Why Frack and What are the Risks

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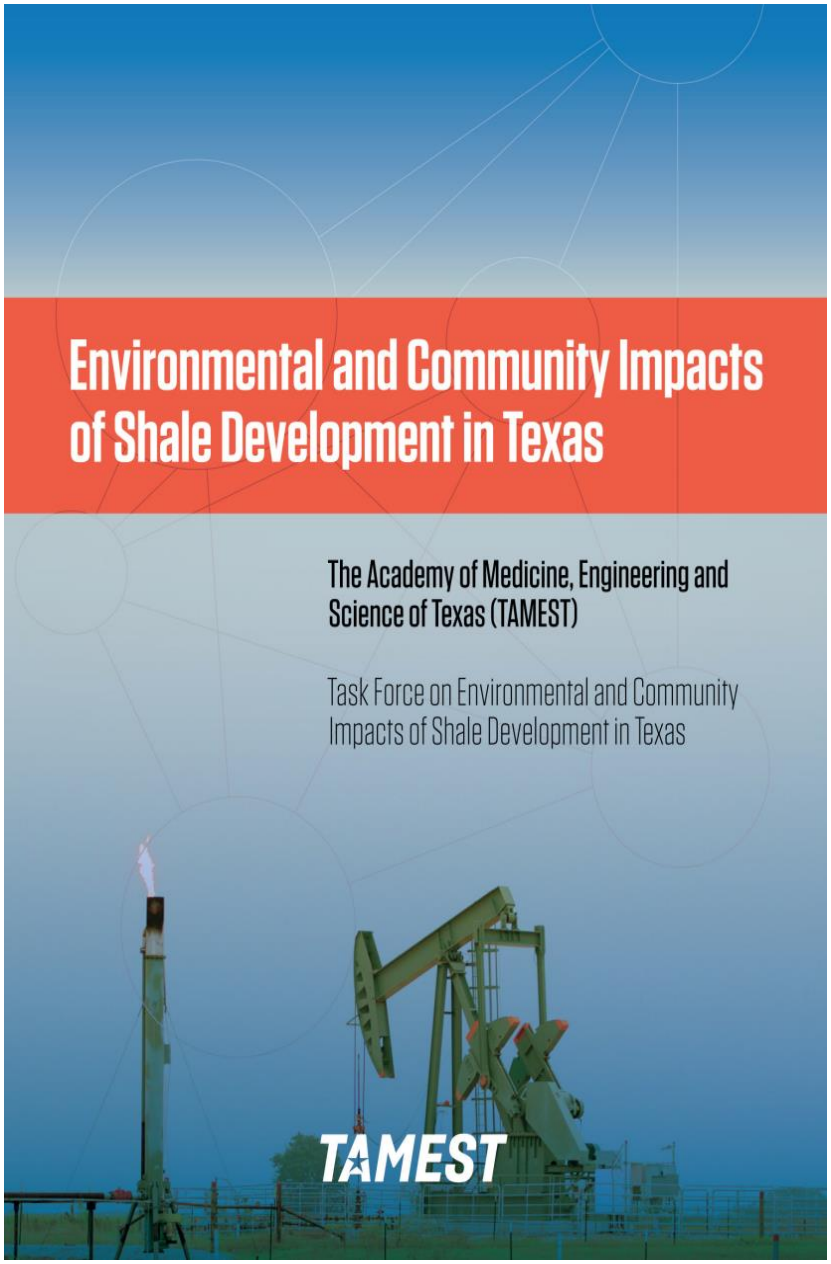
The Academy of Medicine, Engineering and Science of Texas 2017, www.tamest.org

Statement of Task:

- Evaluate the scientific basis of available body of information
- Communicate current state of knowledge

Key steps:

- Review methodologies and approaches
- Identify gaps
- Suggest improvements
- Make recommendations for further research

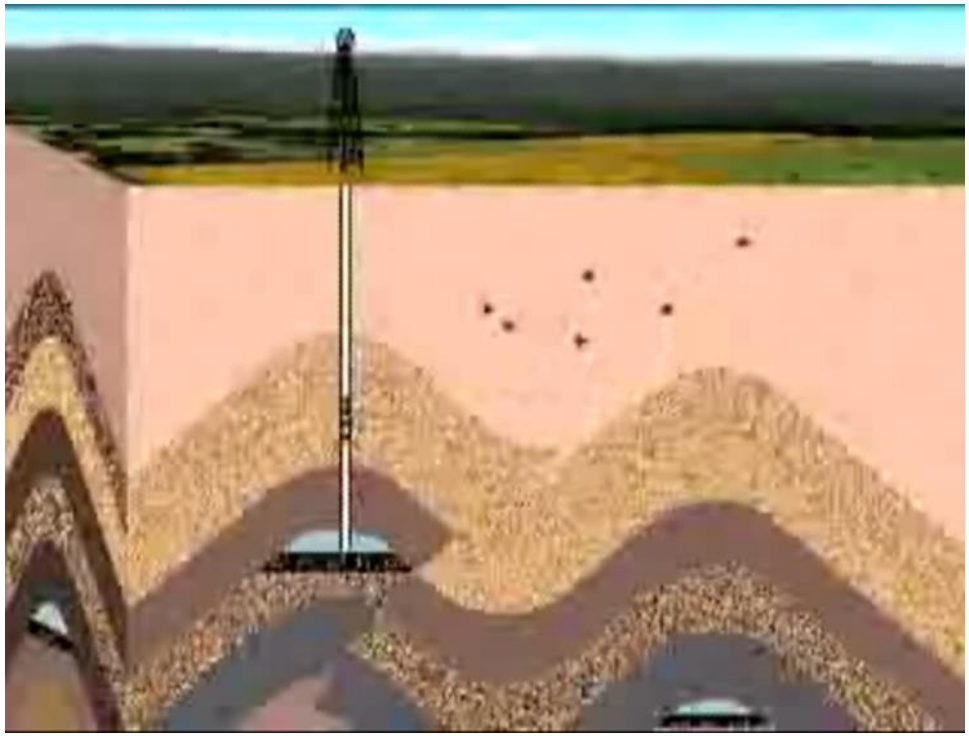


Outline

- What is New about Shale Development
- How Do You Frack Wells
- Why Develop Shale
- Risks
  - Water
  - Air
  - Seismic

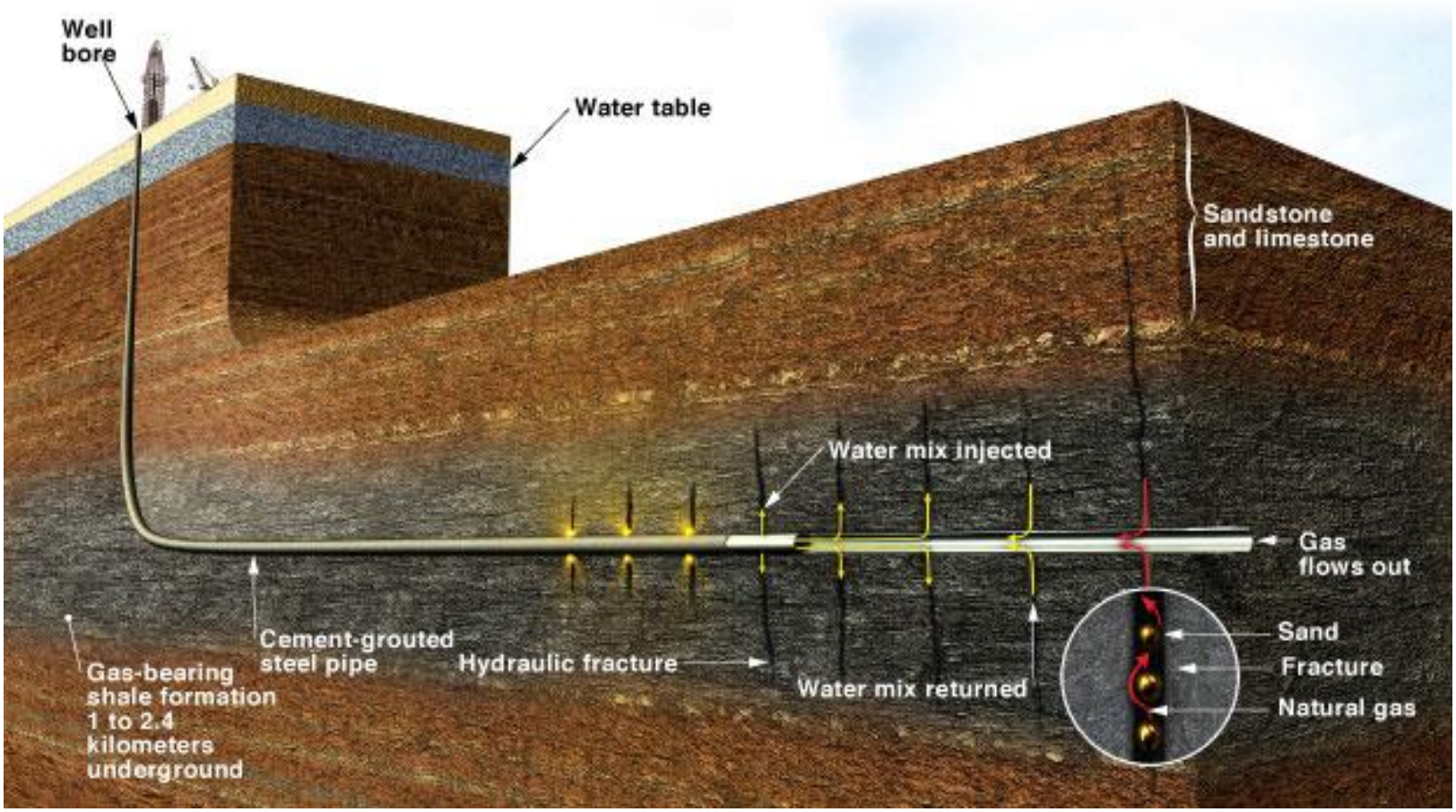
Conventional Production

- Source Rock: Shale
  - Low permeability
  - Not enough surface area in vertical well
- Oil Migration Upward over Millennia
- Reservoir Rock
- Barrier Trap



Shale Development

- Goal: Increase surface area of contact between the rock and the wellbore
- Key:
  - Horizontal Wells and Fracking
  - 1000 to 15000 feet
  - Multiple vertical fractures along its length
  - Fill fractures with sand to create high permeability channels to the wellbore
- Over 1 Million producing wells fracked since 1950


Well bore
Water table
Sandstone and limestone
Water mix injected
Gas flows out
Sand
Fracture
Natural gas
Cement-grouted steel pipe
Hydraulic fracture
Water mix returned
Gas-bearing shale formation 1 to 2.4 kilometers underground

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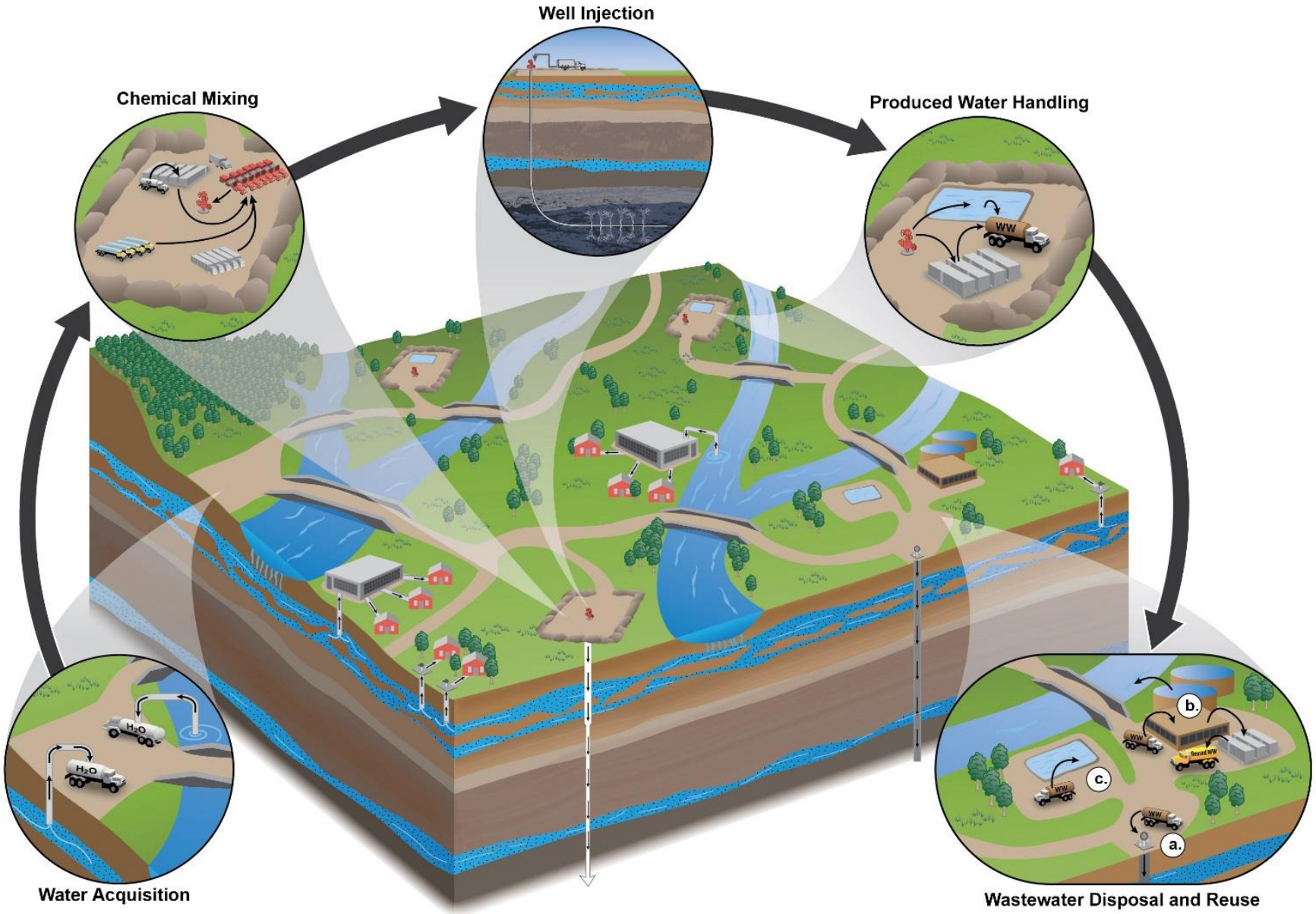
Drilling a Well

Water Cycle

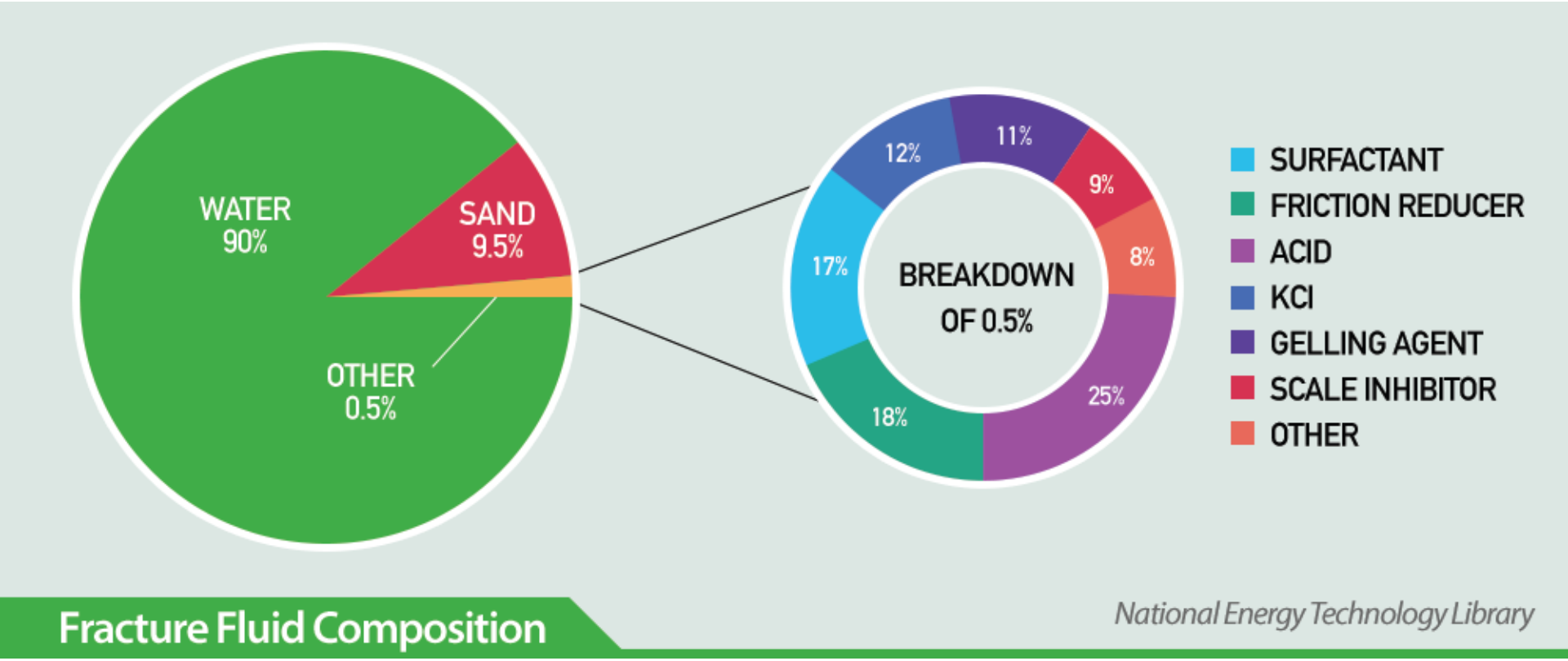

Well Injection
Chemical Mixing
Produced Water Handling
WW
H_2O
H_2O
Water Acquisition
b.
c.
a.
Wastewater Disposal and Reuse

Fracking the Well

Producing Well Pad

Injection Well Pad

Frack Fluid


WATER
90%
SAND
9.5%
OTHER
0.5%
BREAKDOWN
OF 0.5%
12%
11%
9%
8%
25%
18%
17%
SURFACTANT
FRICTION REDUCER
ACID
KCI
GELLING AGENT
SCALE INHIBITOR
OTHER
Fracture Fluid Composition
National Energy Technology Library

Most Common Frac Additives	Composition	CAS Number	Total amt. in avg frac (10k bbl)	Used in recycled water?	Alternate Use
Friction Reducer	Polyacrylamide	9003-05-8	100 to 200 gallons.	50k to 70k ppm is upper limit	baby diapers, floc for drink water
Biocide	Glutaraldehyde	111-30-8	50 to 100 gallons.	decrease w/ increasing salinity	Medical disinfectant
Alternate Biocide	Ozone, Chlorine dioxide UV,	10028-15-6 10049-04-4		Turbidity & v. high salinity hindrances.	Disinfectant in municipal water
Scale Inhibitor (if needed)	Phosphonate & polymers	6419-19-8 & others	10 to 100+ gallons – depends on local	Specific ions like calcium are a problem.	Some cleaners and medical treatment
Gellants (hybrid / gel)	Guar & Cellulose	9000-30-0 9004-62-0	Depends on frac type ~1000 to 2000 lb.	Ca^{++} , Fe^{x} & TDS problem.	Thickening ice cream / soup
Acid	5% TO 15% hydrochloric	7647-01-0	~0 to 2000 gals not universally	Yes	food prep, mfg, swim pools,
Acid Corrosion inhib.	Quat. Ammonium salts, Coa Coa Amines, etc.	Various	2 to 40 gals if acid is used	Yes	Industrial

Apache

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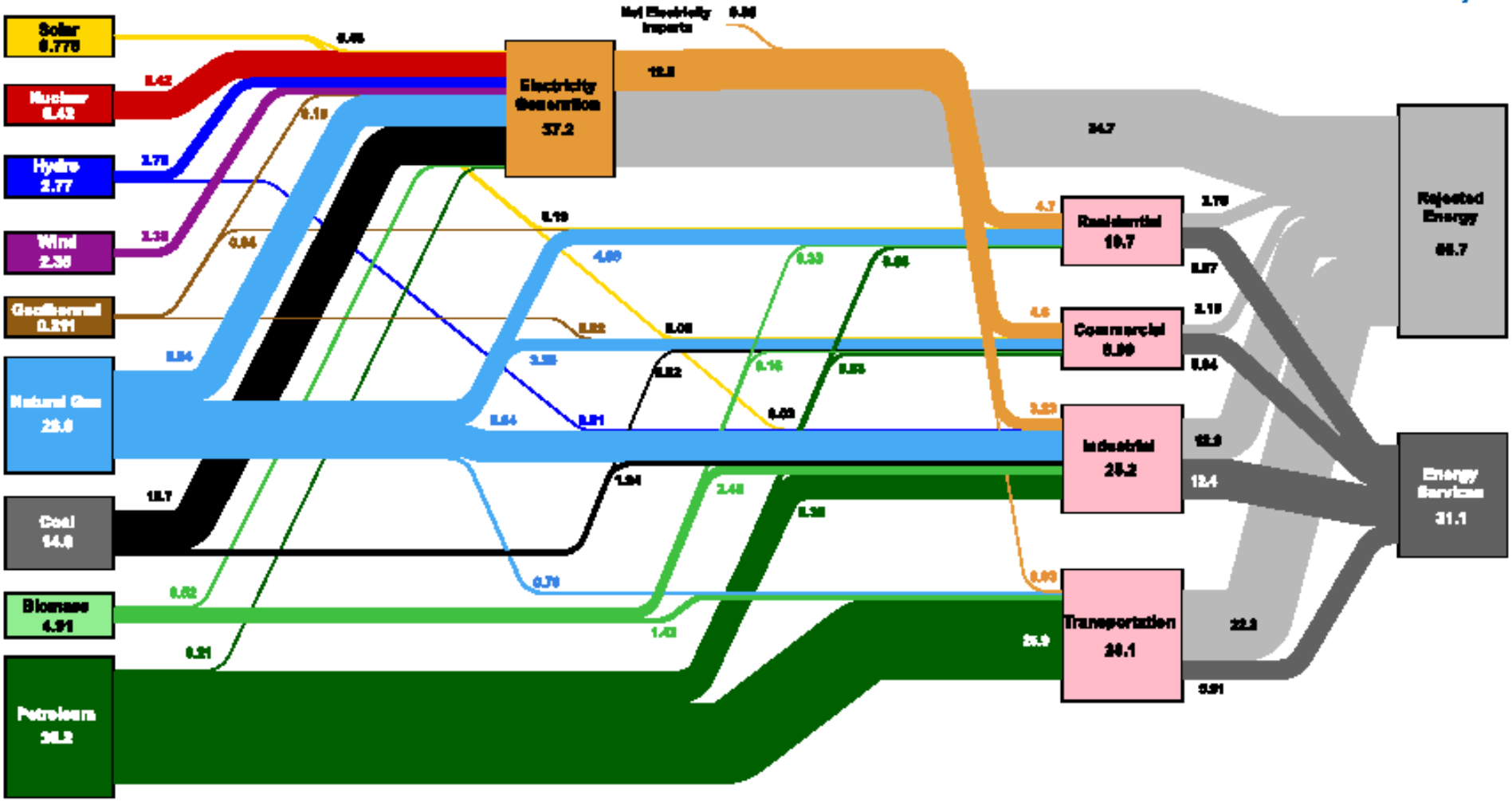
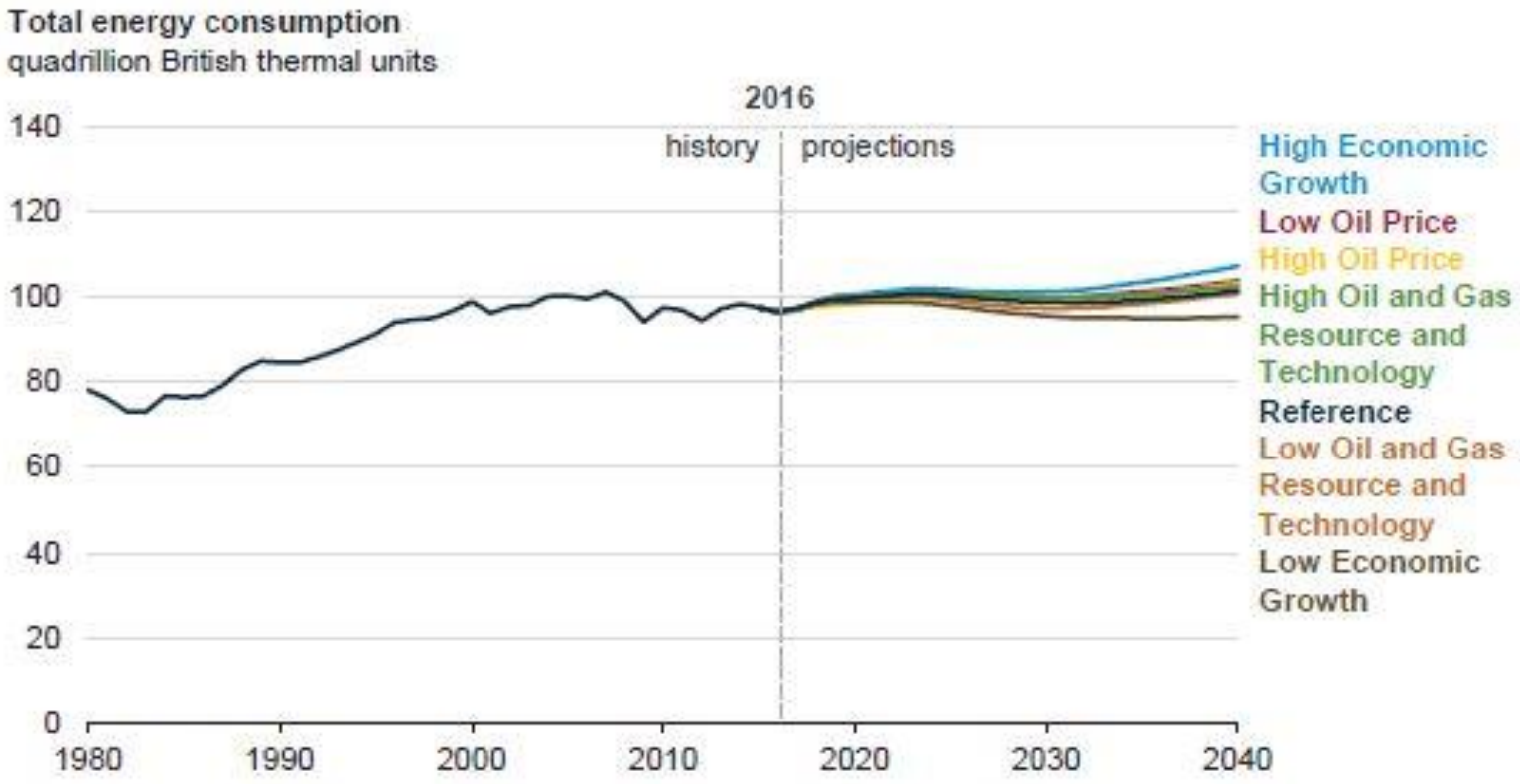
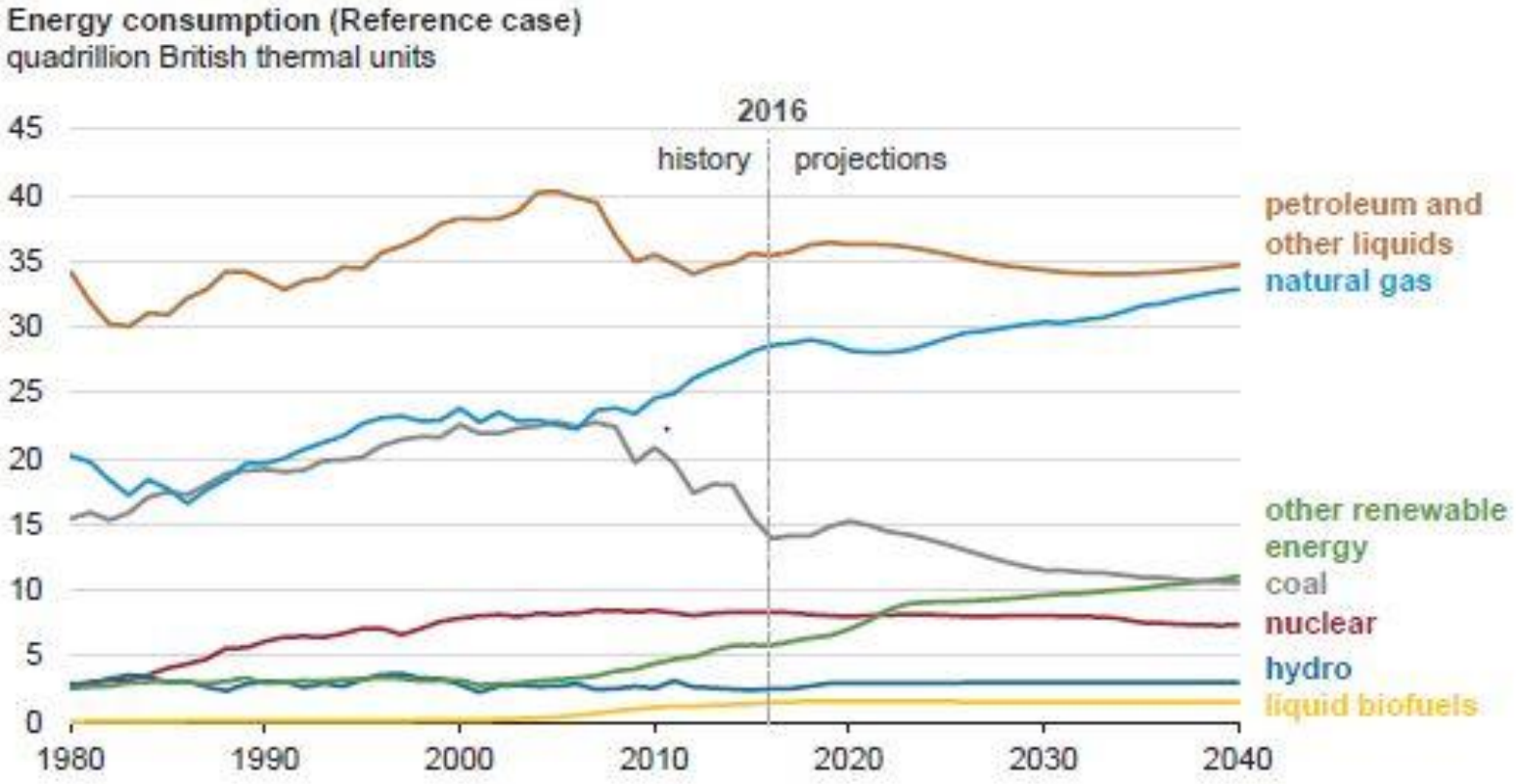
Estimated U.S. Energy Consumption in 2017: 97.7 Quads

Lawrence Livermore National Laboratory



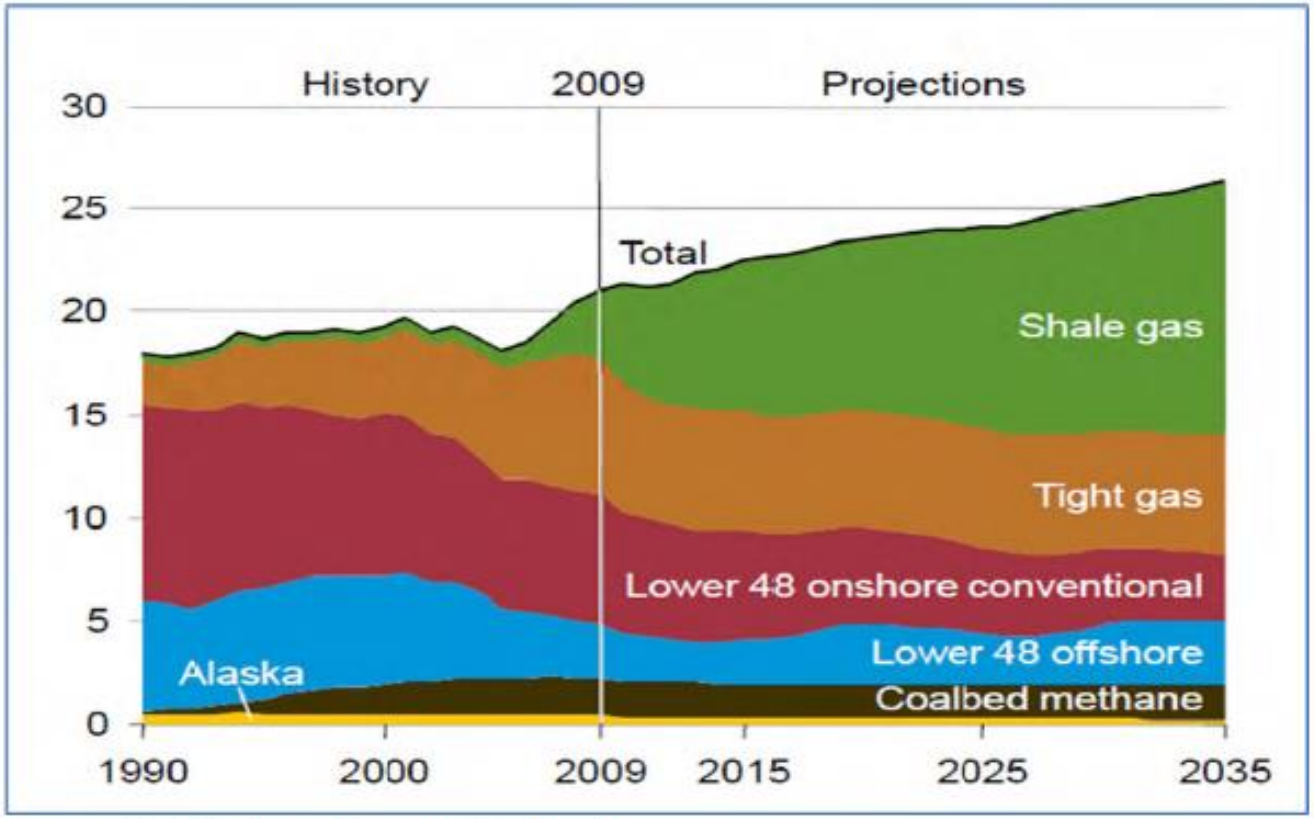
Source: LLNL April, 2018. Data is based on DOE/EIA MER (2017). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. This chart was revised in 2017 to reflect changes made in mid-2016 to the Energy Information Administration's analysis methodology and reporting. The efficiency of electricity production is calculated as the total recoverable electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 21% for the transportation sector, and 46% for the industrial sector which was updated in 2017 to reflect DOE's analysis of manufacturing. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527


Total energy consumption
quadrillion British thermal units
2016
history
projections
140
120
100
80
60
40
20
0
1980
1990
2000
2010
2020
2030
2040
High Economic Growth
Low Oil Price
High Oil Price
High Oil and Gas Resource and Technology
Reference
Low Oil and Gas Resource and Technology
Low Economic Growth


Energy consumption (Reference case)
quadrillion British thermal units
2016
history
projections
45
40
35
30
25
20
15
10
5
0
1980
1990
2000
2010
2020
2030
2040
petroleum and other liquids
natural gas
other renewable energy
coal
nuclear
hydro
liquid biofuels

Importance of Shale Gas to the USA

- Natural gas is an important energy source for the United States. Shale formations represent a growing source of natural gas for the nation and are among the busiest oil and gas plays in the country.



Source: DOE/EIA Annual Energy Outlook 2011

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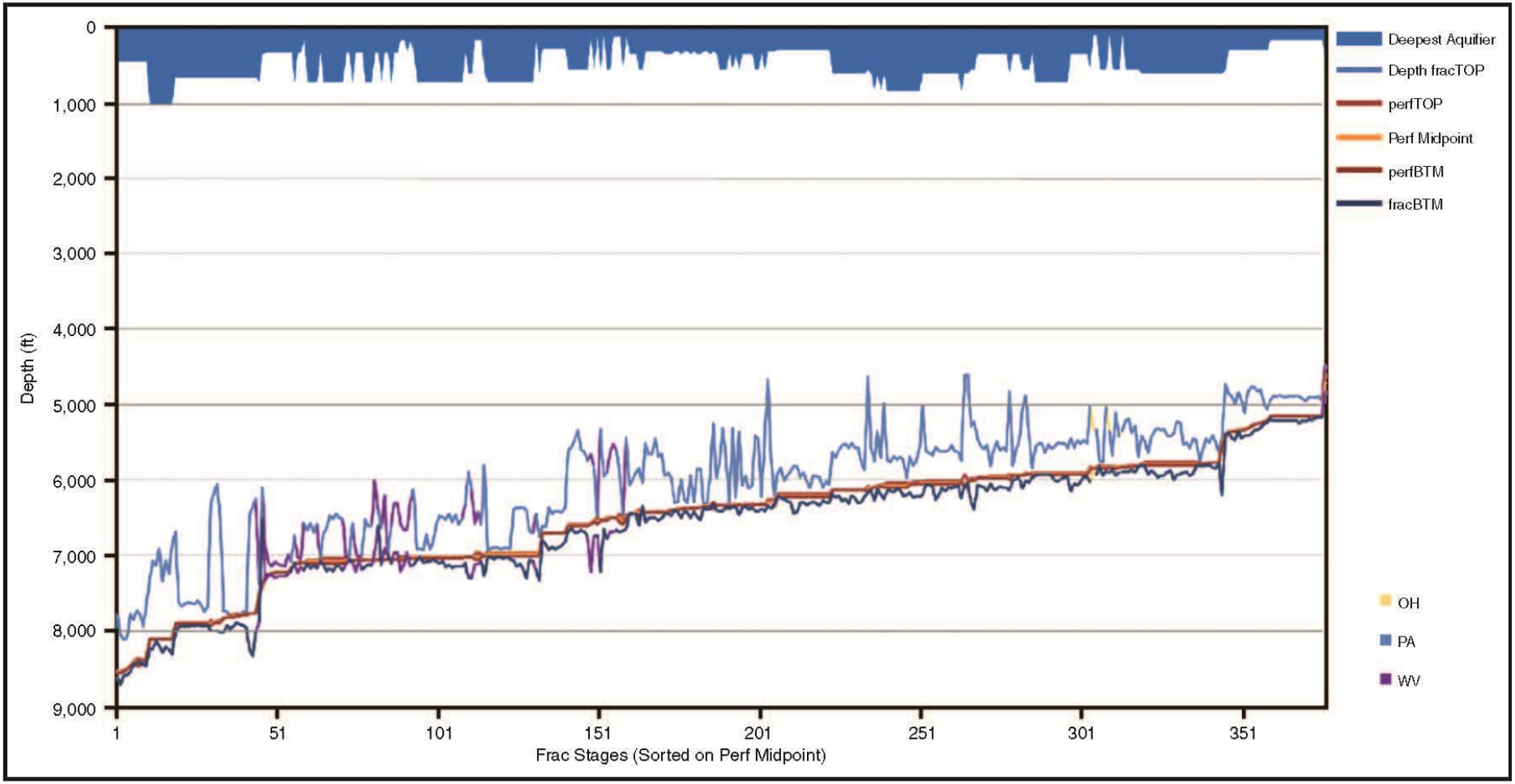
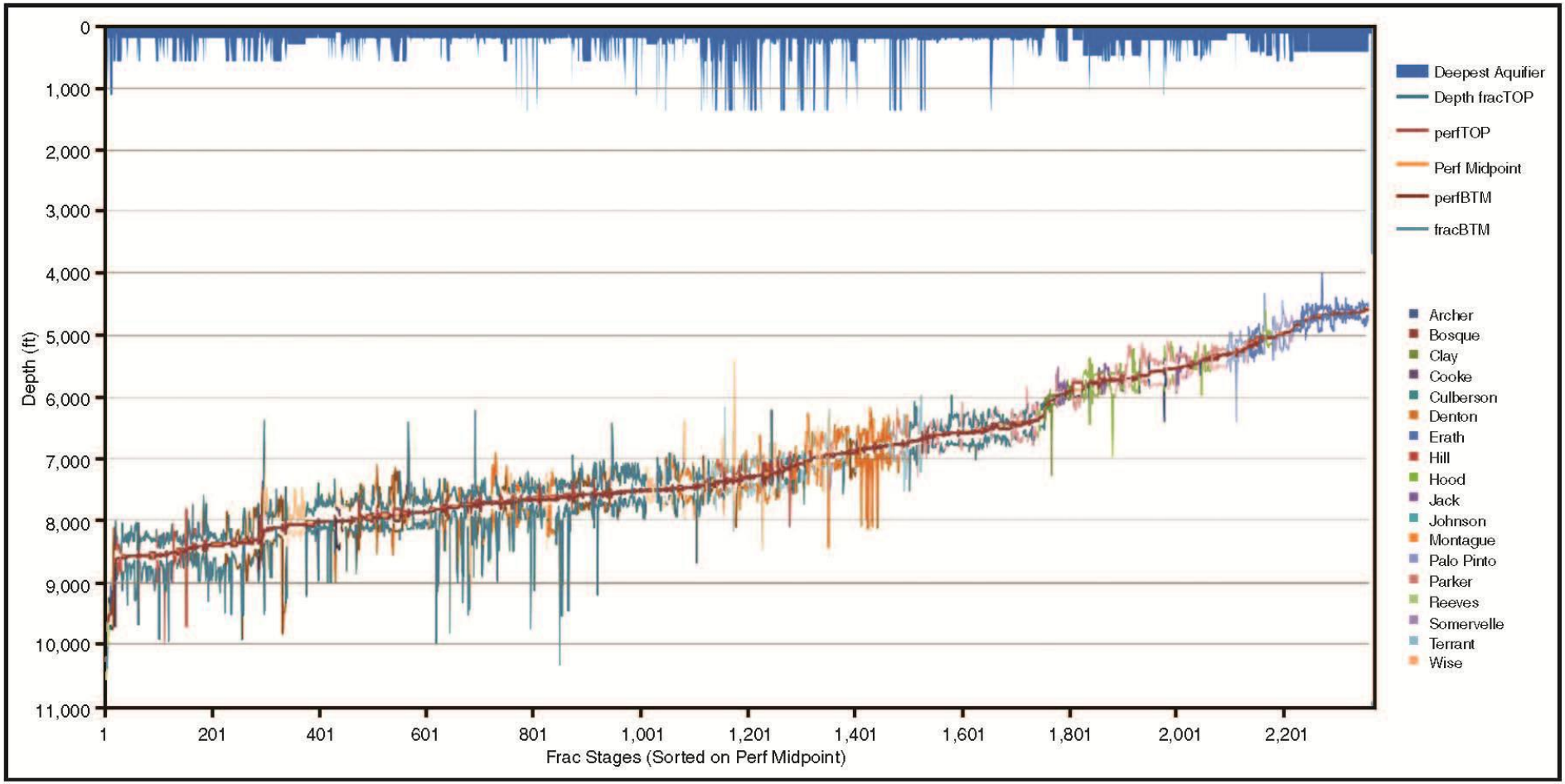
Water - Risks

- Fracking into Fresh Water Zone
  - No known case
- Leak from Casing
- Water Use
- Surface Leak from Pipeline or Truck

Marcellus Shale Mapped Fracture Treatments (TVD)



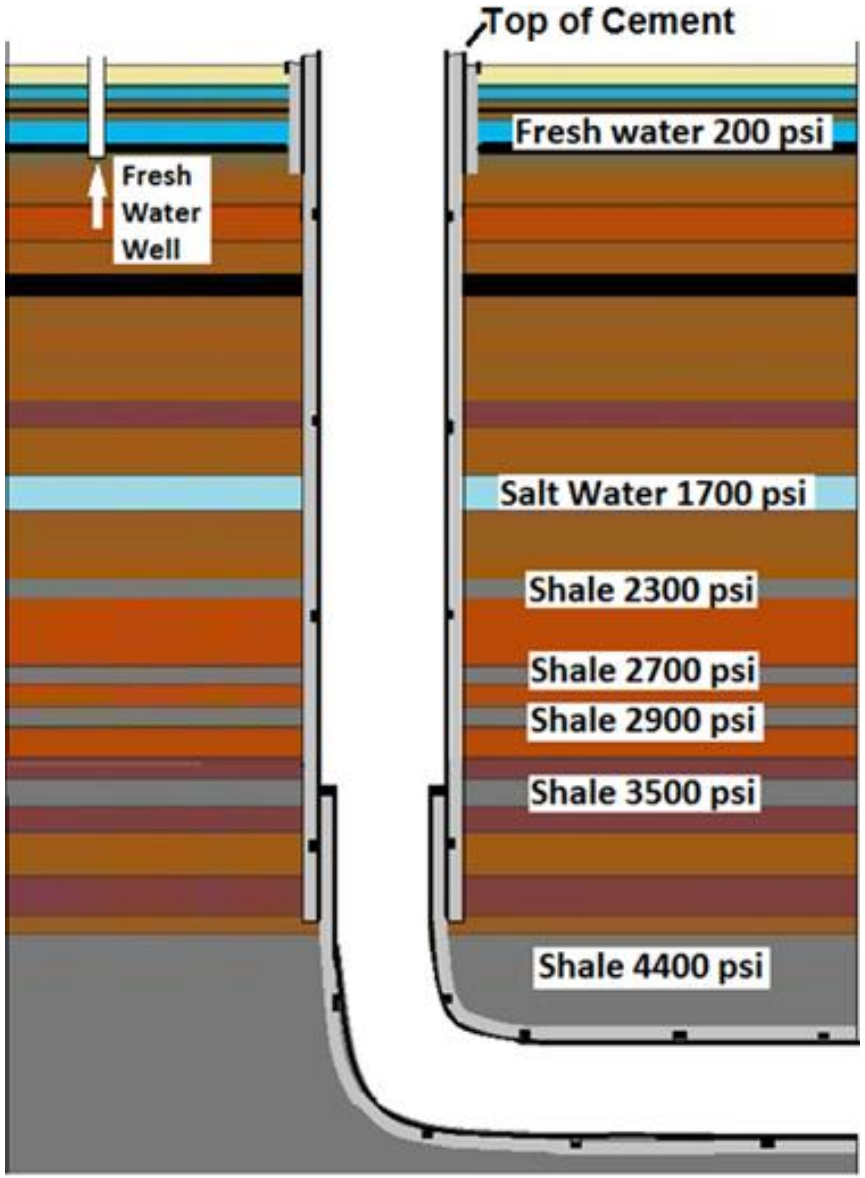
Barnett Shale Mapped Fracture Treatments (TVD)



Water - Risks

- Fracking into Fresh Water Zone
  - No known case
- Leak from Casing
  - Has happened
    - Low probability
    - Local impact
    - Easily fixed
- Water Use
- Surface Leak from Pipeline or Truck

Proper Casing
and
Cementing Required



Leaks From Casing

- Well-studied failure in Bainbridge, Ohio, in 2008.
  - Incomplete casing cementing led to a return of fracturing fluid to the ground surface and upward migration of methane from near surface zones
  - Leading to contamination of drinking water wells and an explosion in a nearby home
- In a study of 211 groundwater contamination incidents in Texas associated with oil and gas activity (Kell, 2011), only 10 incidents were associated with oil and gas drilling and completion
  - None were associated with hydraulic fracturing
  - Many of the noted incidents occurred prior to 1969 and before the RRC revised regulations on cementing
- Because of the industrial nature of this activity, there always will be, some probability of casing failure leading to near surface contamination or contributing to surface spills due to flow up the failed casing

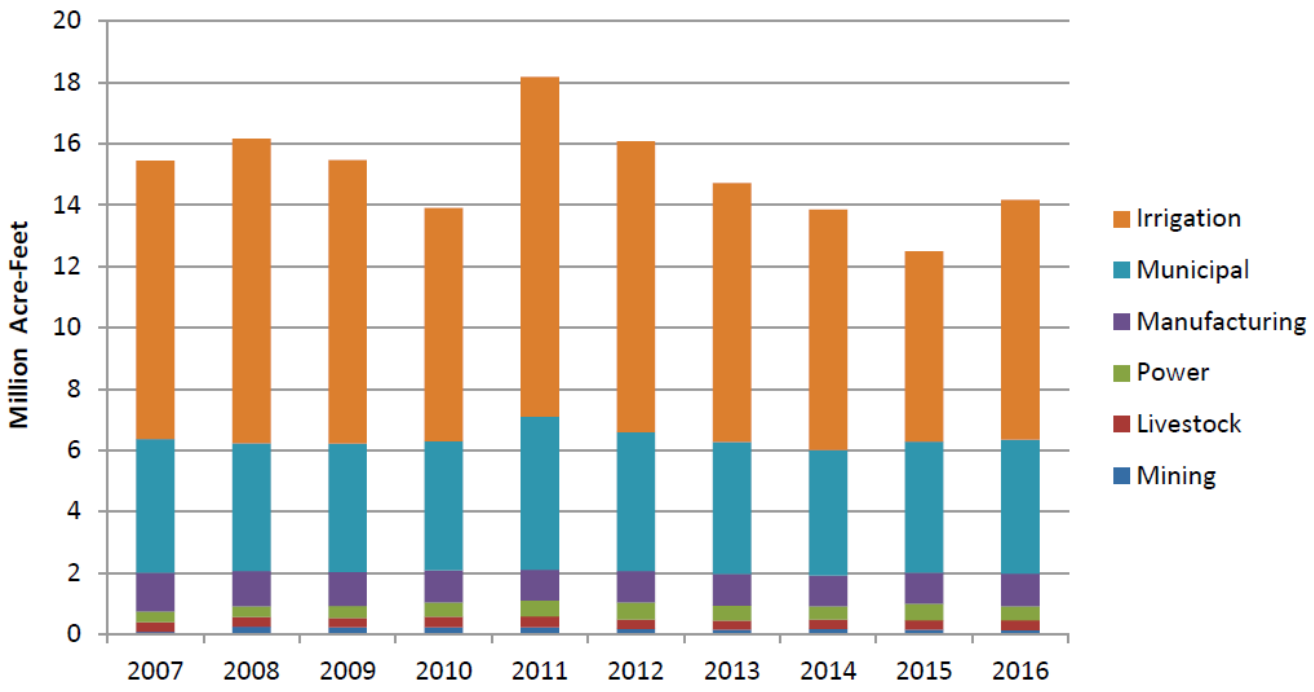
Water - Risks

- Fracking into Fresh Water Zone
  - No known case
- Leak from Casing
  - Has happened
    - Low probability
    - Local impact
    - Easily fixed
- Water Use
- Surface Leak from Pipeline or Truck

Water Use in Texas

Texas Water Development Board

Irrigation **(55%)**
Municipal **(30%)**
Manufacturing **(9%)**
Power **(3%)**
Livestock **(2%)**
Mining **(1%)**



Water Use for Hydraulic Fracturing

From TAMEST report

- Life cycle water use for shale oil and gas is substantially less than life cycle water use for other forms of energy (e.g. coal, nuclear and biofuels)
- Statewide, total freshwater use for shale oil and gas is <1% of total statewide freshwater use. Future use likely to decrease as brackish and produced water use increases
- Locally, freshwater use can be significant, particularly in rural counties without large amounts municipal or agricultural freshwater use
- Use of brackish and produced water can substantially reduce the impact of shale development on freshwater resources

Water - Risks

- Fracking into Fresh Water Zone
  - No known case
- Leak from Casing
  - Has happened
    - Low probability
    - Local impact
    - Easily fixed
- Water Use
- Surface Leak from Pipeline or Truck
  - Highest risk

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Air Emissions - Risks

- During flowback of well and before sufficient production is confirmed to justify a pipeline, gas may be flared
  - Venting yield methane
  - Flaring yields CO2
  - Mainly a problem with oil wells
- Fugitive Emissions
  - Production facilities
  - Compressor stations
  - Gas processing to remove ethane, propane, butane and other natural gas liquids
  - Industry voluntary reductions and monitoring
    - Obama regulations
    - ExxonMobil and others advising Government not to role back

Comparison to Coal for Electric Generation

- EPA (2017) Greenhouse gas Emisions from electric generation down 15% between 2005 and 2014
- NOAA (2012) Emissions in 2012 23% lower than if coal made up same percent of fuel as in 1997
- Alvarez (2012)
  - Need methane leakage rate of less than 3% for gas to be better than coal
  - Actual leakage rate less than 1 %
- NETL (2017)
  - Total national average methane gas emission intensity is 1.7%

Confusing Emissions from Oil Wells with Emissions from Gas Wells

- Barnett Shale- Zavala-Araiza, et al (2015) flyover using infrared camera
  - 0.7% of high gas to oil ratio sites had detectable emissions
  - 1.4% of medium gas to oil ratio sites had detectable emissions
  - 20.6% of low gas to oil ratio sites had detectable emissions
  - 90% of detectable emissions were from storage tanks

Recent federal and state regulations have reduced emissions from multiple types of emission sources.

Examples: Federal

- New Source Performance Standards OOOO and OOOOa (2014):
  - Requirements of reduced emission well completions for gas wells
  - Tanks with potential emissions of >6 tons/yr must have emission controls
  - Leak Detection and Repair Standards

Examples: State

- State permits can require emission controls beyond federal standards, particularly in regions that do not meet National Ambient Air Quality Standards

Emissions in many categories associated with shale resource production are dominated by a small sub-population of high-emitting sources

- ~50,000 wells (of the roughly 500,000 natural gas wells in the United States) vent during a process referred to as a liquid unloading, a small fraction (~3 to 5%) likely account for half of unloading emissions- Allen (2015)
- Pneumatic controllers use pressurized natural gas to control the opening and closing of control valves, and are estimated to be the largest source of methane emissions in the petroleum and natural gas supply chains; ~20 percent of pneumatic controllers at natural gas sites account for 95 percent of pneumatic controller emissions – Prasino (2013), Allen (2015), Gibbs (2015)

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Seismic Risks

- NRC (2012)
  1. Fracking does not pose a high risk for inducing felt seismic events
  2. Injection of water derived from energy technologies into the subsurface poses some risk for induced seismicity, but very few events have been documented over the past several decades relative to the large number of disposal wells in operation
  3. Carbon Capture and Storage (CCS), due to the large net volumes injected may have potential for inducing larger seismic events.

Energy Levels from Fracking

Energy Level from Fracking

Richter Magnitude	Earthquake effects
0-2	Not felt by people
2-3	Felt little by people
3-4	Ceiling lights swing
4-5	Walls crack
5-6	Furniture moves
6-7	Some buildings collapse
7-8	Many buildings destroyed
8-Up	Total destruction of buildings, bridges and roads

Produced Water

- Almost all oil and gas wells produce flowback or connate water
- In US oil and gas wells produce between 40 and 55 million BWPD
- Between 2007 and 2012 U.S. oil production increased by 29%, gas production increased by 22%, but water production increased by less than 1%.
  - Many of the older conventional wells that generated a high lifetime volume of water were closed.
  - Many of the newer wells that were drilled were unconventional wells that generated a lower lifetime total of water.
- Almost all onshore water production is disposed of subsurface

Disposal Wells- Class II Injection Wells

- Approximately 180,000 injection wells in US
- Water injected below frack pressure into highly porous formations
- Earthquakes can occur due to increased pore pressure near old inactive faults
- Solution:
  - Stringent review of injection well permits near historic earthquake locations
  - Legal authority to suspend permit if well is suspected of causing an earthquake

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