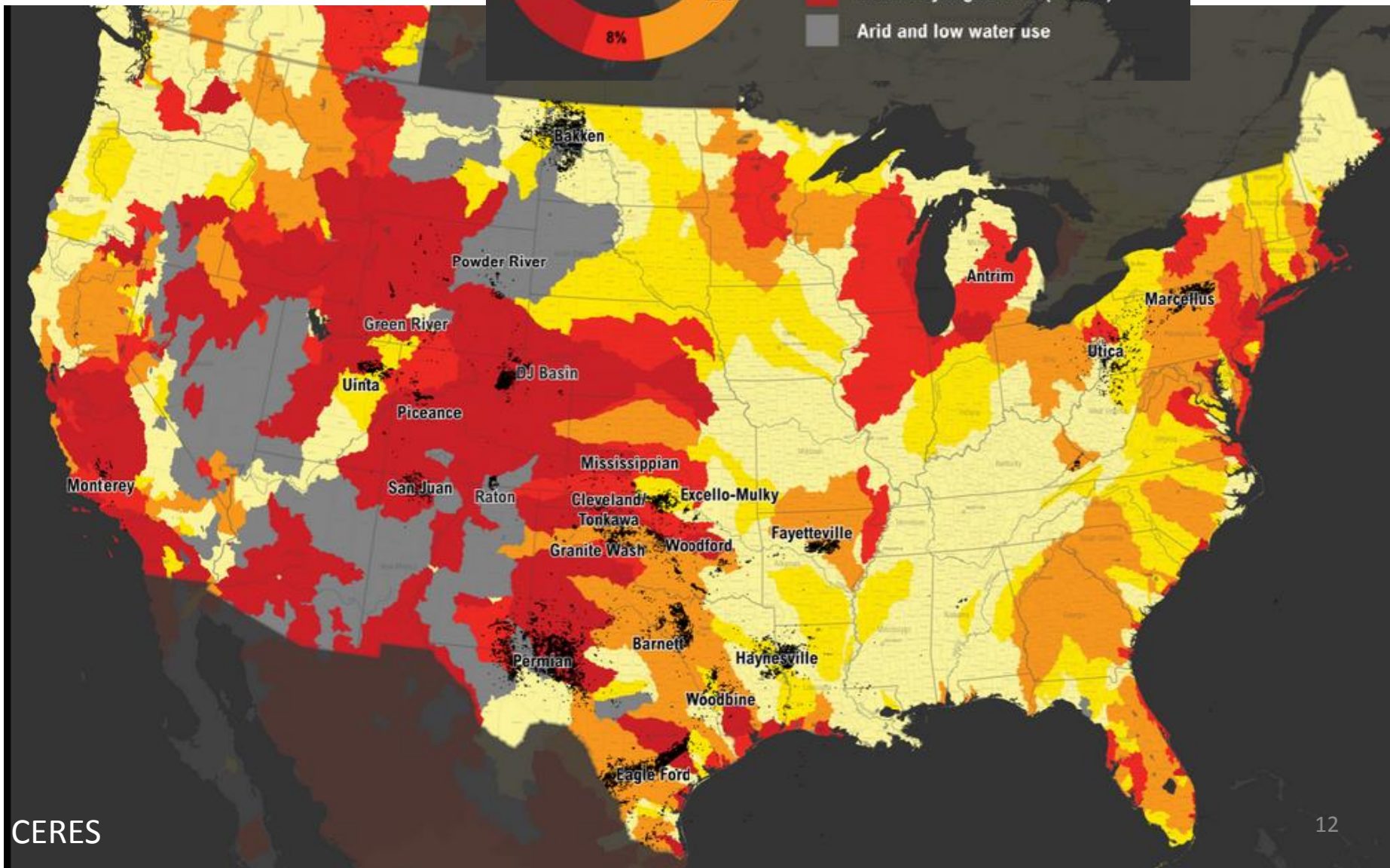
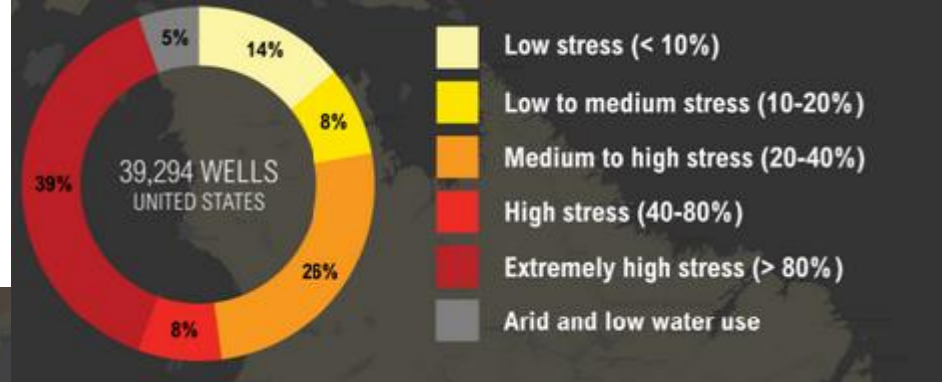


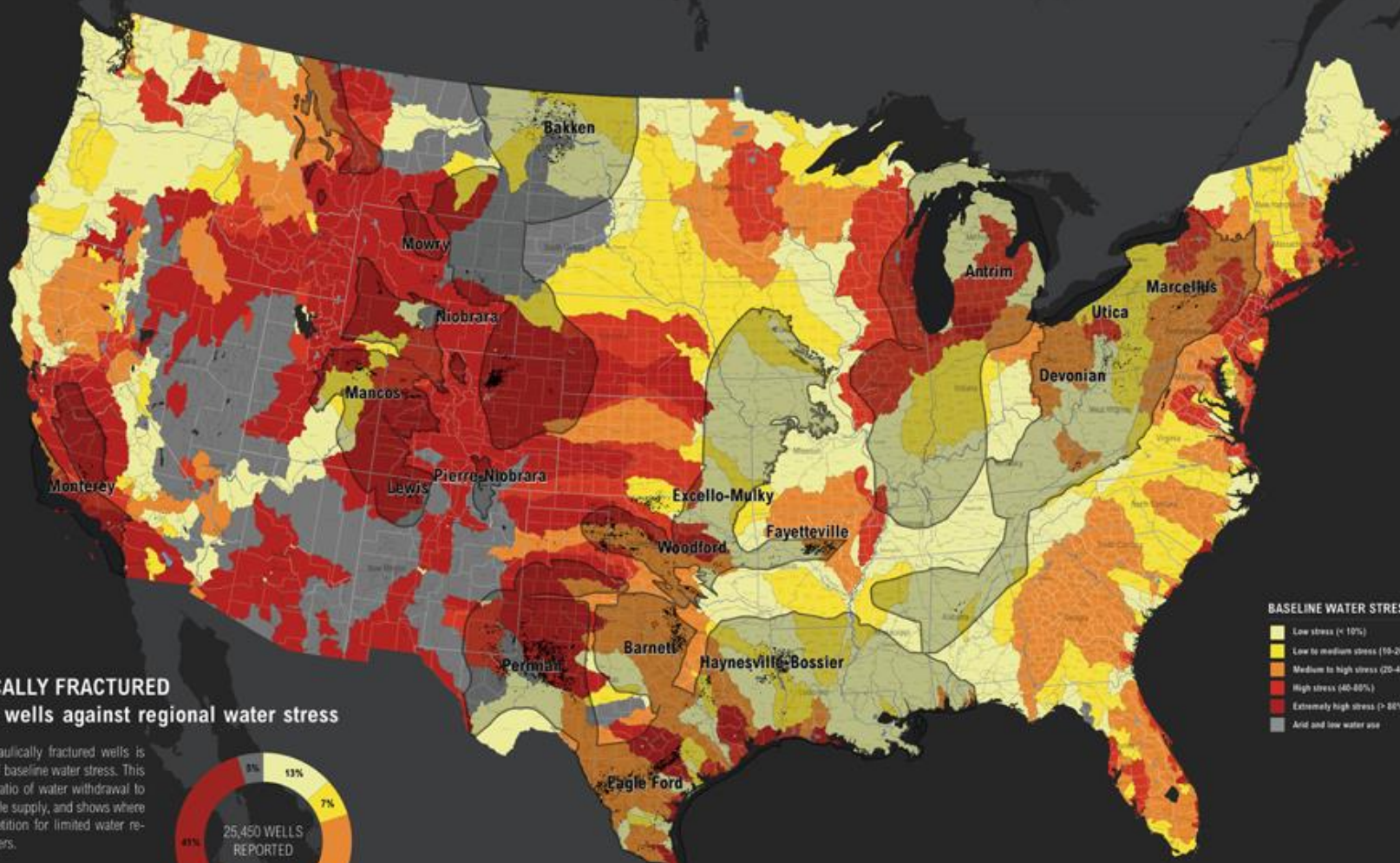
Texas saved 33 gallons of water by generating electricity with that natural gas instead of coal (in 2011)

Water use becomes a local issue...

Illustration: Univ. of Texas at Austin

Water Stress and Shale Development





HYDRAULICALLY FRACTURED oil and gas wells against regional water stress

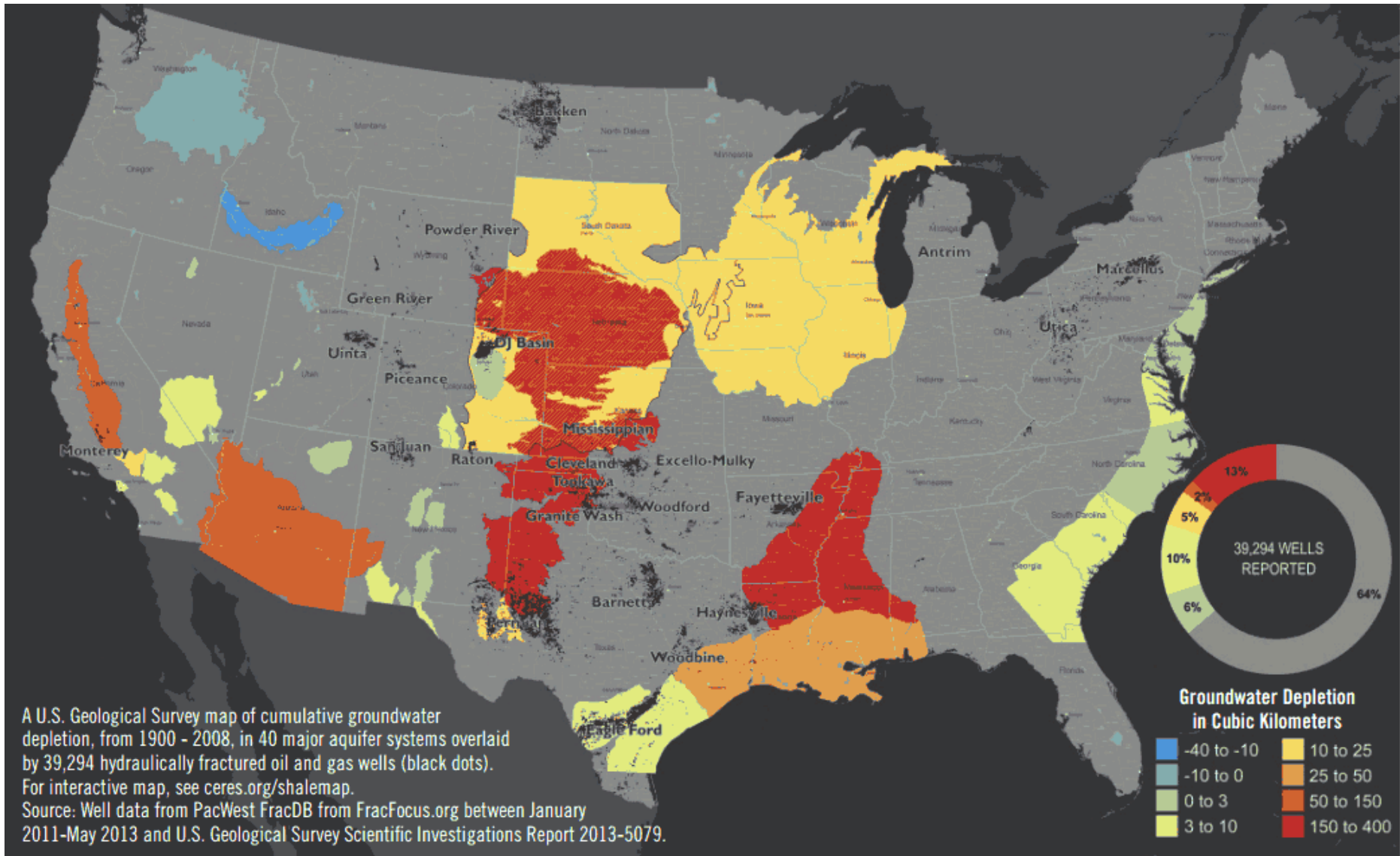
A database of hydraulically fractured wells is overlaid on a map of baseline water stress. This map measures the ratio of water withdrawal to mean annual available supply, and shows where there is high competition for limited water resources amongst users.



Red areas on the baseline water stress map are places where a large portion of available water supply is already being used. The gray areas are dry and undeveloped.

Ceres analysis using WRI Aqueduct Global Water Risk Atlas. Well data sourced from ePactWest FracDB / fracfocus.org. Well data reflects voluntary reporting of wells traced between 01/2011 to 09/2012.

Groundwater Depletion



Aquifer Contamination

Jackson, PNAS, 2013

141 drinking water samples from northeastern PA

- Examined natural gas concentrations and isotopic signatures



npr

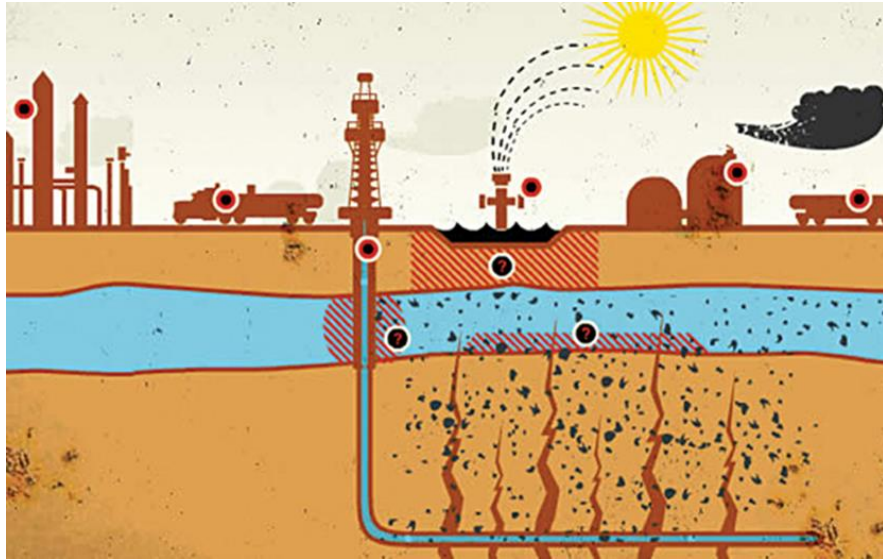
Conclusions:

- Methane detected in 82% of drinking water samples
- Ave methane concentrations were 6x higher for homes <1 km from a natural gas well ($p = 0.0006$)
- Ave ethane concentrations was 23x higher for homes <1 km from a natural gas well ($p = 0.0013$)

Aquifer Contamination

Proven:

- Aquifer contamination with methane due to faulty well casings and cementing.
 - In 2010, the PA Department of Environmental Protection issued 90 violations for faulty well casing and cementing on 64 Marcellus shale gas wells. There were 119 similar violations in 2011.



Gasland

Not Proven:

Gas migration to shallow drinking water aquifers from deep underlying formations

Wastewater

Fracking fluid: water, sand, acids, additives to adjust fluid viscosity (borate), viscosity reducers (ammonium persulfate), corrosion inhibitors (isopropanol, acetaldehyde), iron precipitation control (citric acid), biocides (glutaraldehyde), oxygen scavengers (ammonium bisulfite), scale inhibitors (acrylic polymers), and friction reducers (surfactants)

Flowback fluid: Fluids that return to the surface after fracking process is complete (10-40% of volume of injected fluid)

- Consists of fracking fluid + natural fluids from the shale formation (e.g. brine)

Produced waters: Fluids that are extracted together with the natural gas during production

- Composed of naturally occurring hypersaline formation water + oil, bitumen, and oil condensates

Wastewater

Wastewater Characteristics

- Total Dissolved Salts: ranging from below seawater conc. (25,000 mg/L) to 7x more saline than seawater, depending on the shale formation
- Hydrocarbon contaminants
- Metalloids (arsenic and selenium)
- Radioactive elements (radium)

Wastewater Management

- Recycled for subsequent fracking
- Injected into deep injection wells (not applicable in PA)
- Publicly owned wastewater treatment plant
- Municipal wastewater treatment plant
- Commercially operated wastewater treatment plant
- In some states---spread of roads for dust suppression or deicing

Case Study on Treated Fracking Wastewater

Impacts of Shale Gas Wastewater Disposal on Water Quality in Western Pennsylvania

Warner, et al. 2013, Journal of Environmental Science and Technology

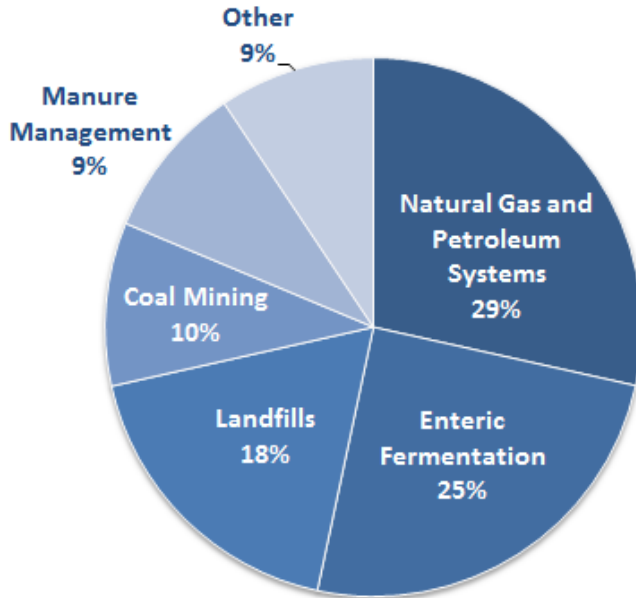
Duke University Study

Looked at the water quality of effluent coming out of water treatment plants receiving fracking wastewaters

Conclusions

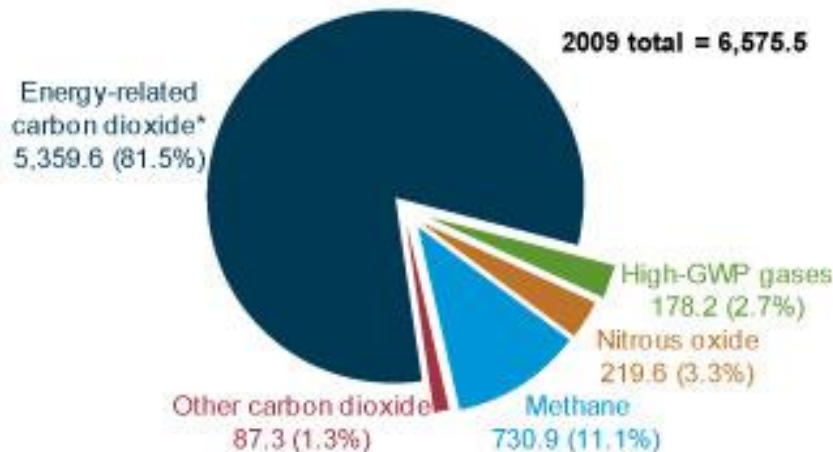
- Increased downstream concentrations of chloride and bromide compared to upstream concentrations (up to 6,700x higher)
- Reduced (>90%) barium and radium levels in treated waters compared to Marcellus Shale produced water
- Radium levels in point of discharge sediment were 200x upstream and background concentrations and were above radioactive waste disposal threshold regulations

Methane Emissions



U.S. EPA (1990-2012)

Figure 1. U.S. greenhouse gas emissions by gas, 2009
million metric tons carbon dioxide equivalent



- Methane lifetime in the atmosphere = 12 years vs . thousands of years for CO₂

- Methane is a more potent greenhouse gas:

1 lb of methane = 21 lbs of CO₂

Recent News (April 2014):

U.S. may be producing 50% more methane than EPA estimate indicated

Regulations...

2005 Energy Policy Act:

Exempts hydraulic fracturing operations from the Safe Drinking Water Act

- with the exception of injection of diesel fuel

Clean Water Act:

Disposal of flowback water and produced water is regulated under the Clean Water Act through the National Pollutant Discharge Elimination Permit Program

State Regulations Vary...

Summary

Pros:

- Less CO₂ emitted
- Miniscule emissions of SO₂ and mercury
- Energy Independence
- Cheap energy

Cons:

- Serious local water use and pollution issues
- Increased methane emissions
- May slow the development of renewable energy