Shale Gas Issues in the United States

Plus comments on alternative energy sources

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and

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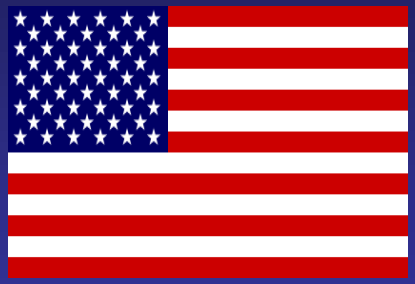
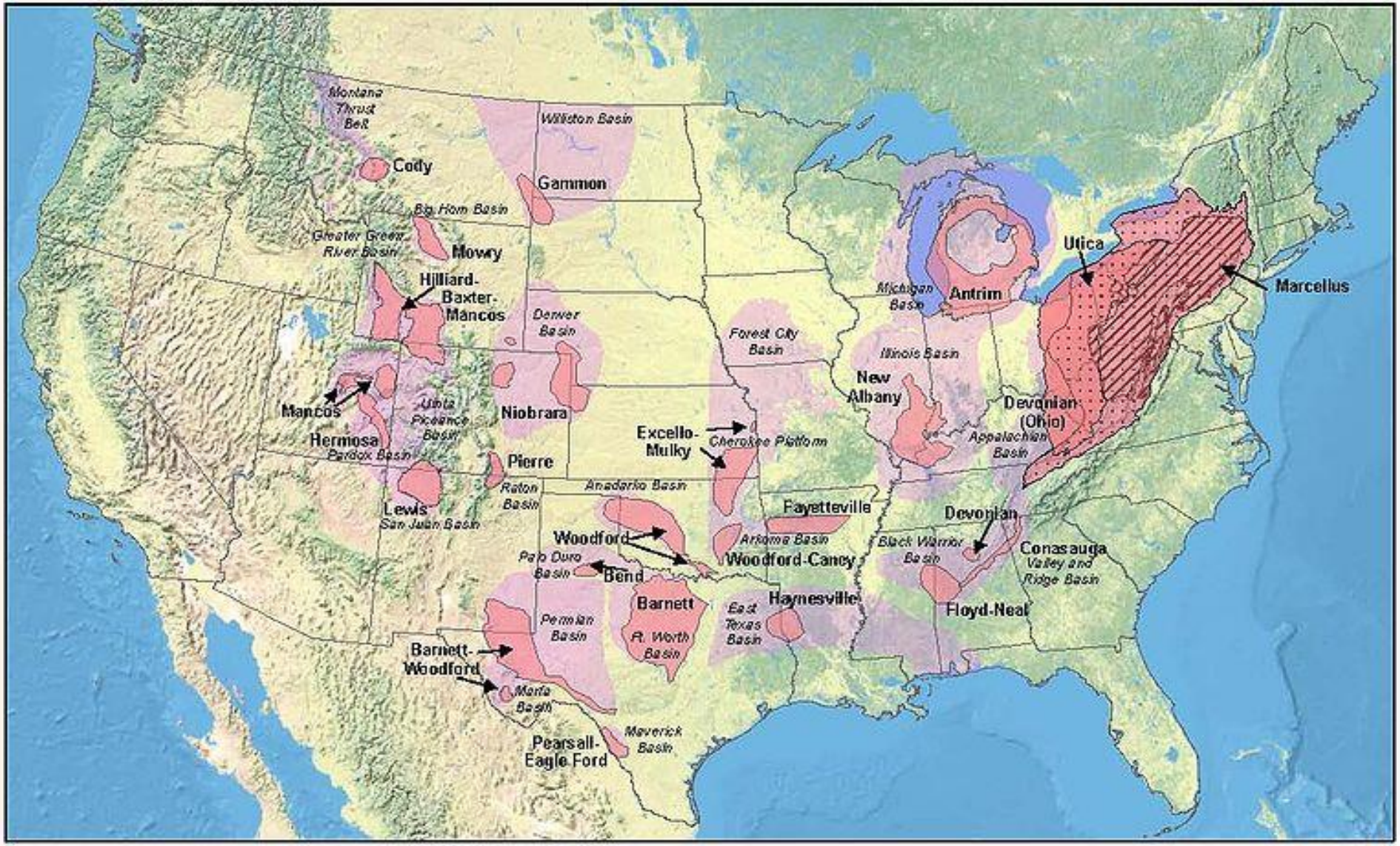


President Obama and President Hu Jintao announced in 2012 a broad agreement to strengthen cooperation between the United States and China on clean energy including a shale gas initiative that states:

<u>Shale Gas Initiative.</u> The two Presidents announced the launch of a new U.S.-China Shale Gas Resource Initiative. Under the Initiative, the U.S. and China will use experience gained in the United States to assess China's shale gas potential, promote environmentally-sustainable development of shale gas resources, conduct joint technical studies to accelerate development of shale gas resources in China, and promote shale gas investment in China through the U.S.-China Oil and Gas Industry Forum, study tours, and workshops.

Why Shale Gas is Viable

- Advances in horizontal drilling
- Advances in hydraulic fracturing
- Increase in price of natural gas
- Anticipated increase in energy demand
- Concerns about coal (environment), oil (reliable sources), nuclear (safety)



United States Shale Gas Plays

www.eia.doe.gov
Energy Information Administration
Office of Oil and Gas

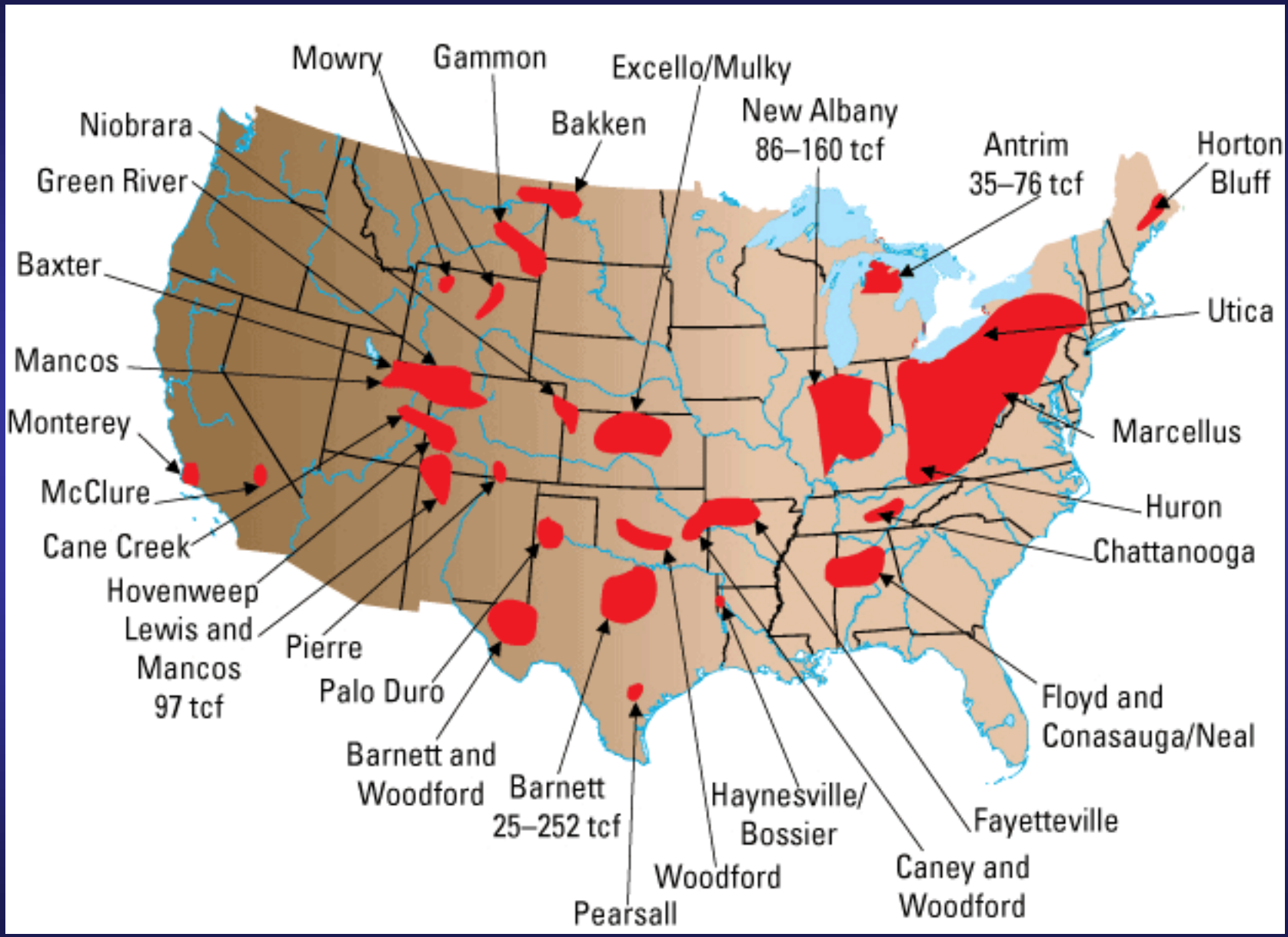
Shale Gas Plays
Basins

Stacked Appalachian Plays
Marcellus
Utica
Devonian (OH shale)

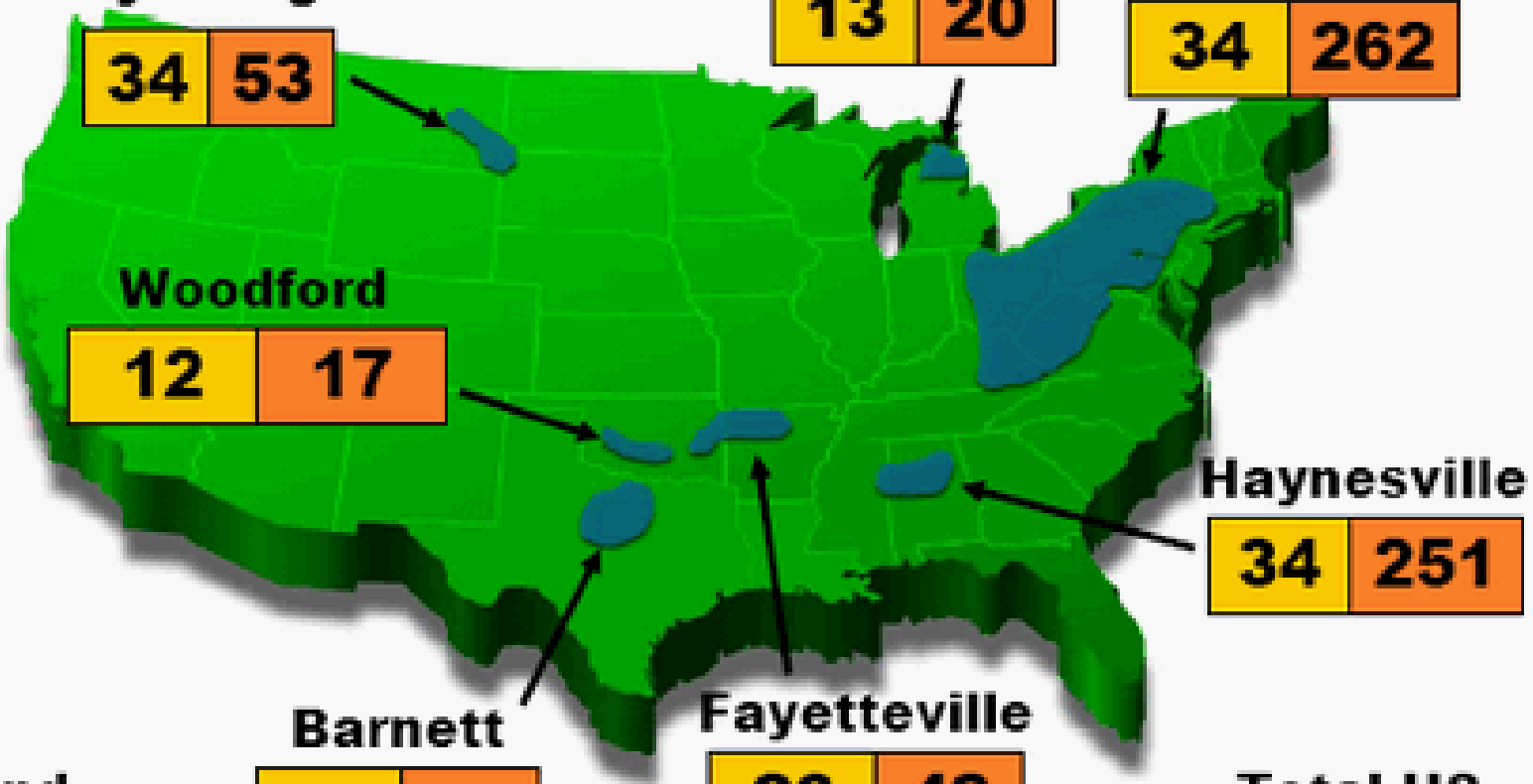
November 2008

Miles
0 150 300 600

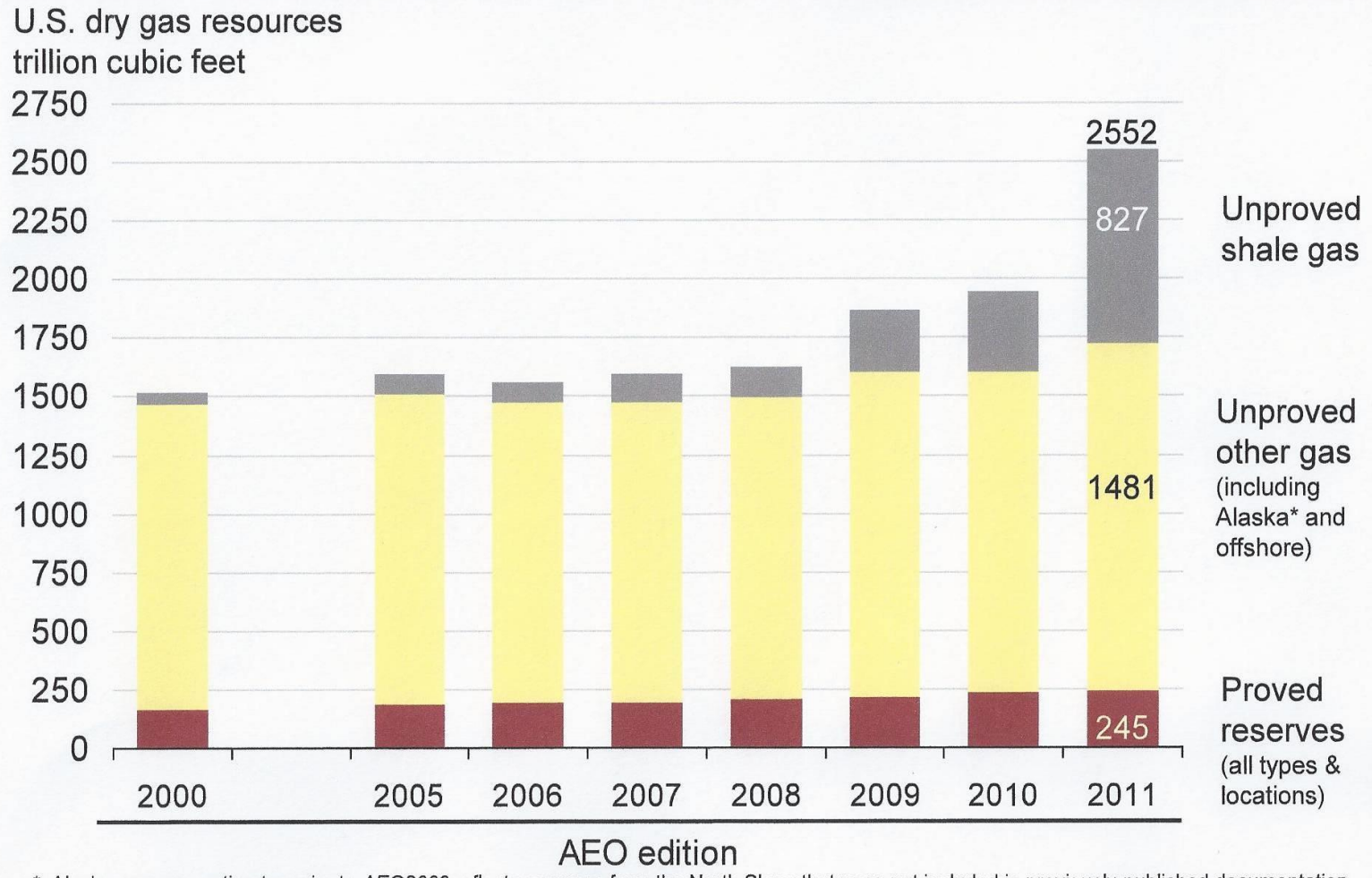
N


Mowry
Gammon
Excello/Mulky
Niobrara
Bakken
New Albany
86–160 tcf
Antrim
35–76 tcf
Horton
Bluff
Green River
Baxter
Utica
Mancos
Monterey
Marcellus
McClure
Huron
Cane Creek
Chattanooga
Hovenweep
Lewis and
Mancos
97 tcf
Pierre
Palo Duro
Floyd and
Conasauga/Neal
Barnett and
Woodford
Barnett
25–252 tcf
Haynesville/
Bossier
Fayetteville
Woodford
Caney and
Woodford
Pearsall

Estimated Recoverable NG For Select Shale Basins (TCF)

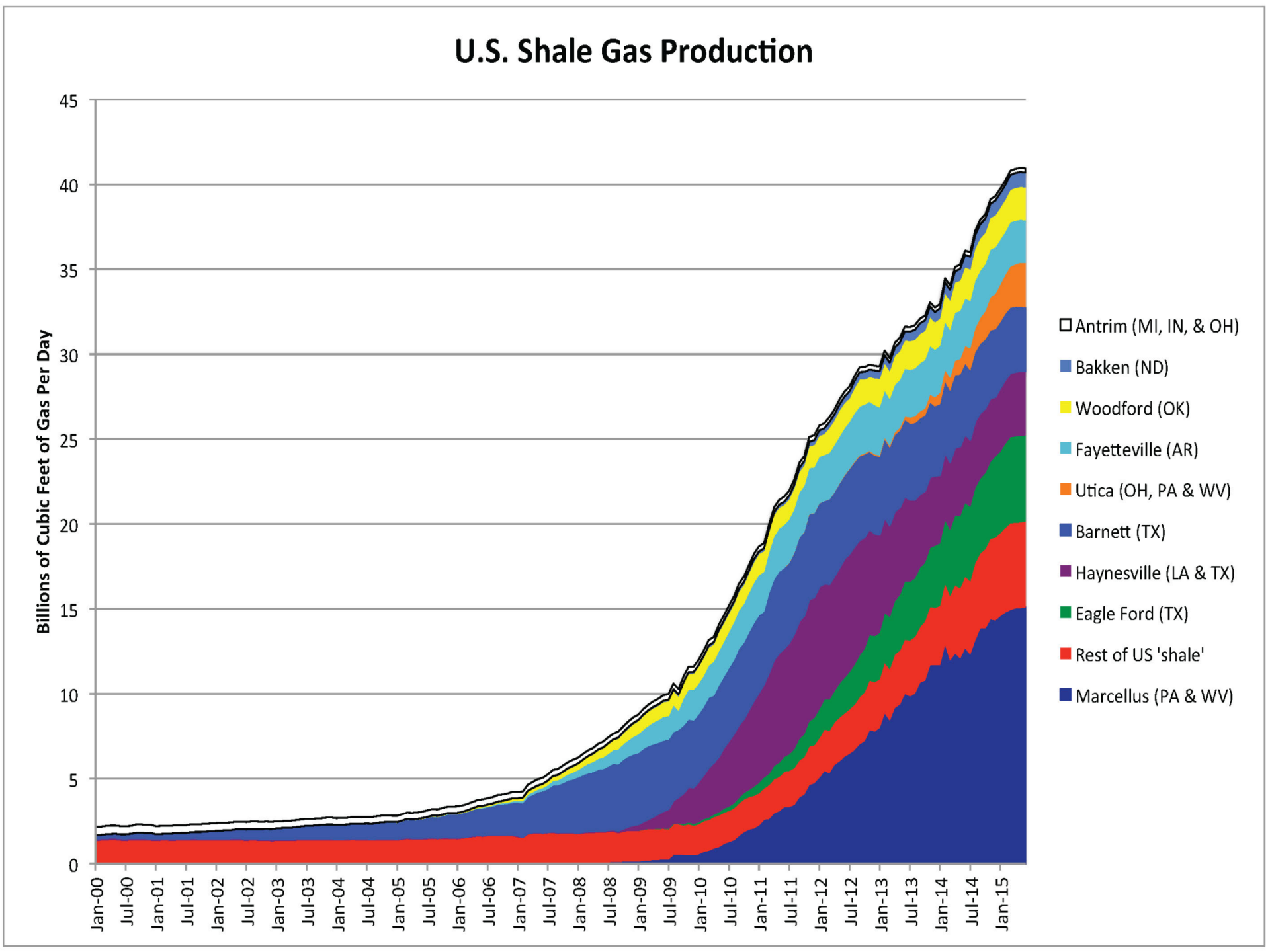


Shale gas has been the primary source of recent growth in U.S. technically recoverable natural gas resources



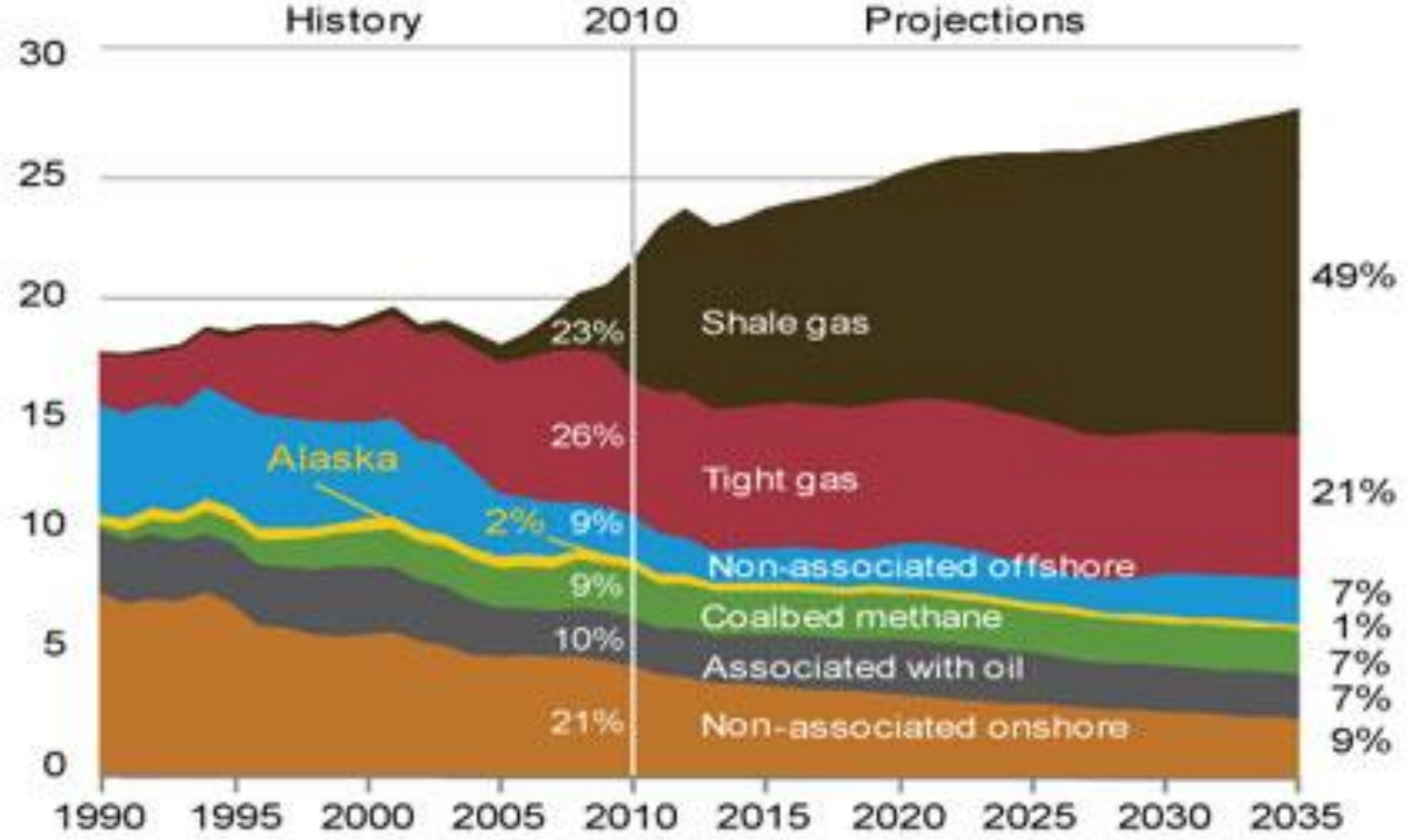
* Alaska resource estimates prior to *AEO2009* reflect resources from the North Slope that were not included in previously published documentation.

Source: EIA, *Annual Energy Outlook 2011*

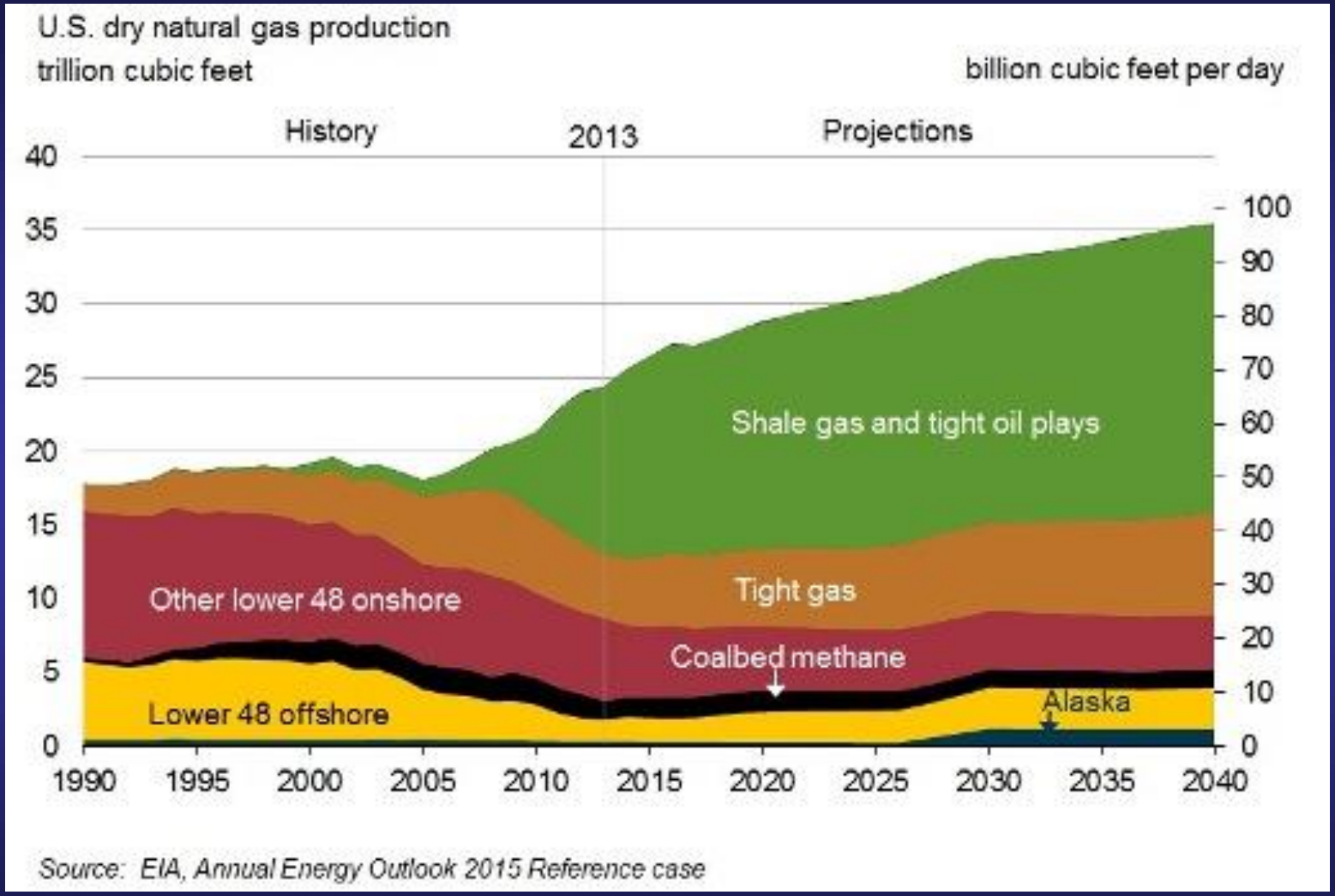

U.S. Shale Gas Production
Billions of Cubic Feet of Gas Per Day
0
5
10
15
20
25
30
35
40
45
Jan-00
Jul-00
Jan-01
Jul-01
Jan-02
Jul-02
Jan-03
Jul-03
Jan-04
Jul-04
Jan-05
Jul-05
Jan-06
Jul-06
Jan-07
Jul-07
Jan-08
Jul-08
Jan-09
Jul-09
Jan-10
Jul-10
Jan-11
Jul-11
Jan-12
Jul-12
Jan-13
Jul-13
Jan-14
Jul-14
Jan-15
Antrim (MI, IN, & OH)
Bakken (ND)
Woodford (OK)
Fayetteville (AR)
Utica (OH, PA & WV)
Barnett (TX)
Haynesville (LA & TX)
Eagle Ford (TX)
Rest of US 'shale'
Marcellus (PA & WV)

U.S. Natural Gas Production, 1990-2035

trillion cubic feet

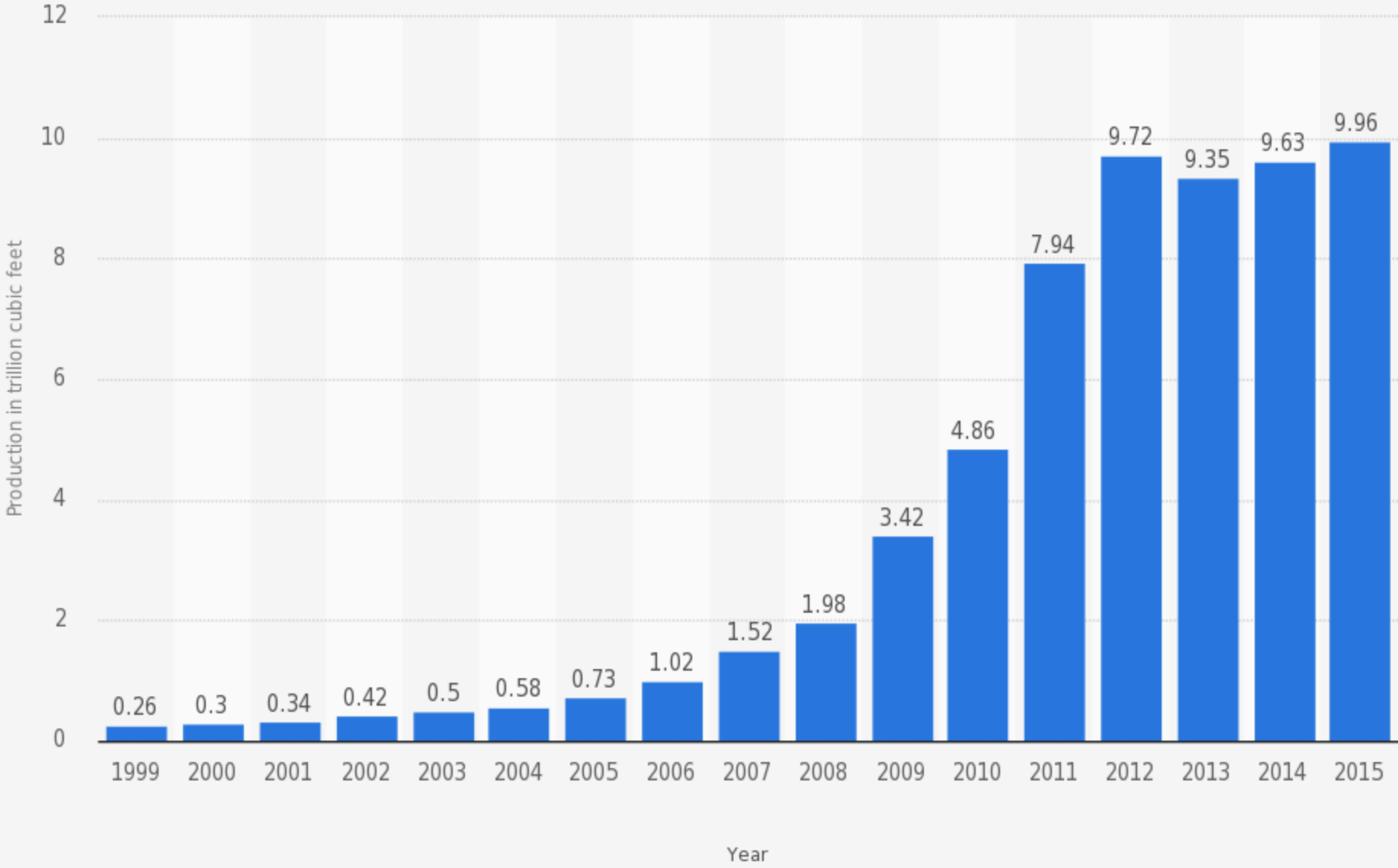


Source: U.S. Energy Information Administration, AEO2012 Early Release Overview, January 23, 2012.



Source: EIA, Annual Energy Outlook 2015 Reference case

U.S. shale gas production from 1999 to 2015 (in trillion cubic feet)



Source::
EIA

Additional Information:
United States

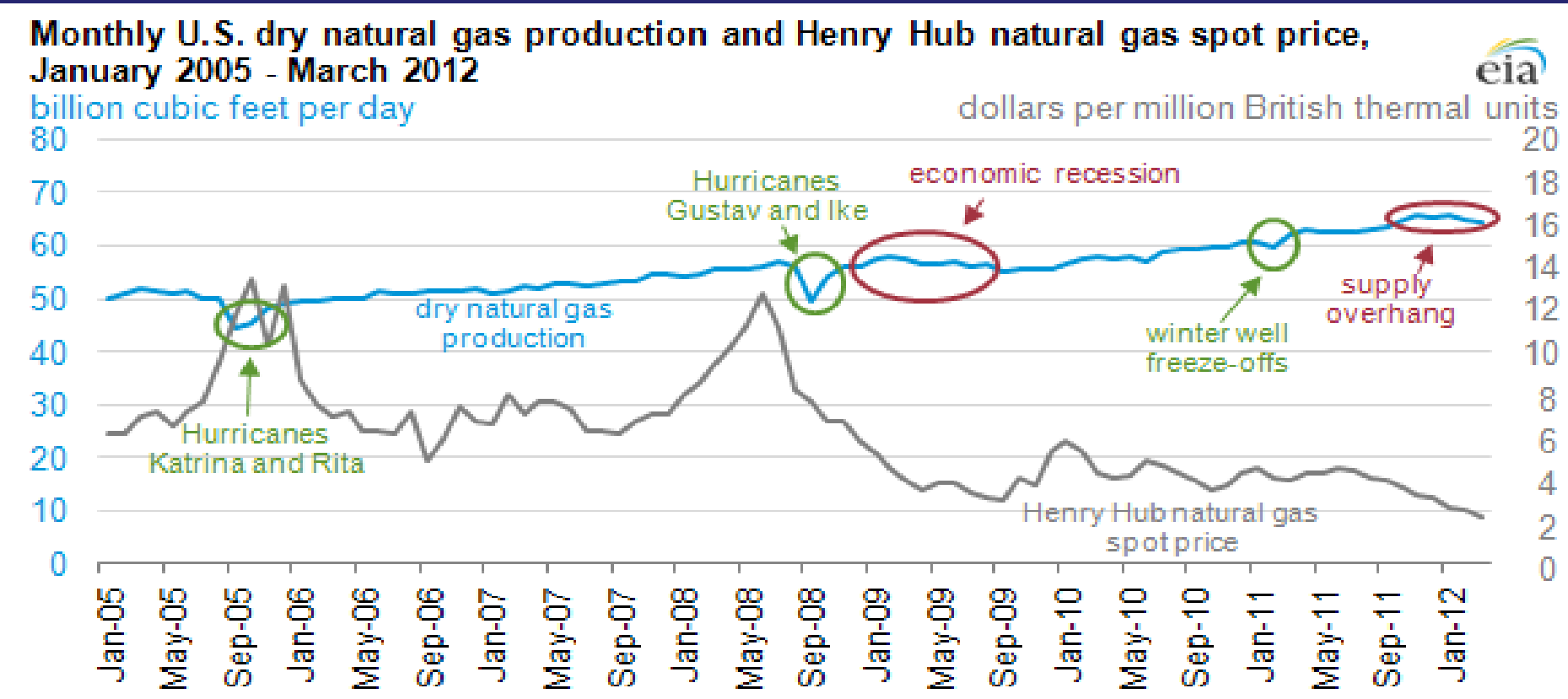
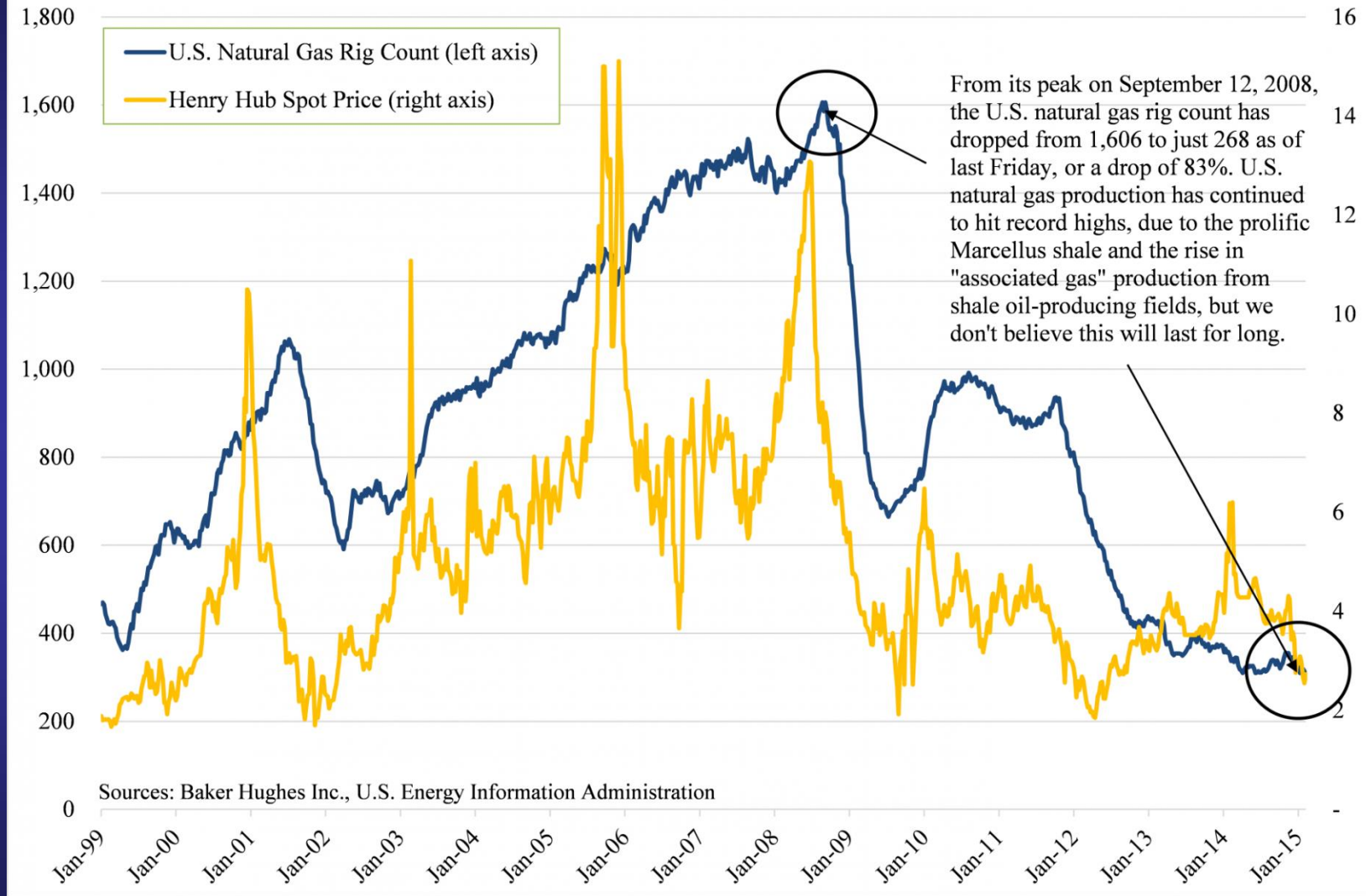
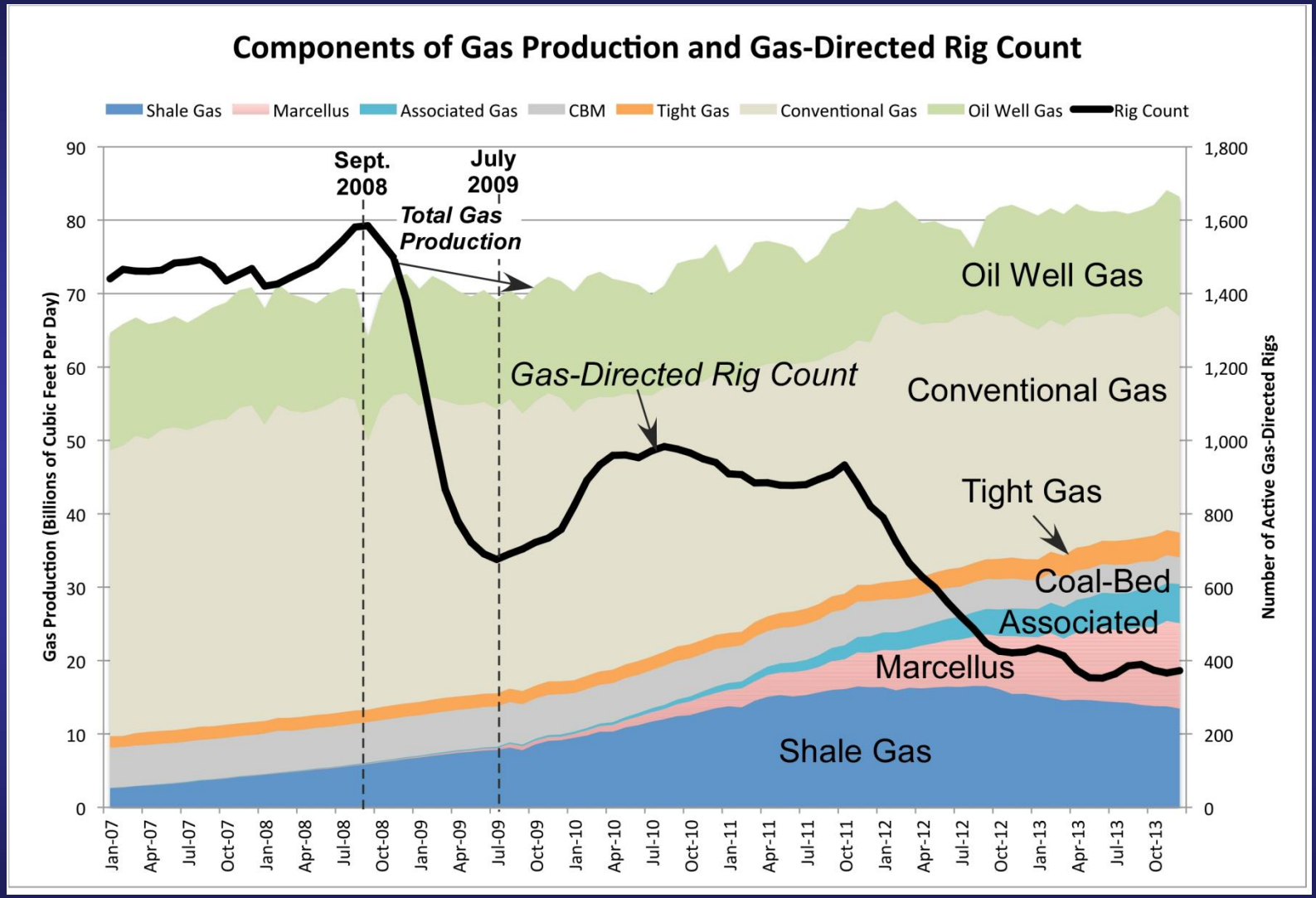

Monthly U.S. dry natural gas production and Henry Hub natural gas spot price, January 2005 - March 2012
eia
billion cubic feet per day
dollars per million British thermal units
80
70
60
50
40
30
20
10
0
20
18
16
14
12
10
8
6
4
2
0
Hurricanes Gustav and Ike
economic recession
supply overhang
dry natural gas production
winter well freeze-offs
Hurricanes Katrina and Rita
Henry Hub natural gas spot price
Jan-05
May-05
Sep-05
Jan-06
May-06
Sep-06
Jan-07
May-07
Sep-07
Jan-08
May-08
Sep-08
Jan-09
May-09
Sep-09
Jan-10
May-10
Sep-10
Jan-11
May-11
Sep-11
Jan-12

Figure 1: U.S. Natural Gas Rig Count vs. Henry Hub Spot Price (January 8, 1999 to March 6, 2015)



Sources: Baker Hughes Inc., U.S. Energy Information Administration


Components of Gas Production and Gas-Directed Rig Count
Shale Gas
Marcellus
Associated Gas
CBM
Tight Gas
Conventional Gas
Oil Well Gas
Rig Count
Gas Production (Billions of Cubic Feet Per Day)
Number of Active Gas-Directed Rigs
Sept. 2008
July 2009
Total Gas Production
Gas-Directed Rig Count
Oil Well Gas
Conventional Gas
Tight Gas
Coal-Bed
Associated
Marcellus
Shale Gas
0
10
20
30
40
50
60
70
80
90
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
Jan-07
Apr-07
Jul-07
Oct-07
Jan-08
Apr-08
Jul-08
Oct-08
Jan-09
Apr-09
Jul-09
Oct-09
Jan-10
Apr-10
Jul-10
Oct-10
Jan-11
Apr-11
Jul-11
Oct-11
Jan-12
Apr-12
Jul-12
Oct-12
Jan-13
Apr-13
Jul-13
Oct-13

Concerns Spread Over Environmental Costs of Producing Shale Gas

The extent to which utilities will burn natural gas to slash carbon dioxide emissions tied to global warming is a national issue. But on the ground, where it's being produced, the issues become very local

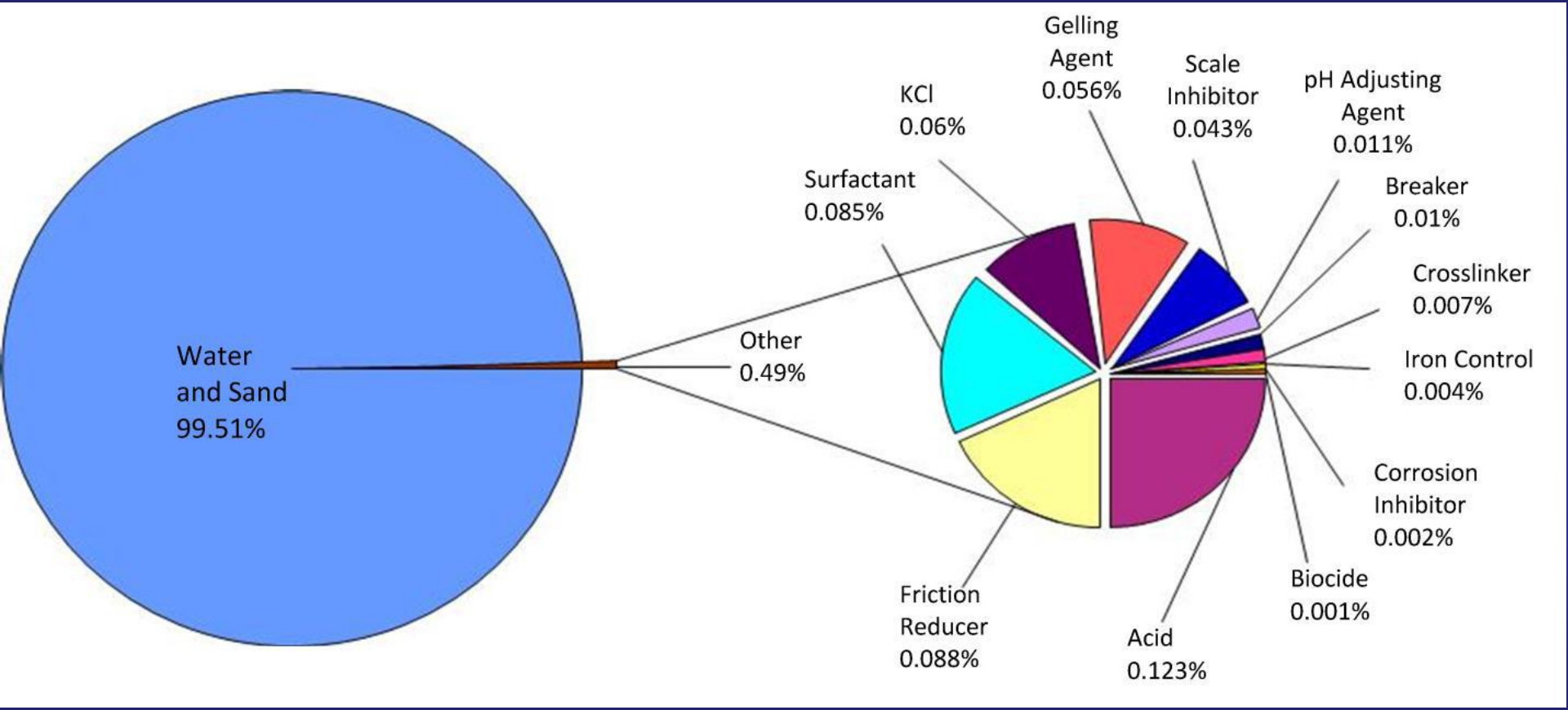
Scientific American

July 9, 2010

What are the Concerns?

- Air Quality – benzene, radioactivity
- Water Quality – methane, radioactivity, fracking chemicals
- Environment – leakage or disposal of waste water, sludge, etc.
- Home Value – Noise, dust, traffic, appearance
- Water requirements

COMPOSITION OF A FRACTURE FLUID



Generally 3-12 chemical additives

Produced water from oil production

- **High Salinity**
- Organics
- Radioactivity
- Trace elements

Evaporation Ponds


Do Not Drink
this Water
WATER
UNDER
ATTACK.COM


FRACK
PROTECT
WATER
WHO
GAIN
FRACK

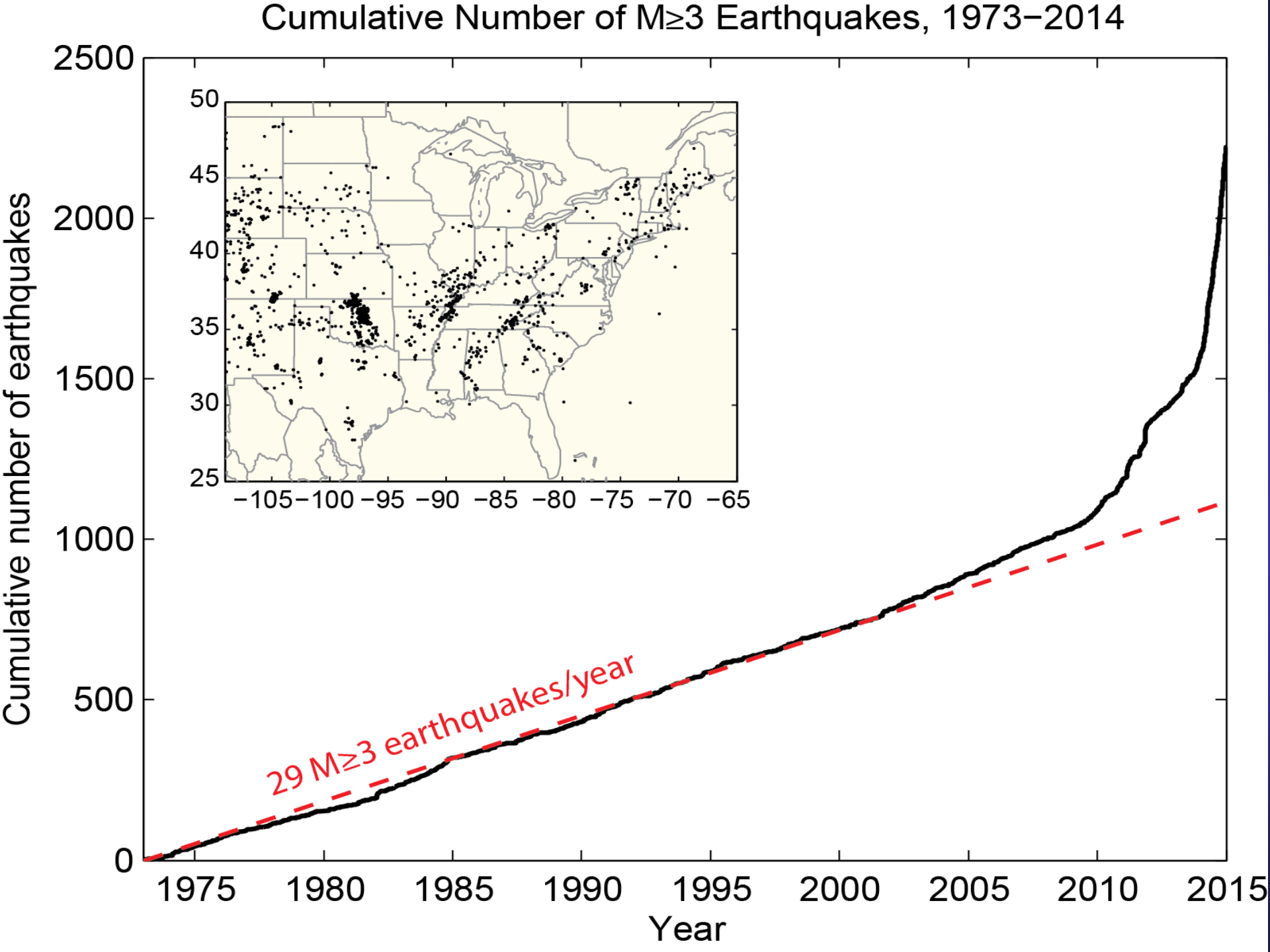

FRACK
Protect
Our Kids'
FRACK
Marcellus Shale
Severance Tax YES
Forced Pooling NO
Marcellus Shale
Severance Tax YES
Forced Pooling NO

The most current controversy has to do with swarms of small earthquakes (<4). In Texas, Oklahoma and elsewhere preliminary data indicates that reinjection of produced waters is the primary cause of the microseisms.

Is Fracking Triggering Earthquakes In Texas?

A dramatic increase in earthquakes in Texas is causing alarm, with many pointing the figure at the fracking industry.

Irving police had no reports of injuries or major damage in the 11 earthquakes that hit the area since Tuesday, but asked the public to stop calling 911 to report the shaking unless someone was hurt or there was another emergency.
The magnitudes ranged from 1.6 to 3.6, according to the USGS.


Cumulative Number of M≥3 Earthquakes, 1973−2014
Cumulative number of earthquakes
Year
29 M≥3 earthquakes/year
0
500
1000
1500
2000
2500
1975
1980
1985
1990
1995
2000
2005
2010
2015
50
45
40
35
30
25
−105
−100
−95
−90
−85
−80
−75
−70
−65

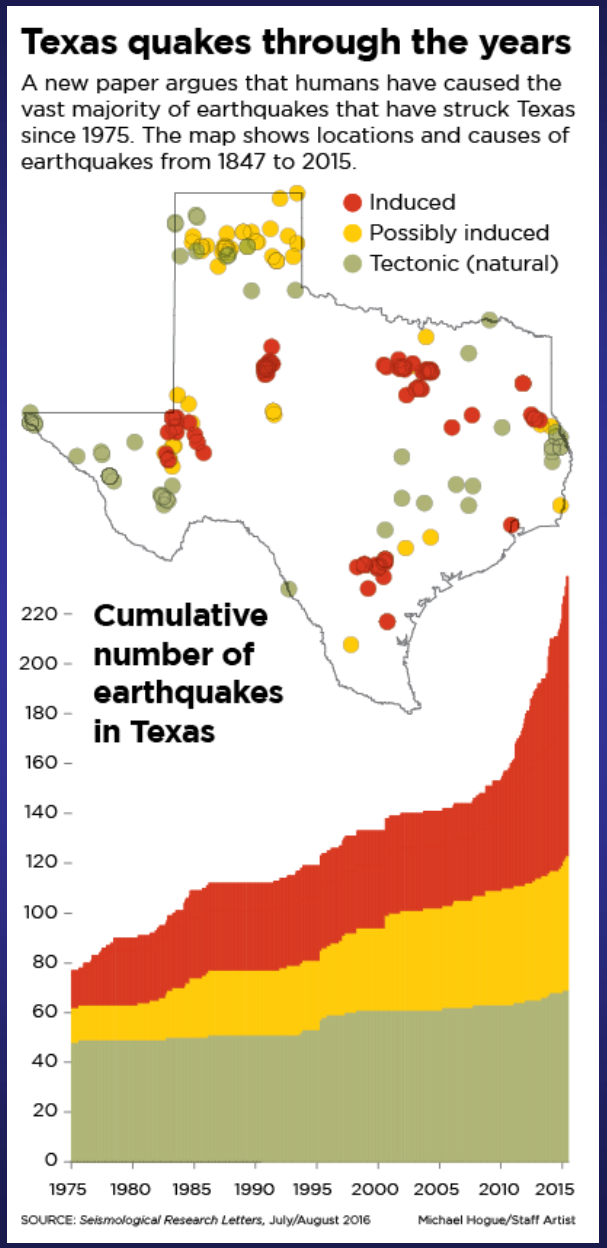
Study links earthquakes in Texas to natural gas drilling

UT study: Fracking-related activities have caused majority of recent Texas Earthquakes – May 20, 2016

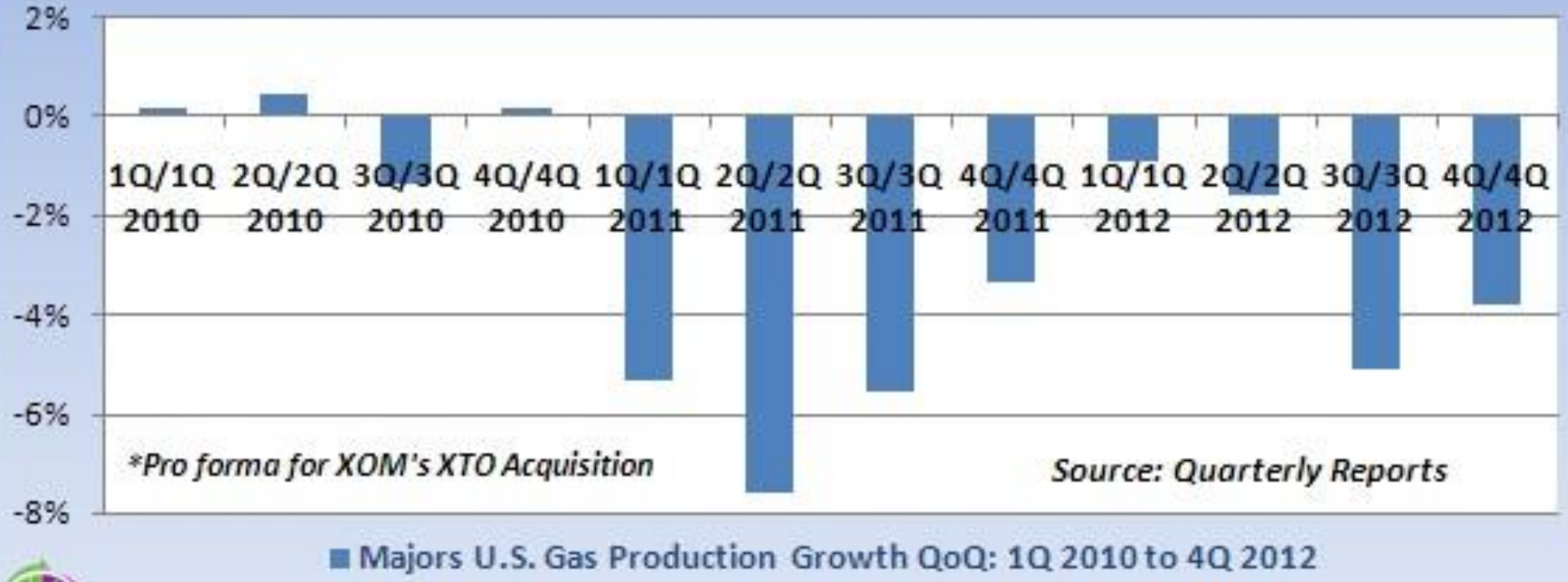
Spate of small earthquakes shuts down fracking activity in Lawrence County, PA. April, 28, 2016

Do fracking activities cause earthquakes? Seismologists and the state of Oklahoma say yes! Earthquakes increasing in volume and intensity around fracking and waste disposal sites. April 28, 2016

Fracking triggers 90% of large quakes in B.C., Alberta oil and gas patch.
But less than 1% of fracking activity directly responsible for earthquakes. March 29, 2016



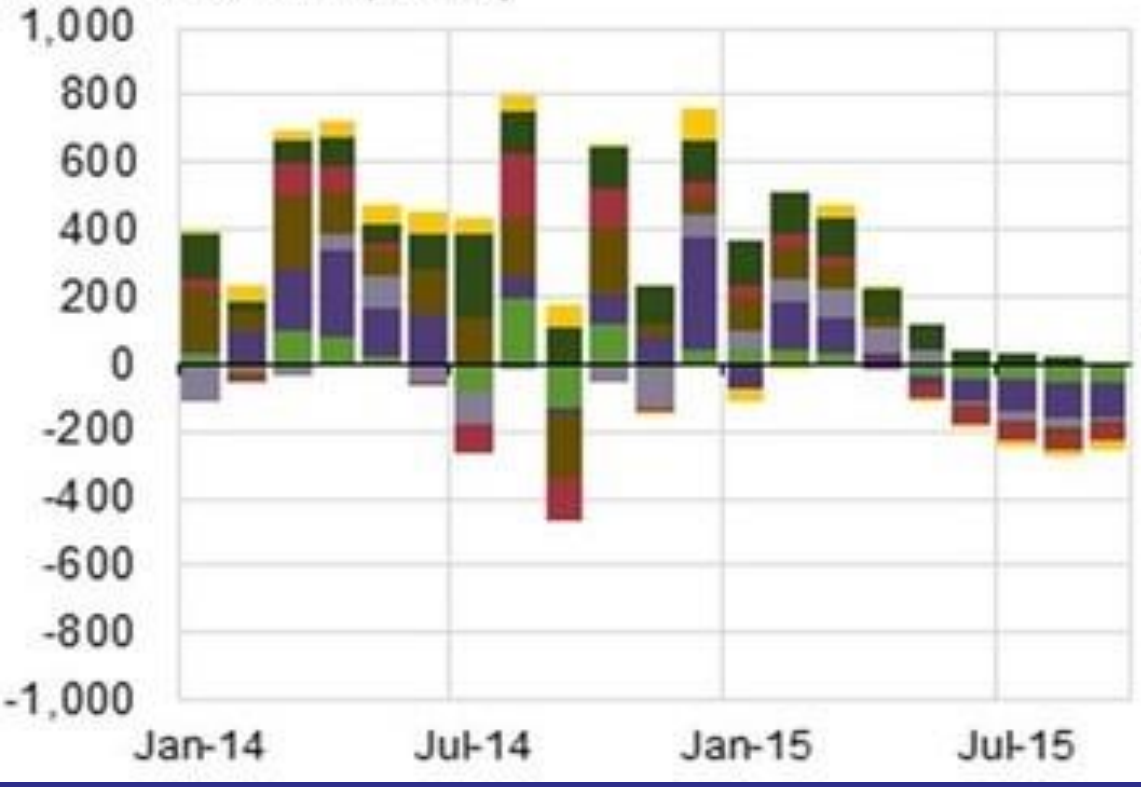
Shale Gas Production has Slowed Majors' U.S. Gas Production Decline*



EnergyTrends INSIDER

Monthly change in natural gas production in DPR regions (Jan 2014-Sep 2015)

million cubic feet per day



eia

Has U.S. shale gas production finally stopped growing?

According to the EIA's August Monthly Drilling Productivity Reports the answer is yes—even the monster Marcellus play in Pennsylvania is declining in production.

But this may not be true.

The Stock Market is saying that gas production will continue with gas prices remaining in a tight $2.65-$2.95 per gigajoule range.

Will US shale gas bring global energy prices tumbling down?

BBC News June 2015

The U.S. is looking beyond its own borders to become a major player in global gas markets. In fact by the end of this decade, the **country plans to challenge Qatar, the undisputed king of liquefied natural gas (LNG).**

US shale gas could, then, have a profound impact not just domestically, but on the rest of the world. The reality however will be somewhat different.

With US gas prices around the $3 mark, the economics of gas liquefaction and export depend entirely on getting a higher LNG price in the export market.

Take the basic cost of the gas at $3, add in a small mark up, liquefaction costs of $3 and transport costs of $2, and suddenly the economics don't work that well.


Global gas prices, 2000-2015
$ Million metric British units
20
15
10
5
0
2000 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15
Japan LNG import price
Asia gas price
Europe gas price
US gas price
Source: Bloomberg, Argus LNG
BBC

What Do I Expect?

<u>Truth</u> – Scientists must determine the true sources of the pollutants and earthquakes .

<u>Compromise</u> – The gas industry (and States) must make more efforts to honestly communicate with the public and to accommodate concerns.

<u>Results</u> – New technological advances
Somewhat higher costs
Gas resources off limits

Continued development of shale gas but at a lower pace. Exports may alter the picture.

Acquiring and maximizing the value of oil and gas assets through innovation.

UpCurve Energy

Coalbed Methane (CBM)

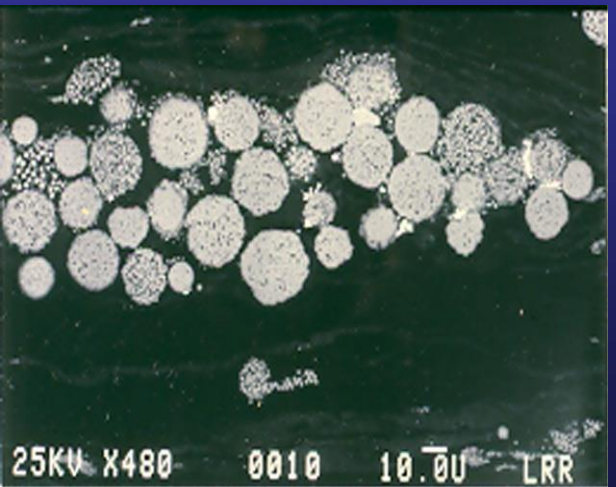
(Coal Bed Methane Coalbed Gas Coal Seam Gas)

An Introduction

COAL

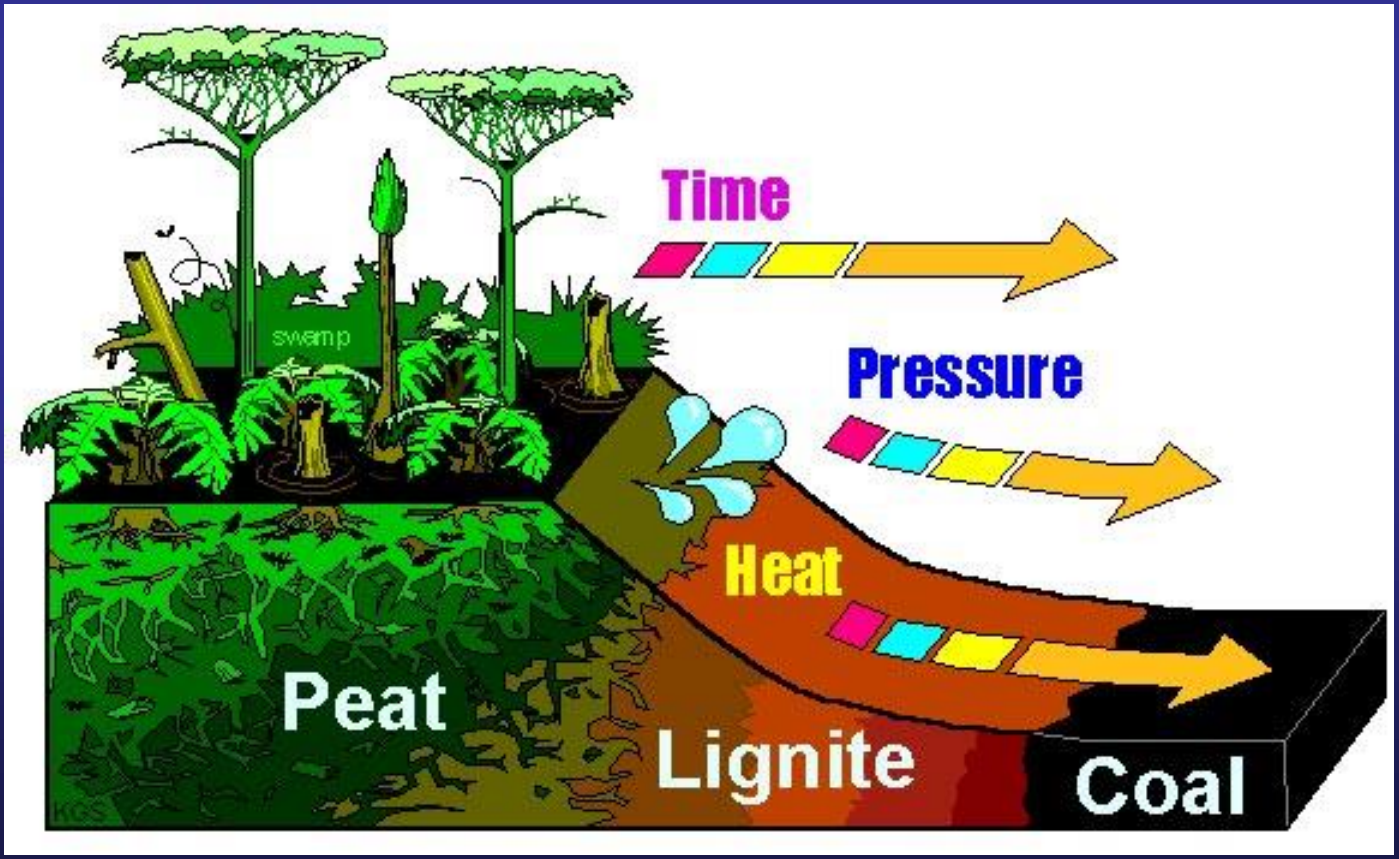
- Organic Matter
- Minerals
- Elements
- Water
- Oil
- Gas

Figure IN-5. Ferris coal beds.



Coalification

As pressure increases, water is squeezed out and pore size is reduced. Water and carbon dioxide are the first products released. At later stages, oxygen and hydrogen are released. Methane is eventually expelled.



Temperature

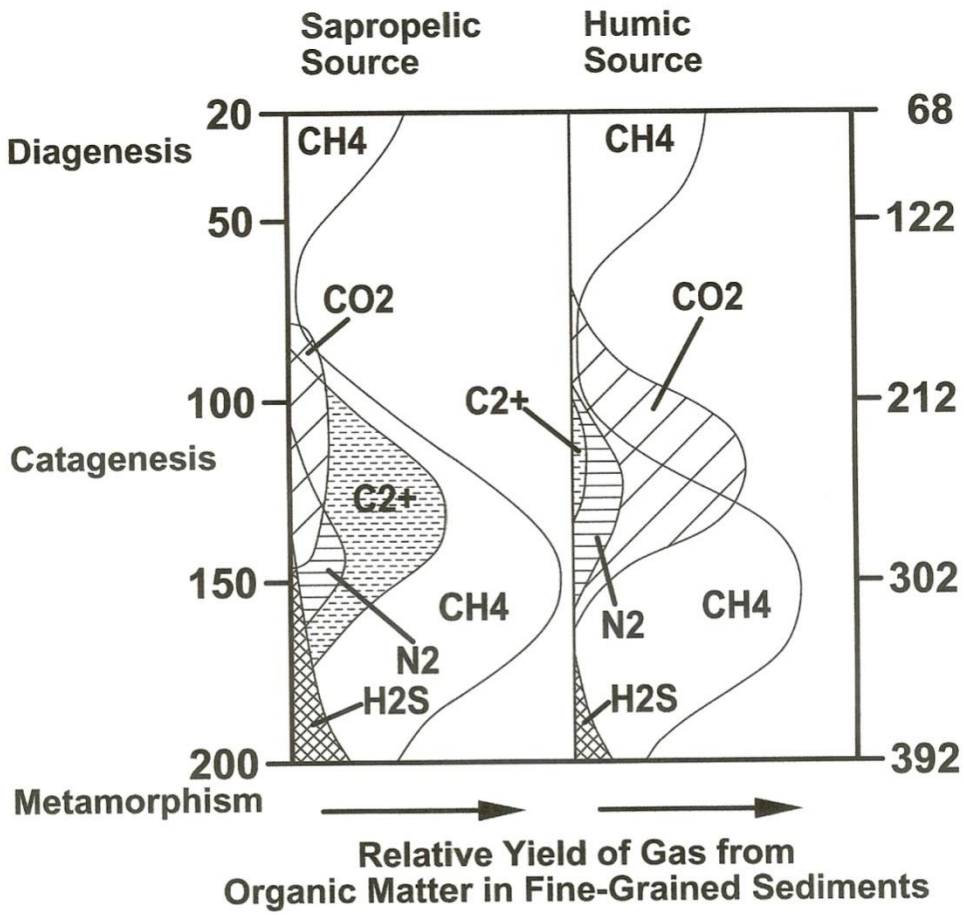
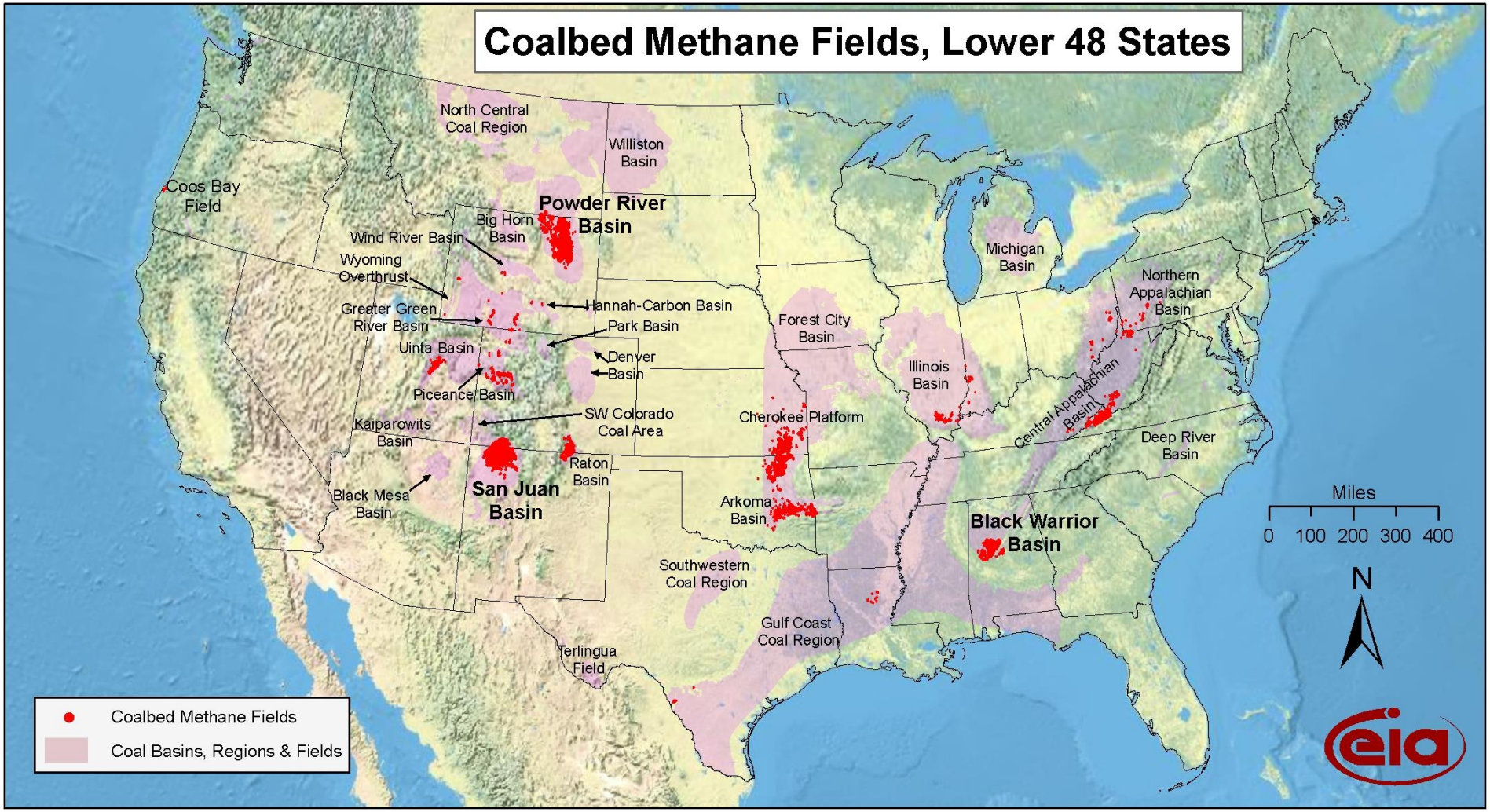


Fig. 5-1. Generation of gases with depth: C2+ represents hydrocarbons heavier than CH4; N2 is generated initially as NH3.

Methane Retention

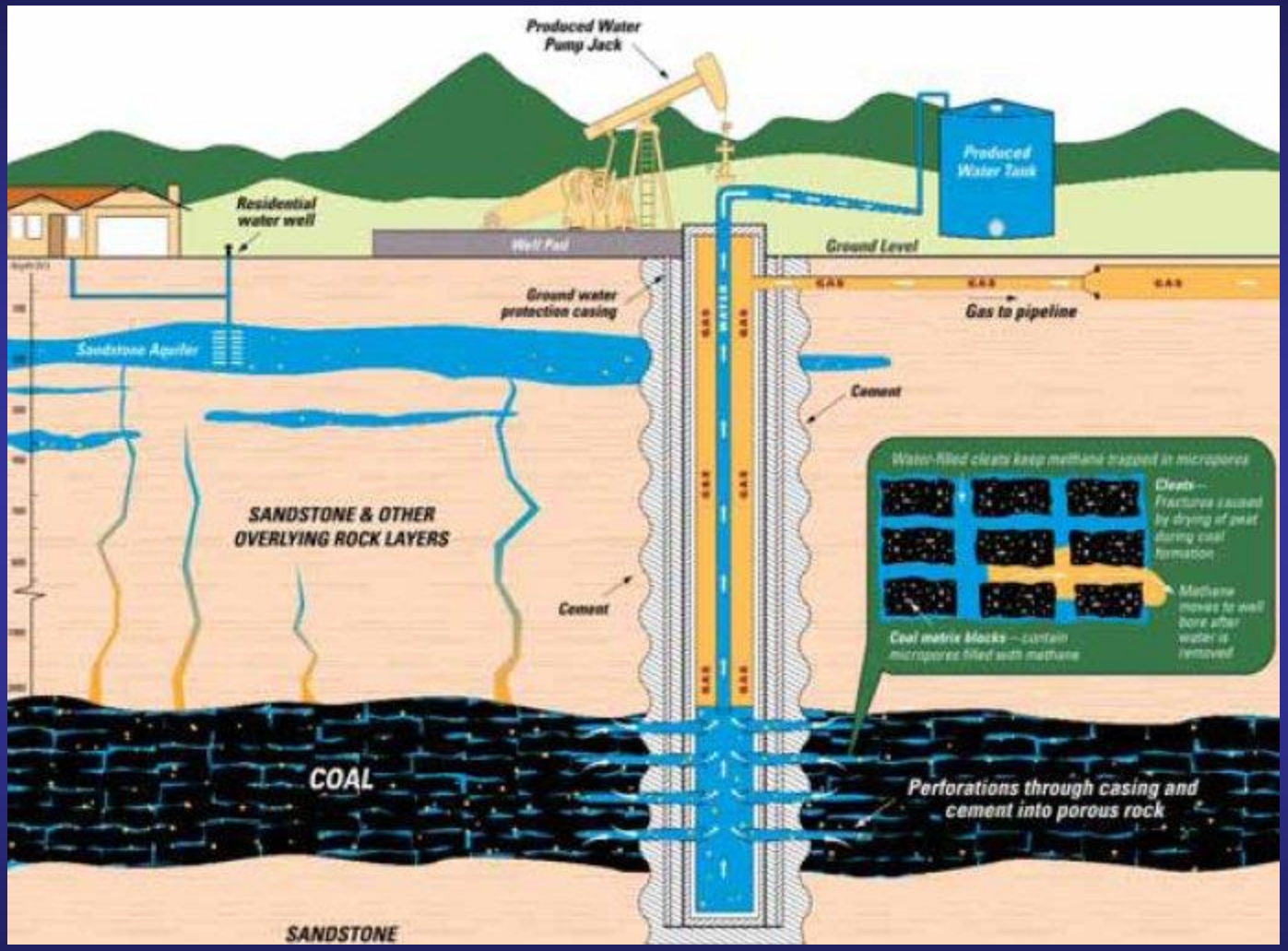
- **Absorbed molecules on the surface of the organics**
- Free gas within the coal pores or fractures
- Dissolved in water within the coal bed

Methane in Coal Mines



Source: Energy Information Administration based on data from USGS and various published studies
Updated: April 8, 2009

2007 **reserve** estimate – 21,875 BCF


Produced Water
Pump Jack
Produced
Water Tank
Residential
water well
Well Pad
Ground Level
Ground water
protection casing
GAS
GAS
GAS
Gas to pipeline
Sandstone Aquifer
Cement
SANDSTONE & OTHER
OVERLYING ROCK LAYERS
Cement
Water-filled cleats keep methane trapped in micropores
Cleats –
Fractures caused
by drying of peat
during coal
formation
Methane
moves to well
bore after
water is
removed
Coal matrix blocks – contain
micropores filled with methane
COAL
Perforations through casing and
cement into porous rock
SANDSTONE

Advantages of CMB

- Low exploration costs
- Shallow source (greater depth limits permeability)
- Inexpensive to complete
- Existing technology
- May be used for CO_2 storage
- May degas ahead of coal mining

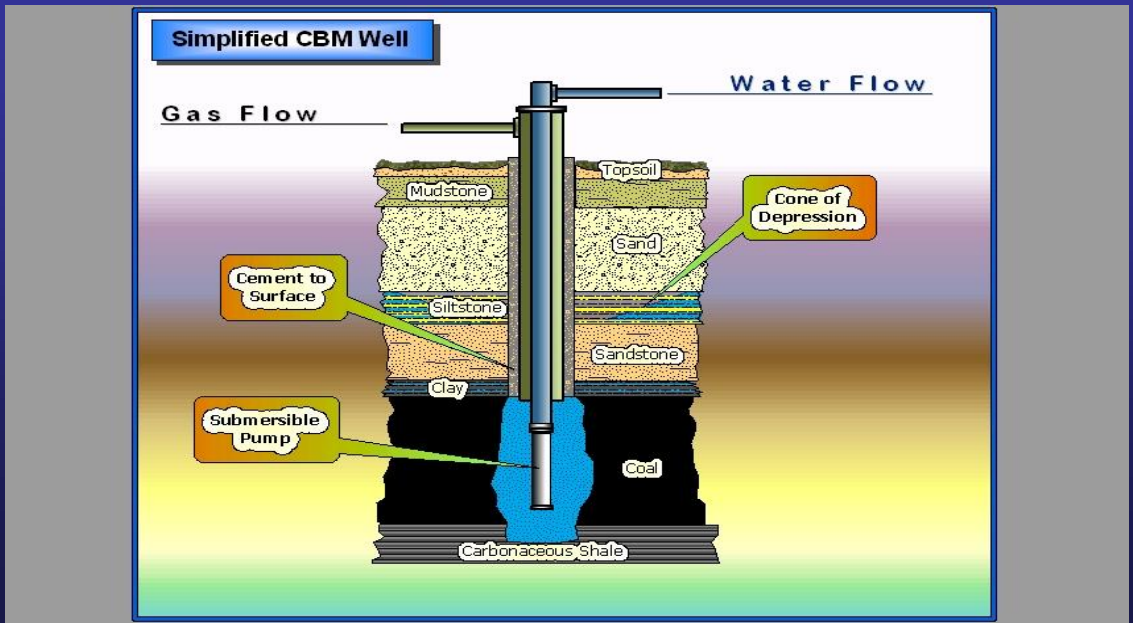
CBM Environmental Concerns

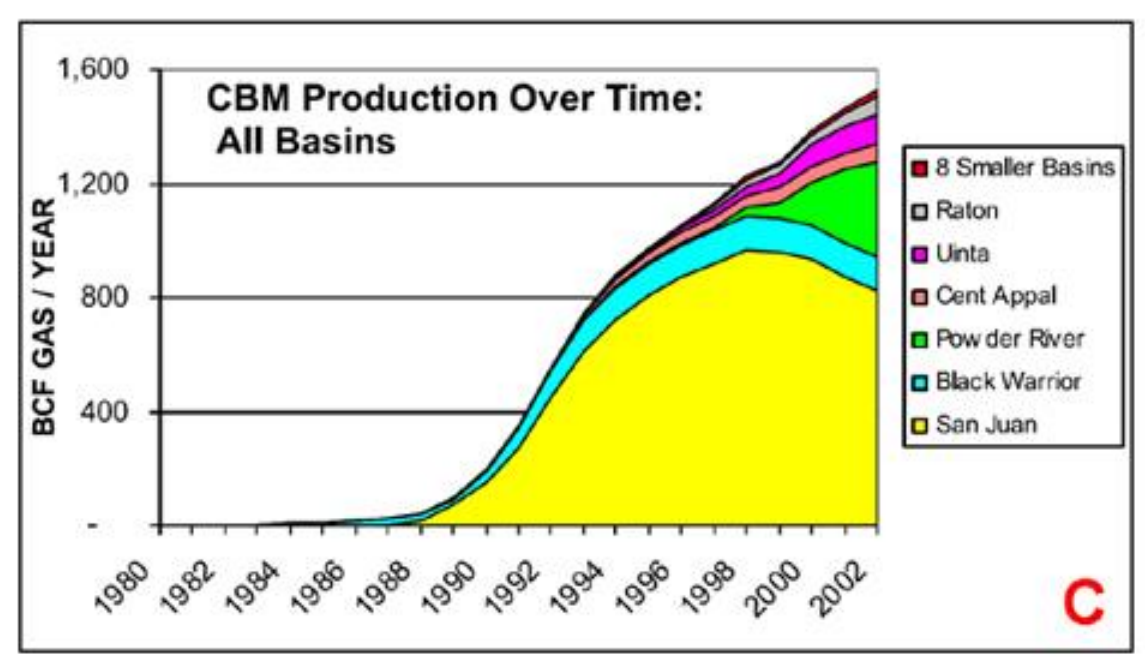
- Large Volumes of Produced Waters (average well 17,000 gallons of water/day = 6.2 million gallons/year)
- Some enriched in salts, organics, radon, methane
- Drawdown of aquifer
- Disposal issues:
  - Pollutes surface waters
  - Reinjection is costly
  - Chemical treatment – very costly
  - Freezing – only in cols climates
  - Evaporation ponds - dust

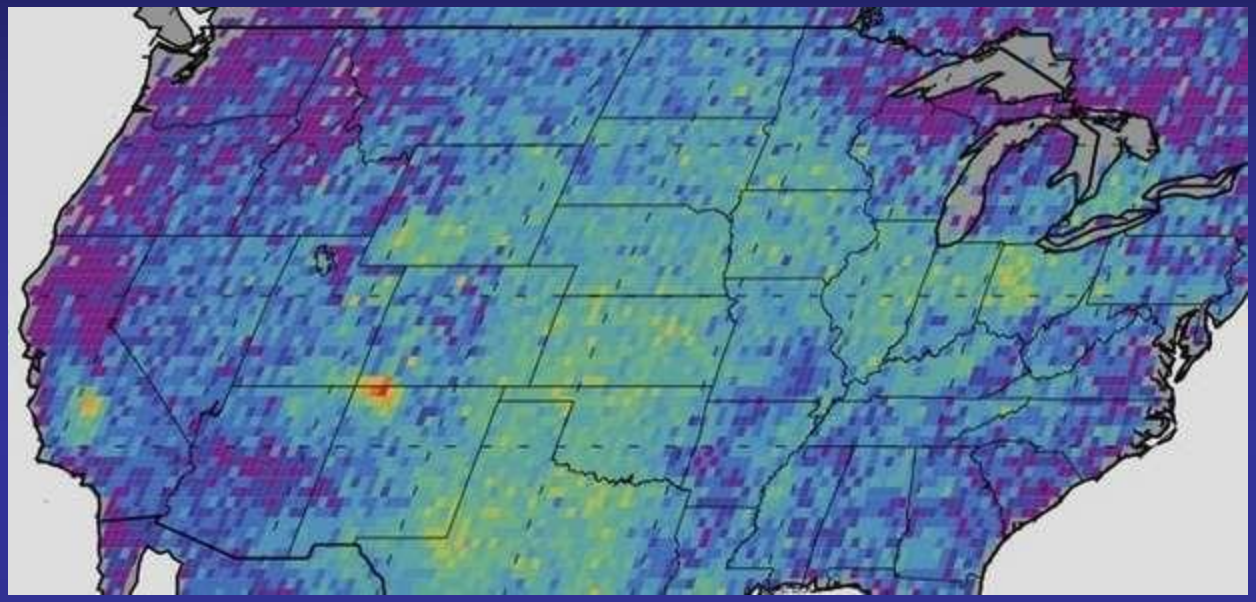
Methane is a potent greenhouse gas – Climate Change Issues

Disadvantages of CBM

- Requires dewatering
- Need to stimulate flow (fracing)
- Environmental concerns
- Gas leakage (+/-)
- Methane migration in ground water




CBM Production Over Time:
All Basins
BCF GAS / YEAR
1,600
1,200
800
400
-
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
8 Smaller Basins
Raton
Uinta
Cent Appal
Powder River
Black Warrior
San Juan
C



Methane Emissions from gas production – note the San Juan Basin

Other Sources of Energy

- Tar Sands
- Oil Shale
- Nuclear
- Hydropower
- Wind
- Solar
- Geothermal
- Biomass
- ????

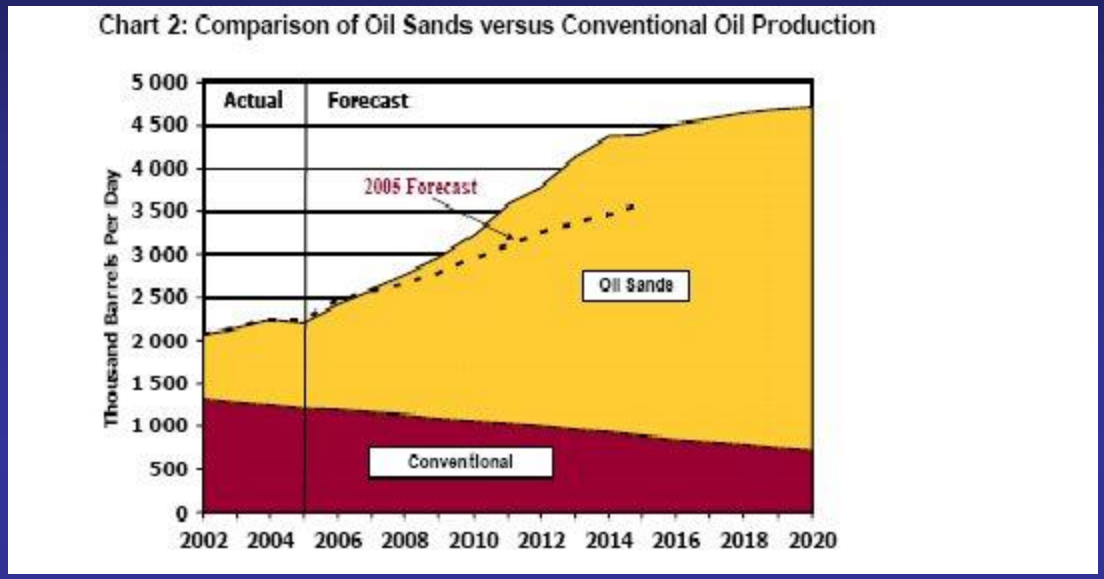
Tar Sands (Oil Sands)

Unconventional petroleum deposit consisting of a mixture of sand, clay, water and bitumen.

- **Canada and Venezuela each have reserves approximately equal to the world's reserves of conventional crude oil!**

Tar sands may represent as much as two-thirds of the world's total "liquid" hydrocarbon resources!

Canadian Production



Canada Production – about 3 million barrels/day

Venezuela – about 500,000 barrels/day

Reserves – USA, Russia

Environmental Concerns

- Land – Deforestation, Fragile Environments, Toxic Chemicals, Cost
- Water – Large amounts needed for separation process, water pollution
- Air – CO_2, H_2S, Heavy metals

Oil Shale

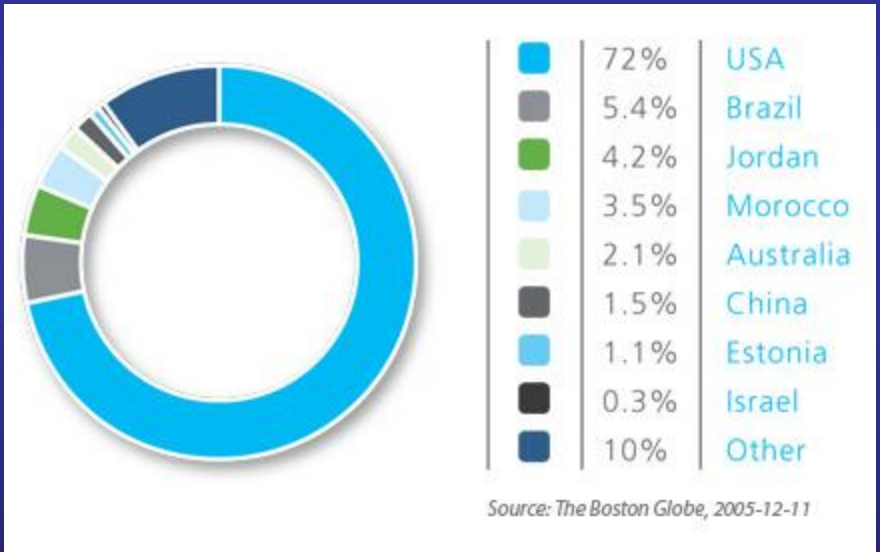
An organic-rich, fine grained sedimentary rock containing kerogen (solid organic compounds).

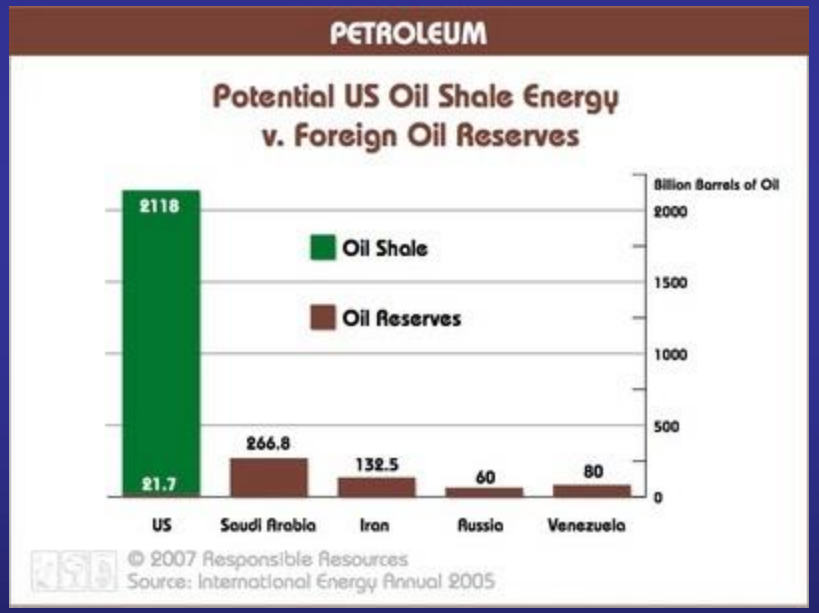
Resources are estimated at about 3 trillion barrels of oil, far exceeding world's proven conventional oil reserves!

Oil Shale

Estonia (62%), China, Brazil, German, Israel, and Russia use oil shale for energy (oil or power) or for chemicals.

USA (70%), Russia, and Brazil account for 86% of the world's oil shale resources.





Environmental Concerns – Acid mine drainage, environmental damage, sulfur gas, dust, **heavy metals, high water usage.**

Nuclear Energy - $117/megawatt-hour

Issues

- No carbon dioxide
- Efficient
- Disposal of radioactive waste
- Fear! Of explosion, meltdown, etc.
- Time

Hydropower

Issues

- Cheap electricity
- Little pollution (though reservoir may have environmental impacts)
- Multiuse – water activities/drinking water source/flood control
- Needs running water

Wind Energy $115/megawatt-hour

Issues

- Variable and intermittent winds/storage
- Aesthetics/birds/noise
- Essentially no pollution
- Costly maintenance

Solar Energy - $236/megawatt hour

Issues

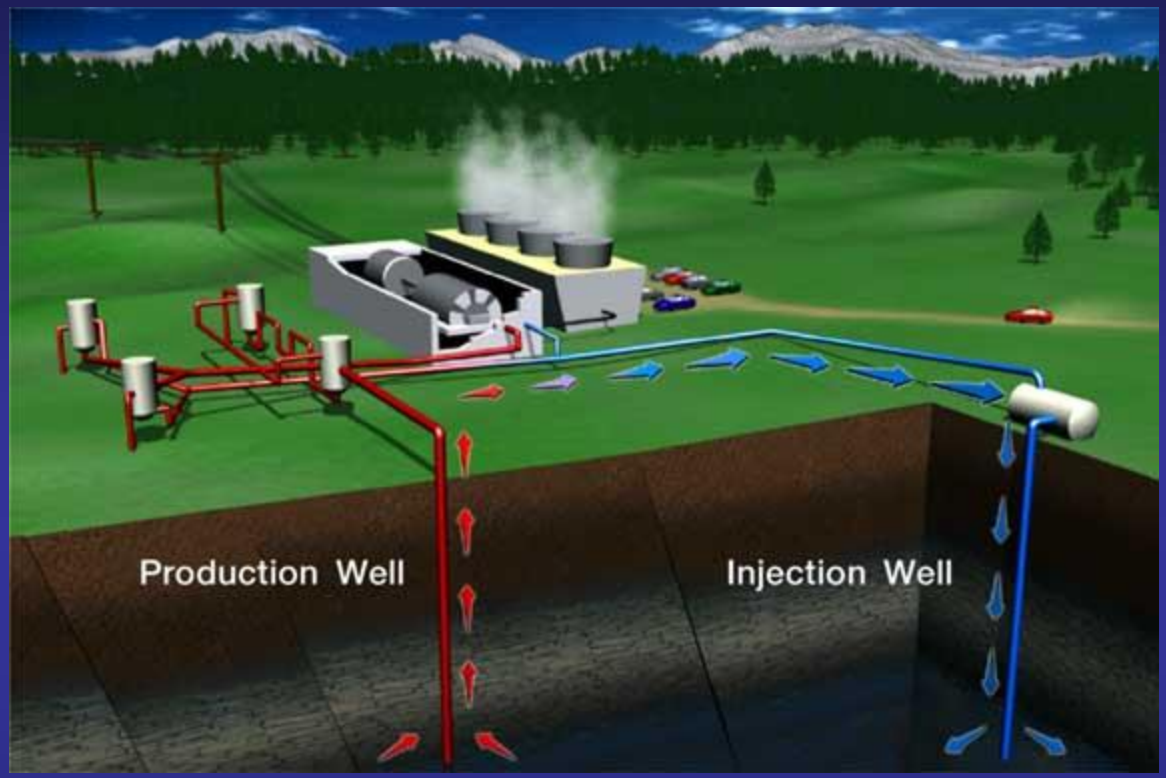
- High Cost
- Intermittent/large footprint/storage
- No pollution

Biomass

Issues

- Renewable/abundant
- Carbon neutral
- Expensive
- Large footprint

Geothermal Energy



Issues

- Inexpensive, reliable, sustainable
- No pollution
- Location, location, location

Geothermal energy is the energy stored in the form of heat below the earth's surface. Geothermal heat and water have been used for thousands of years. The Romans, Chinese, and Native Americans used hot mineral springs for bathing, cooking and for therapeutic purposes.

Today geothermal water is used in many applications such as district heating, systems which provide steam or hot water to multiple units, as well as for heating and cooling of individual buildings, including offices, shops and residential houses, by using geothermal heat pumps. Moreover, it has industrial potential for raising plants in greenhouses, drying crops, heating water at fish farms and other industrial processes.

In general, ground temperature increases about
3 degrees C with every 100 meters in depth
(30 degrees C/km)

Advantages of Geothermal Energy

- Almost unlimited supply of renewable energy.
- Theoretically more than adequate to supply humanity's energy needs.
- Widespread – promotes national security
- Negligible environmental impacts (little greenhouse gas)
- Requires little water, land, energy input
- Safe, reliable
- Low cost per kW/h

Geothermal Energy - Limitations

- Plant sittings - must be near where heat is most accessible – thin crust, plate boundary, hot spots

Location, location, location

- Unique nature of each potential geothermal plant.
- High capital costs – financial risk.
- Scalability – surge in demand. (New drilling techniques, storage systems)
- Thermal plumes (hot or coal water).

Geothermal Energy - Projections

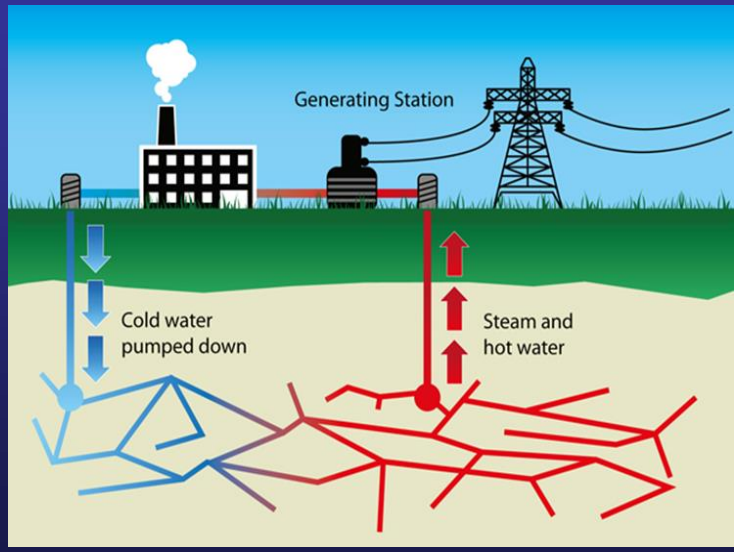
- By 2030 – 10% of global energy production.
- In 50 -100 years it will be a substantial contributor to world energy supply.

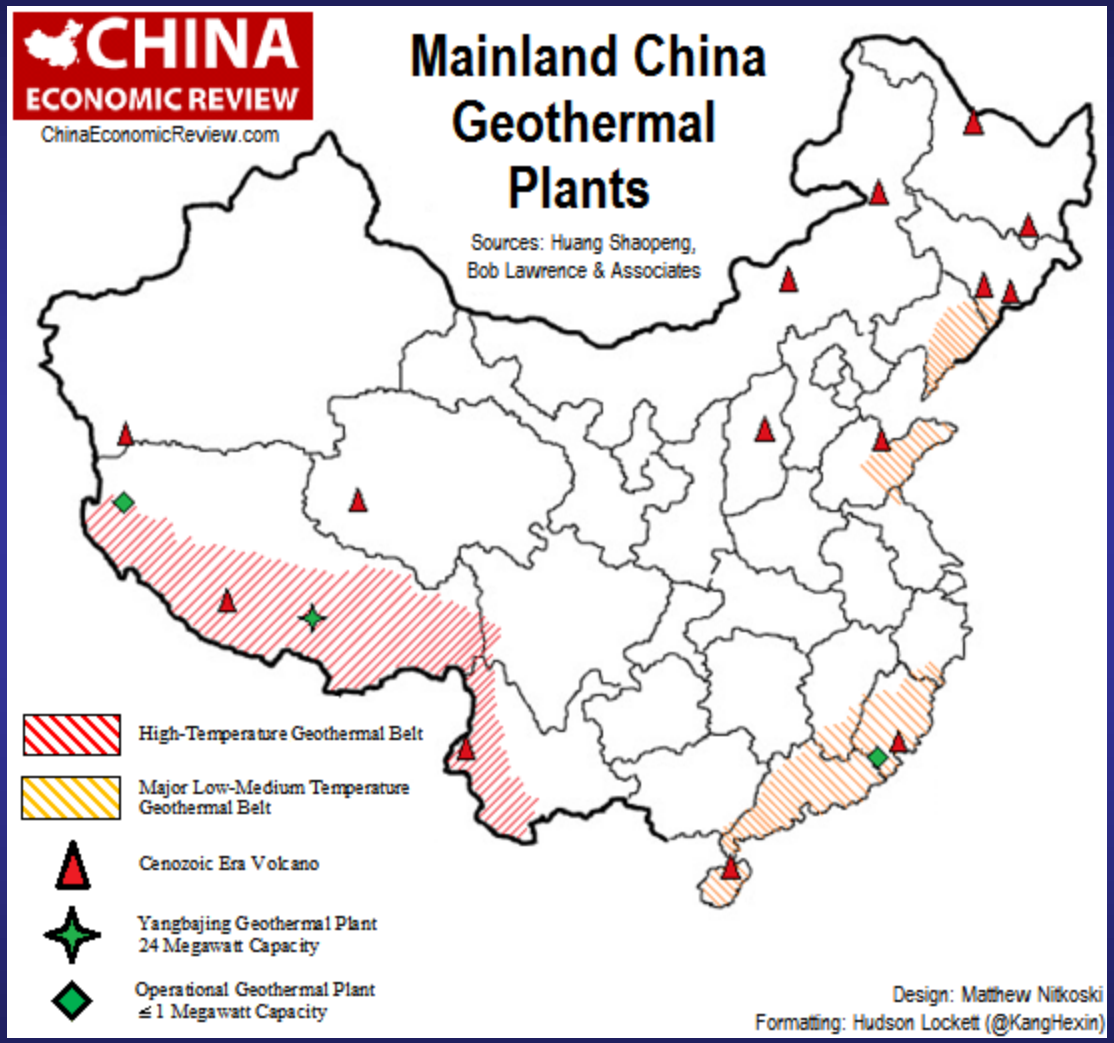
There are two types of Geothermal Energy

We can think of them as:

Passive – using the heat from hot springs and geysers to heat homes, greenhouses, bathing, and therapeutic purposes.

Active or Enhanced Geothermal Systems – drilling conduits and injecting fluids into hot rocks and harvesting the heat for generating electric power.

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ChinaEconomicReview.com
Mainland China Geothermal Plants
Sources: Huang Shaopeng, Bob Lawrence & Associates
High-Temperature Geothermal Belt
Major Low-Medium Temperature Geothermal Belt
Cenozoic Era Volcano
Yangbajing Geothermal Plant 24 Megawatt Capacity
Operational Geothermal Plant ≤ 1 Megawatt Capacity
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