

Shale gas & fracking – ETH Zurich, April 2nd, 2014



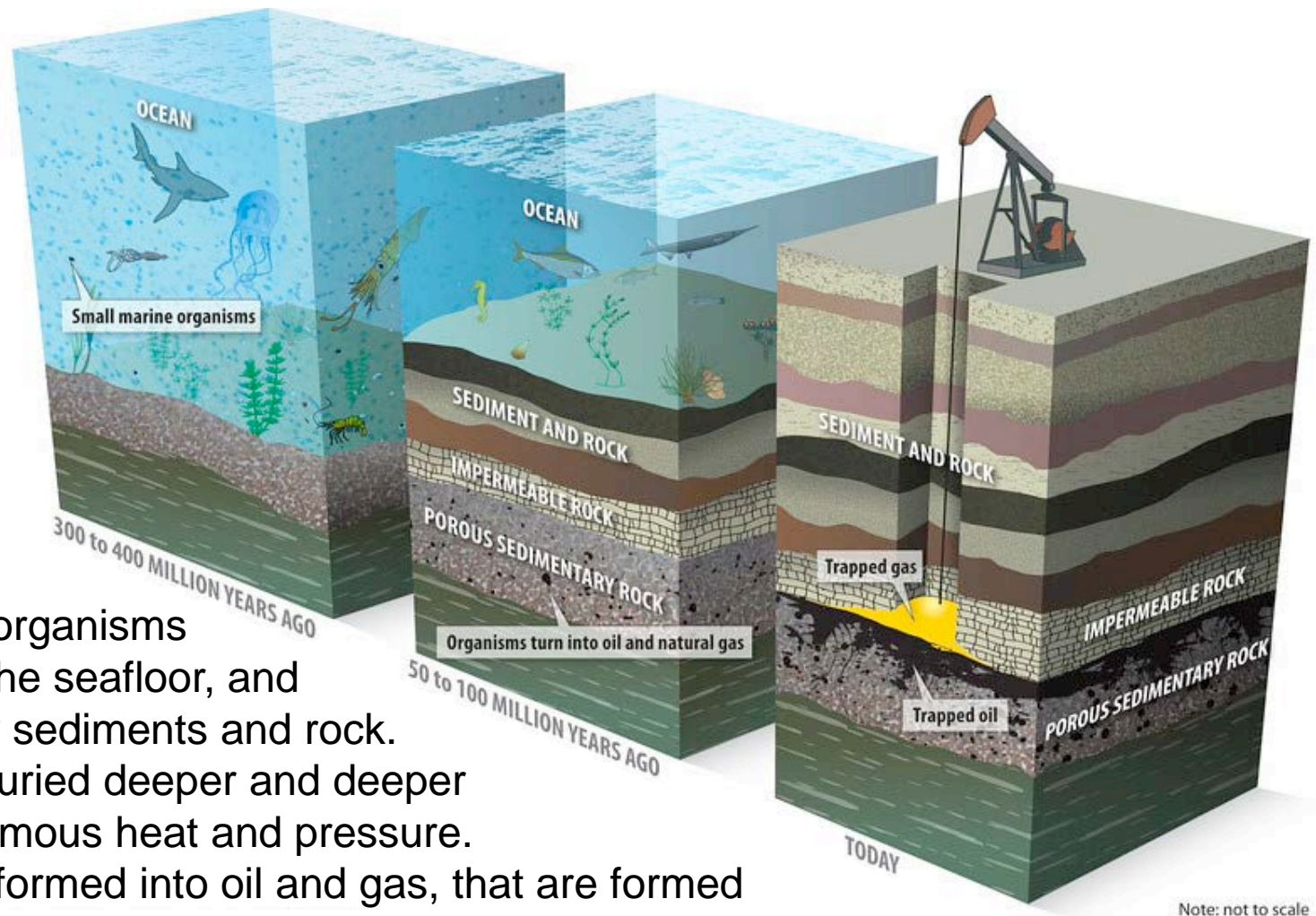
Technology overview

Marco Mazzotti (with M. Hänchen and M. Werner), ETH Zurich

Outline

- What is *shale gas*?
- What is *fracking*?
- Where is *shale gas* available and produced?
- What are the issues with *shale gas* and *fracking*?

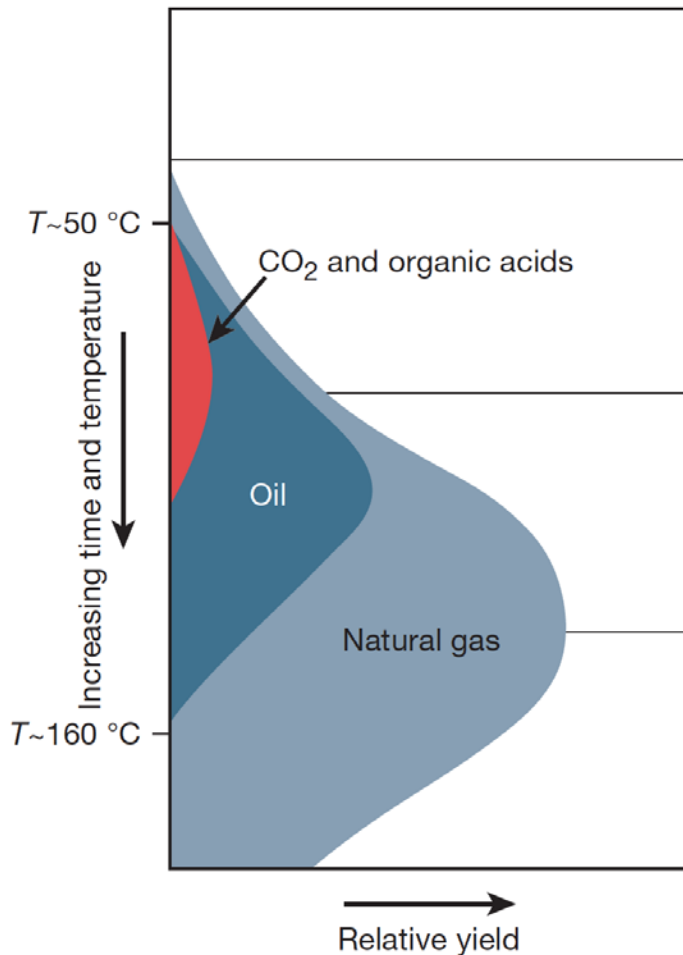
How oil and gas were formed



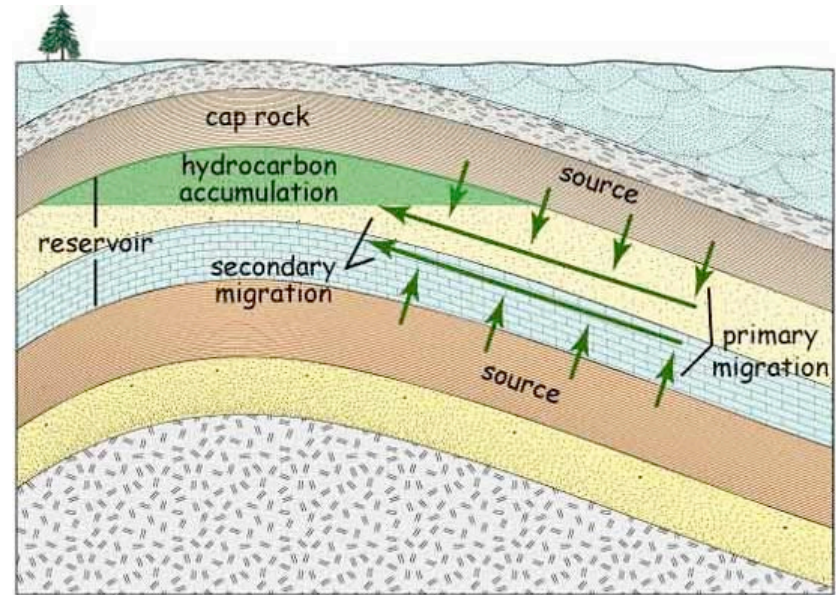
- Tiny dead organisms buried on the seafloor, and covered by sediments and rock.
- Remains buried deeper and deeper under enormous heat and pressure.
- Thus transformed into oil and gas, that are formed within the *source rock* and accumulate in *geological traps*.
- Coal stems from decay and burial of higher terrestrial plants.

How oil and gas accumulations were formed

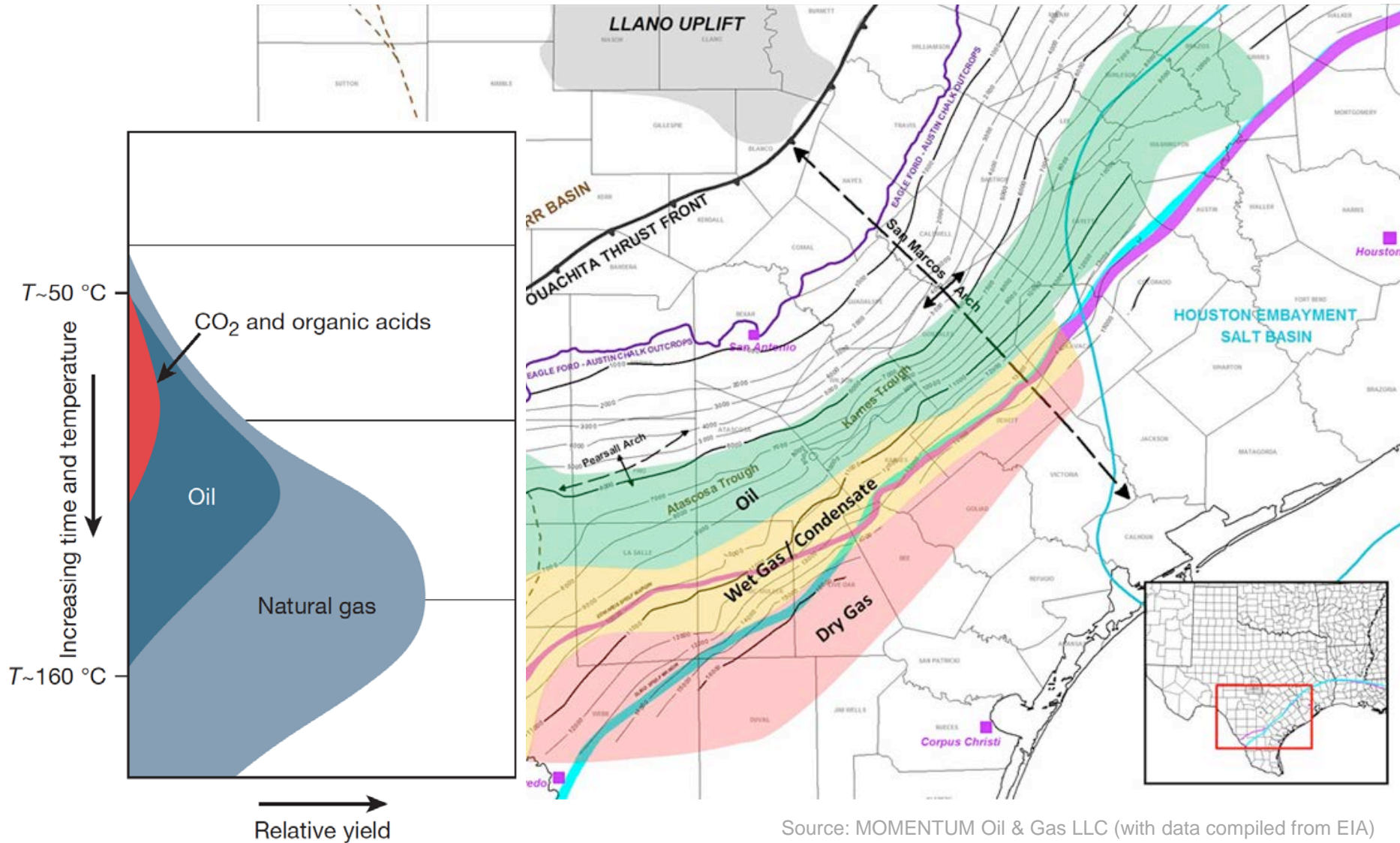
- Geochemical processes within the *source rock*



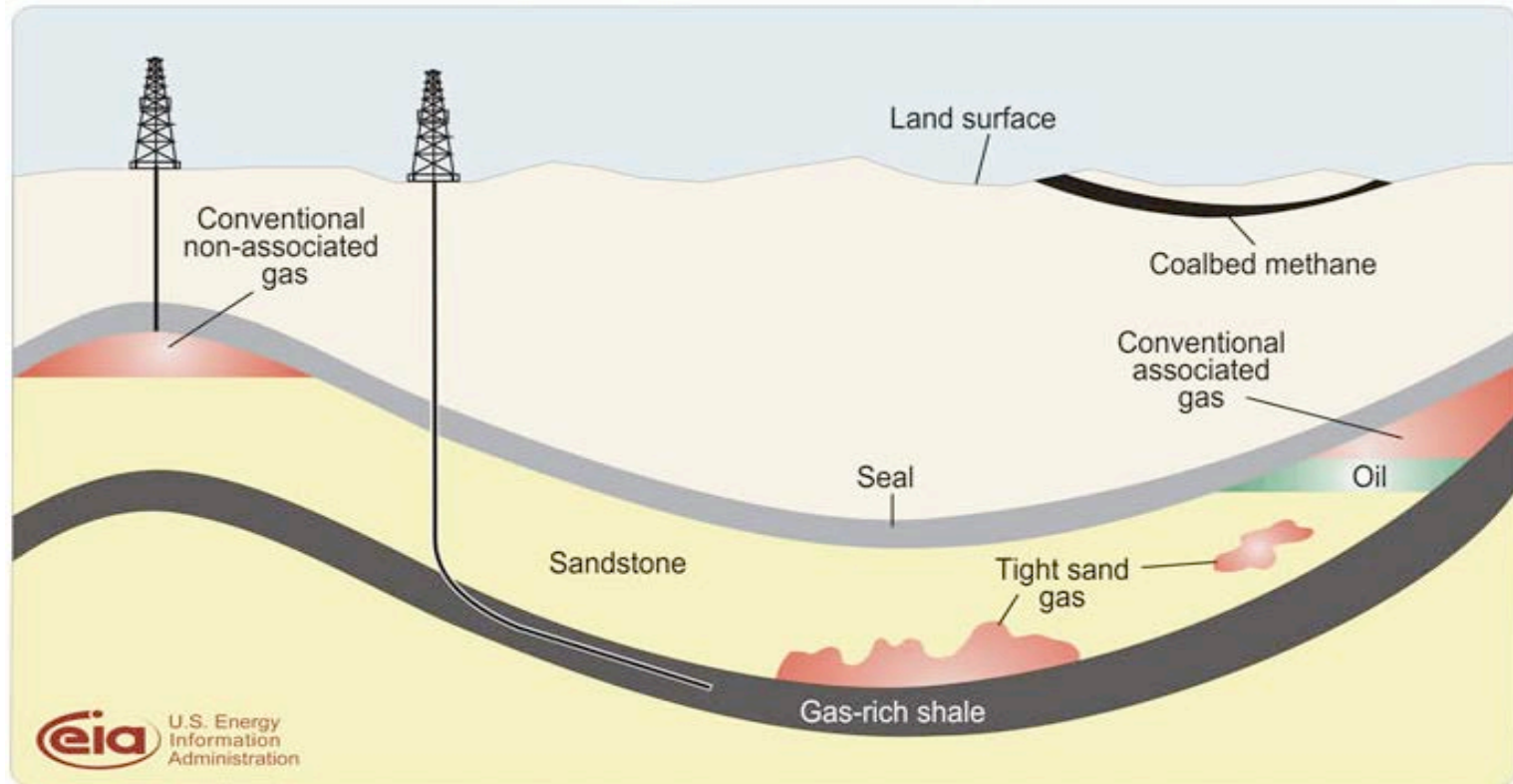
- Primary and secondary migration, and trapping



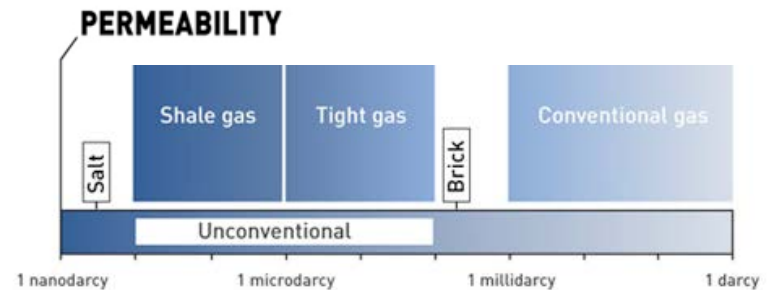
Eagle Ford shale play structure map



Schematic geology of natural gas resources



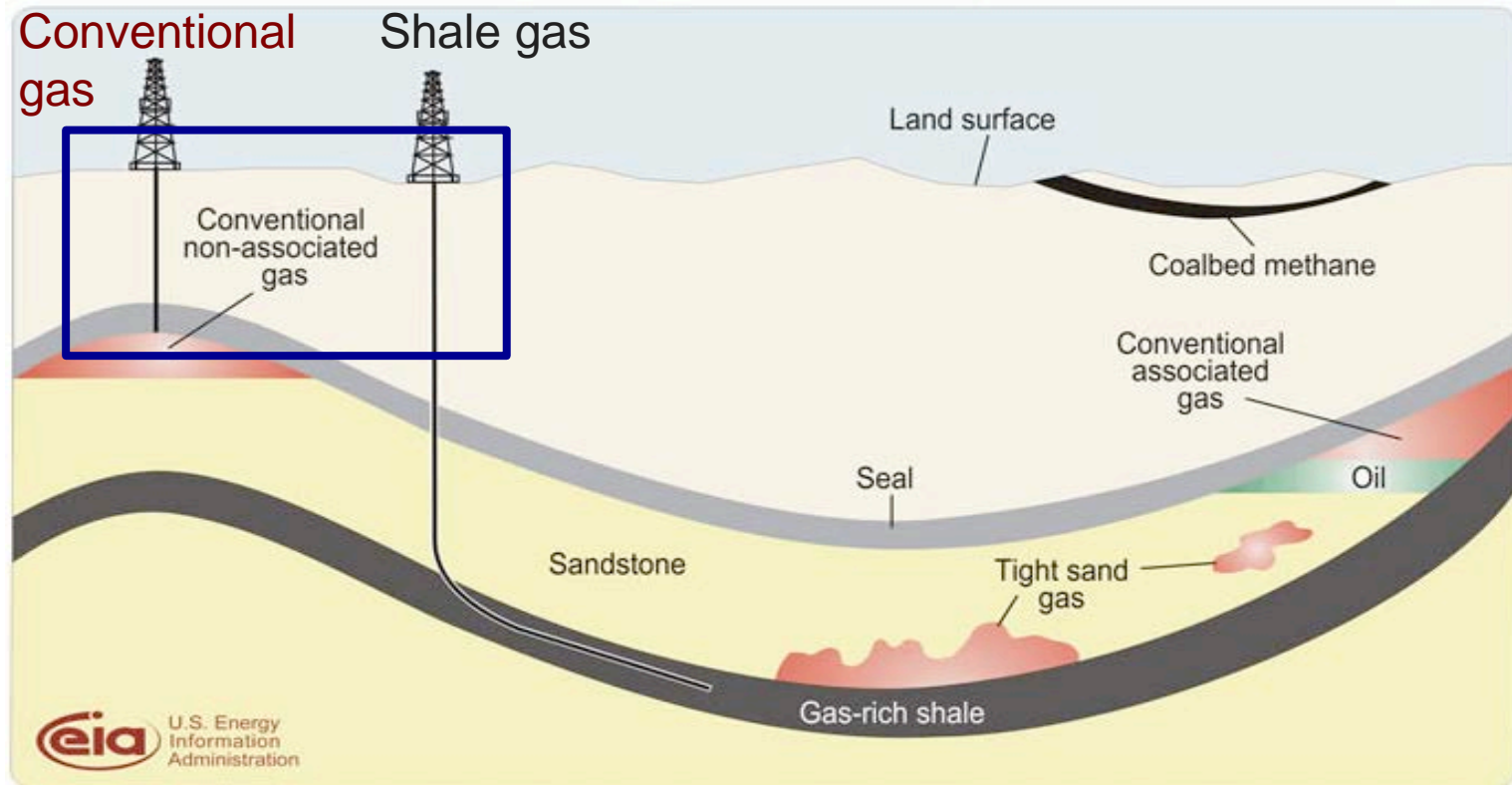
- Shale gas in poorly permeable *source rock* (difficult to produce)
- Conventional gas in permeable sandstone (easier to produce)



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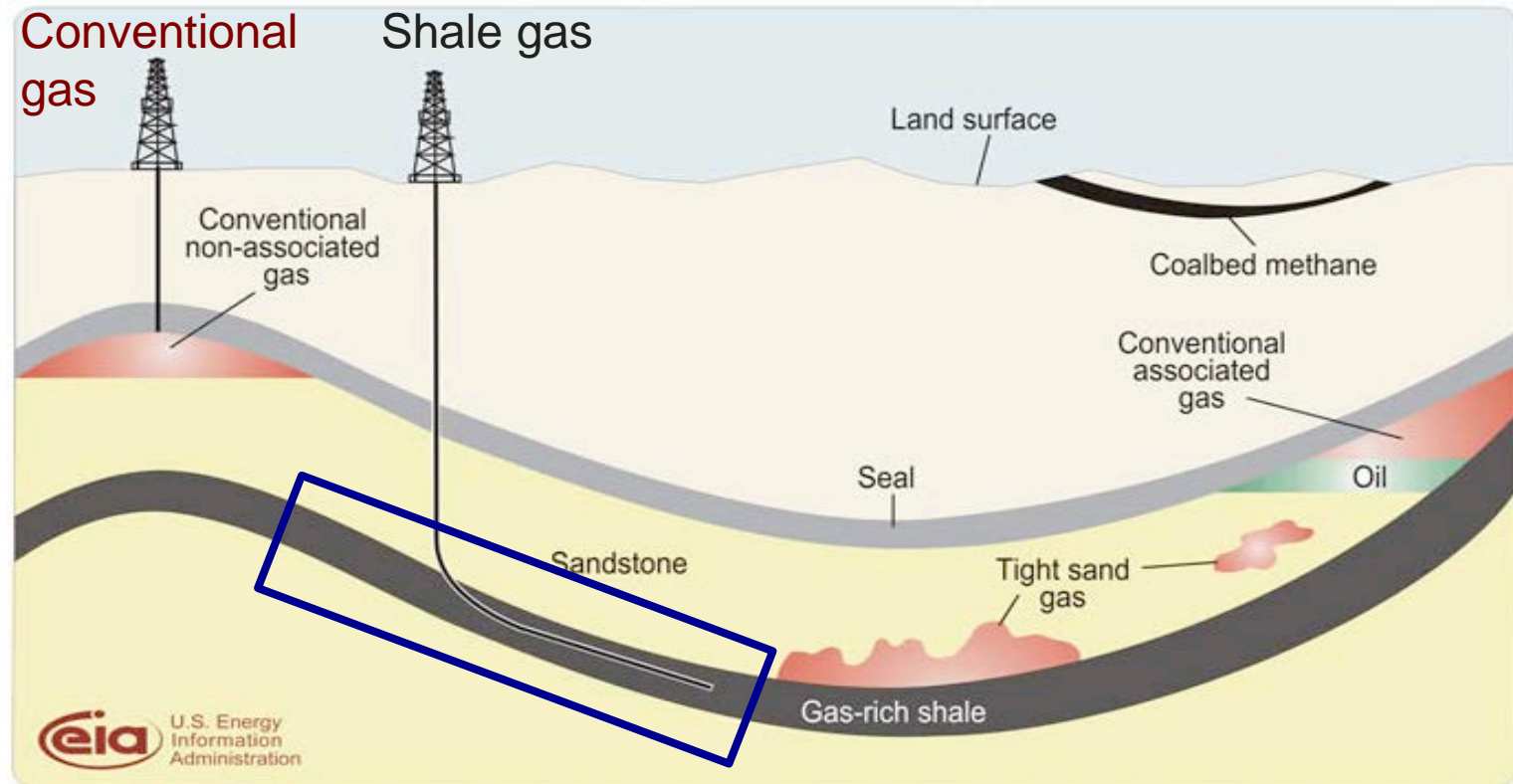
Natural gas production



- Shale gas in poorly permeable *source rock* (difficult to produce)
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Similar features of the vertical well

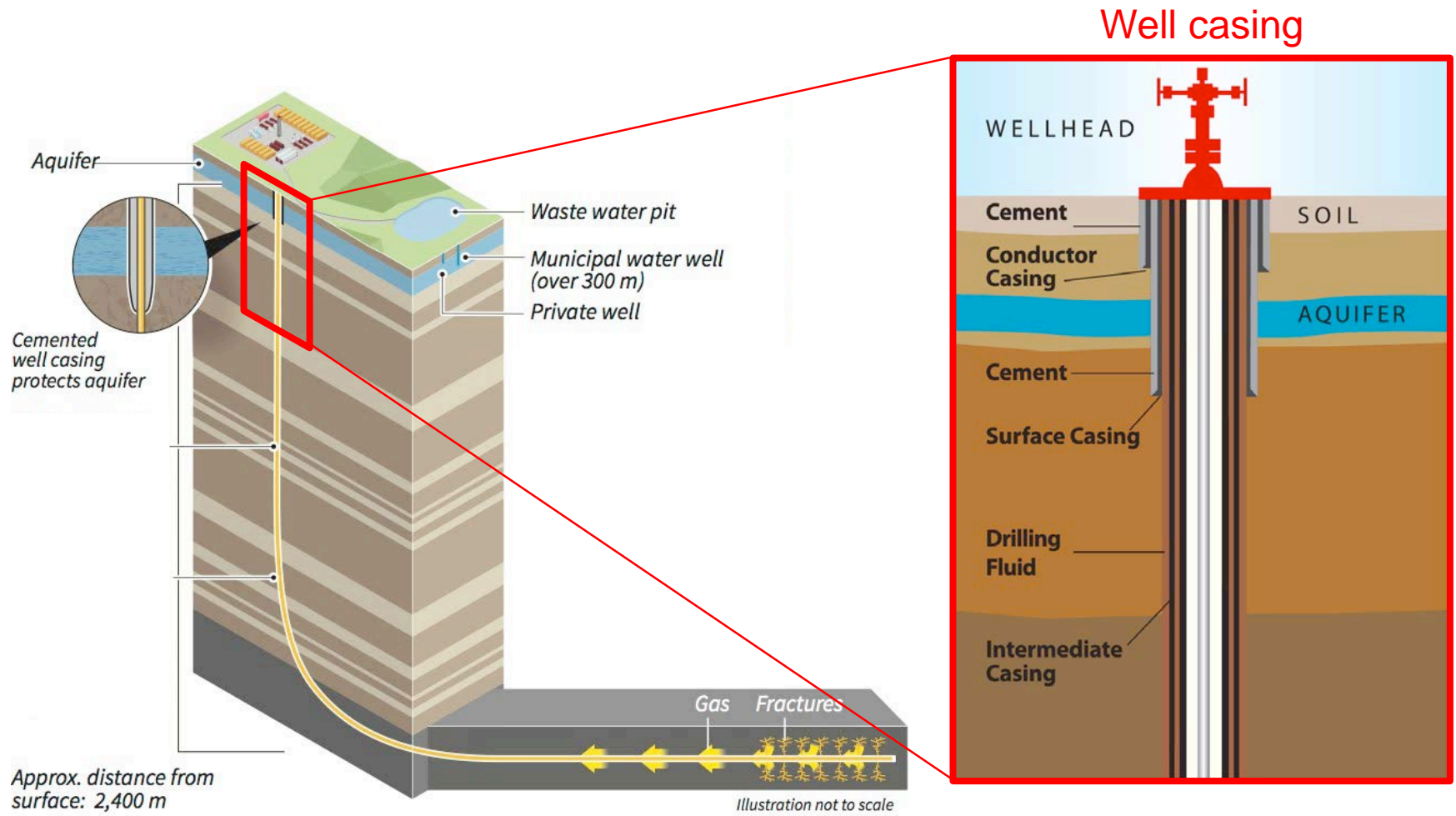
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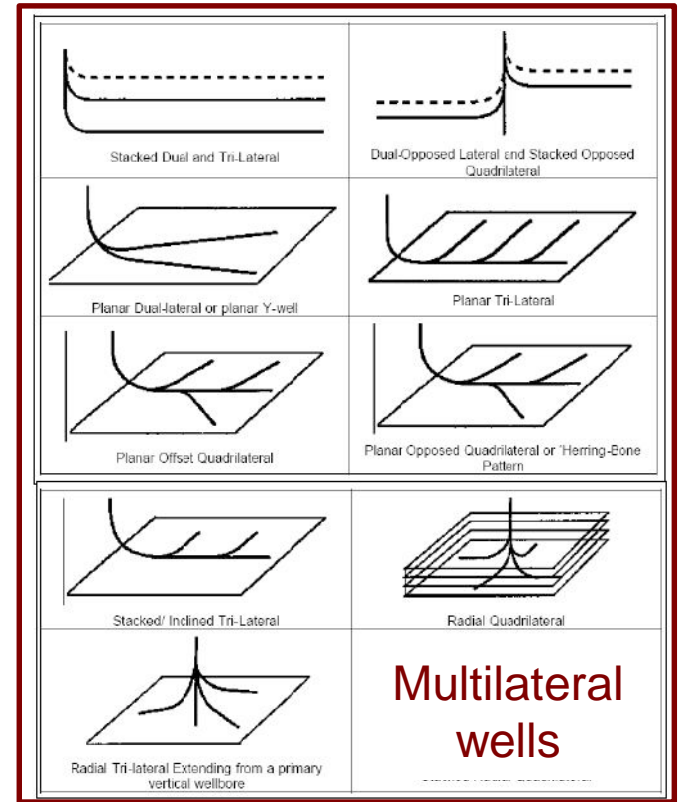
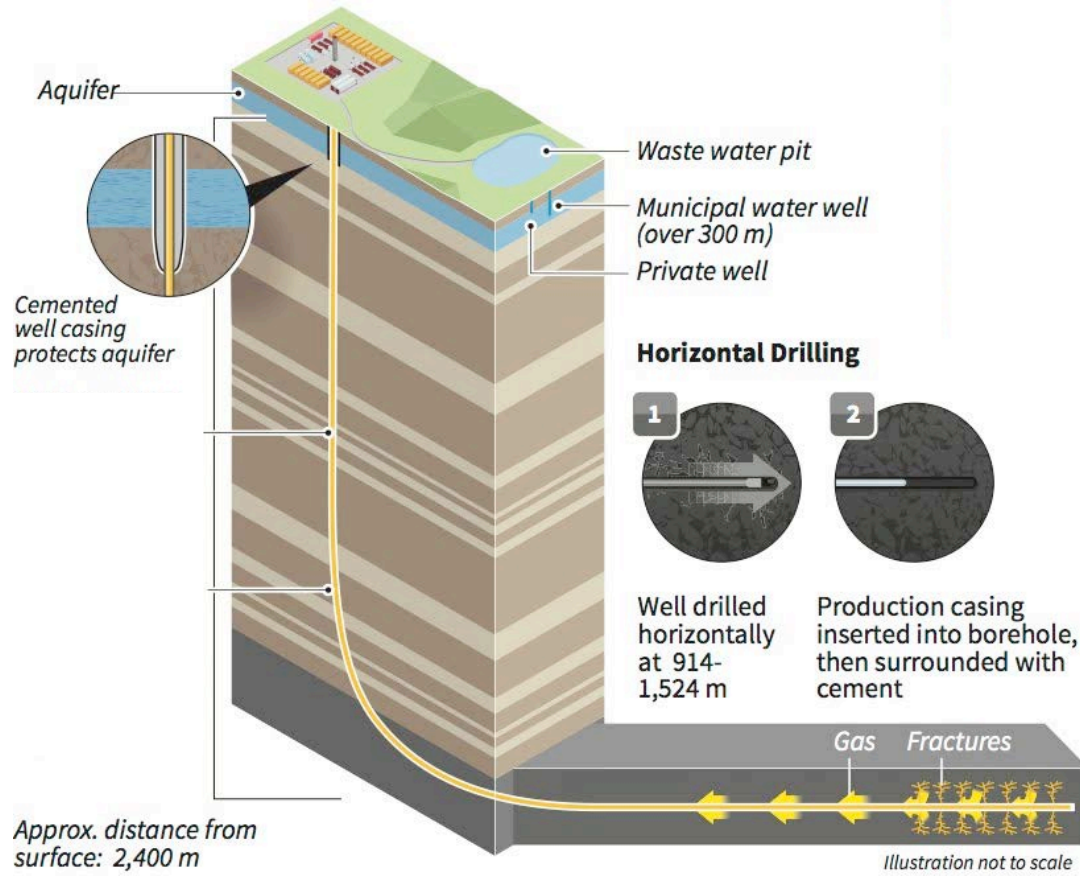
- Horizontal drilling
- Hydraulic fracturing

Horizontal drilling and fracking



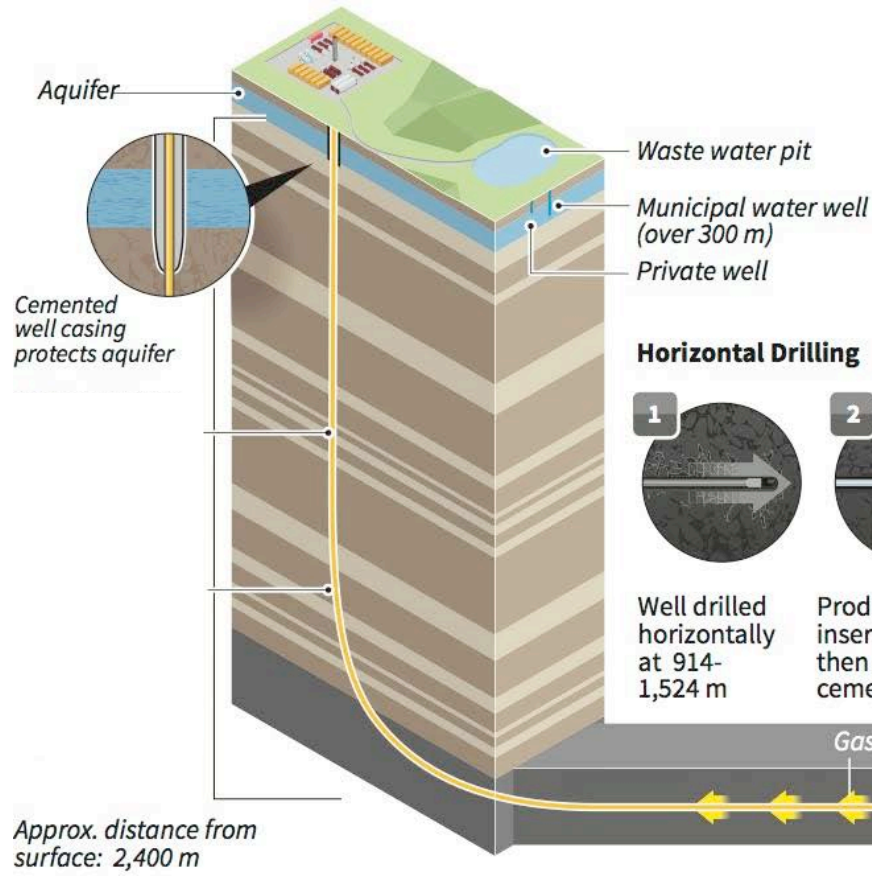
Sources: National Geographic, Chesapeake Energy, EIA., USGS

Horizontal drilling and fracking

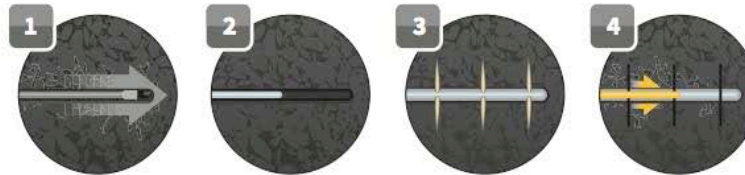


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Horizontal drilling and fracking



Horizontal Drilling



1 Well drilled horizontally at 914-1,524 m

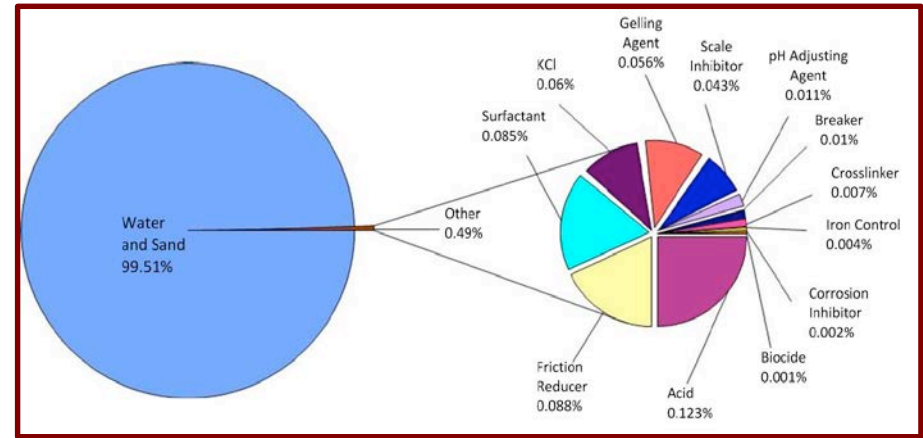
2 Production casing inserted into borehole, then surrounded with cement

3 Charges then detonated inside a perforating gun, blasting small holes into the shale

4 Pressurised mixture of water, sand and chemicals then pumped into the well at 15,900 litres a minute

Illustration not to scale

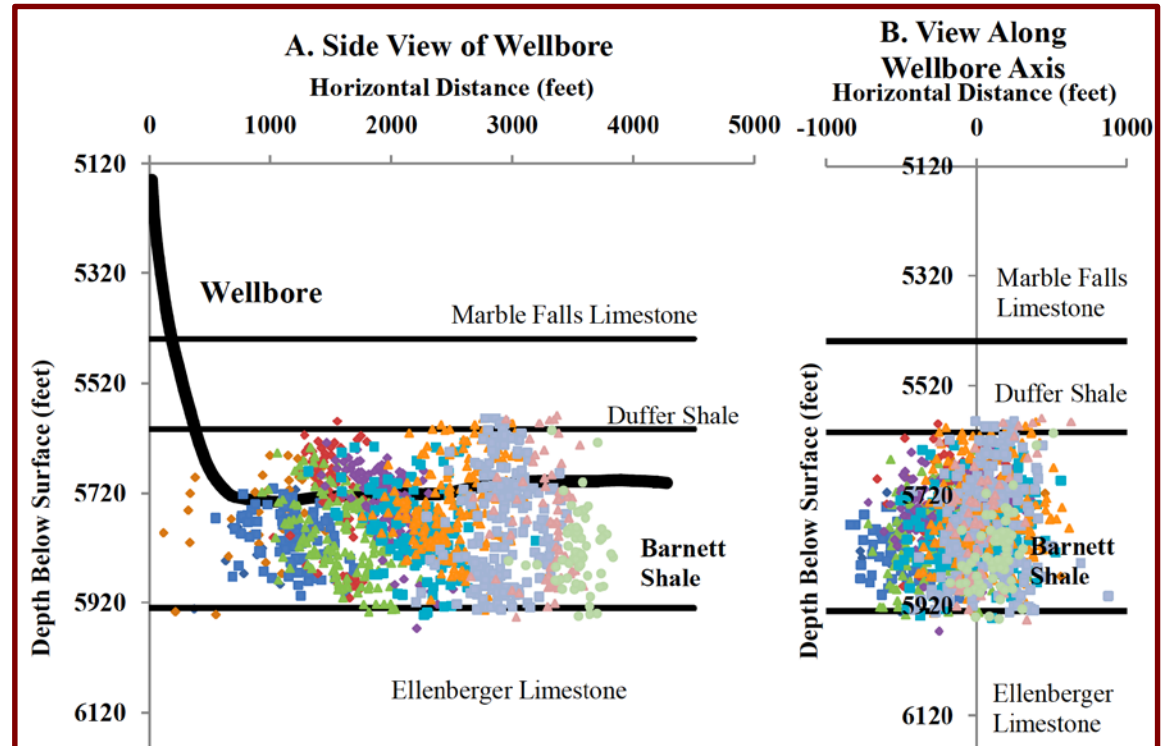
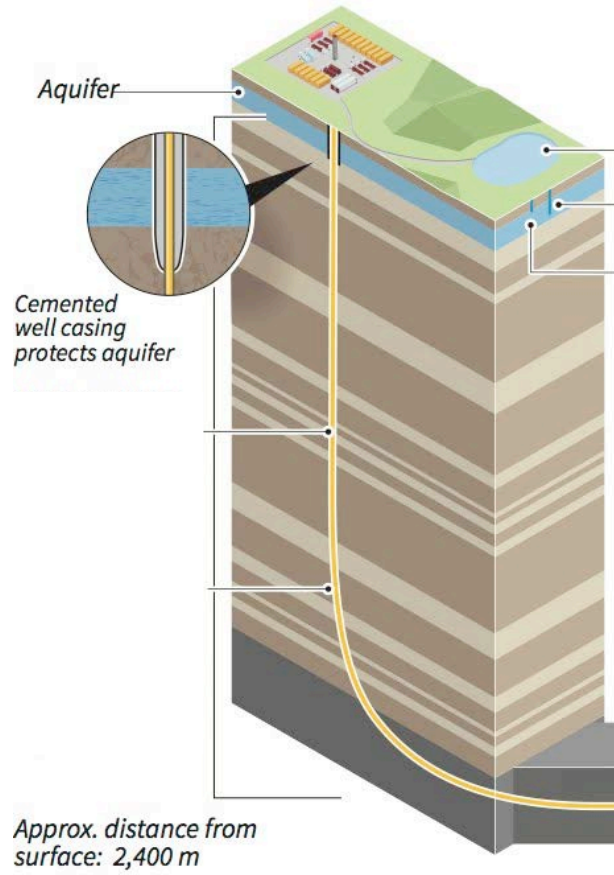
Slickwater



Sources: National Geographic, Chesapeake Energy, EIA., USGS

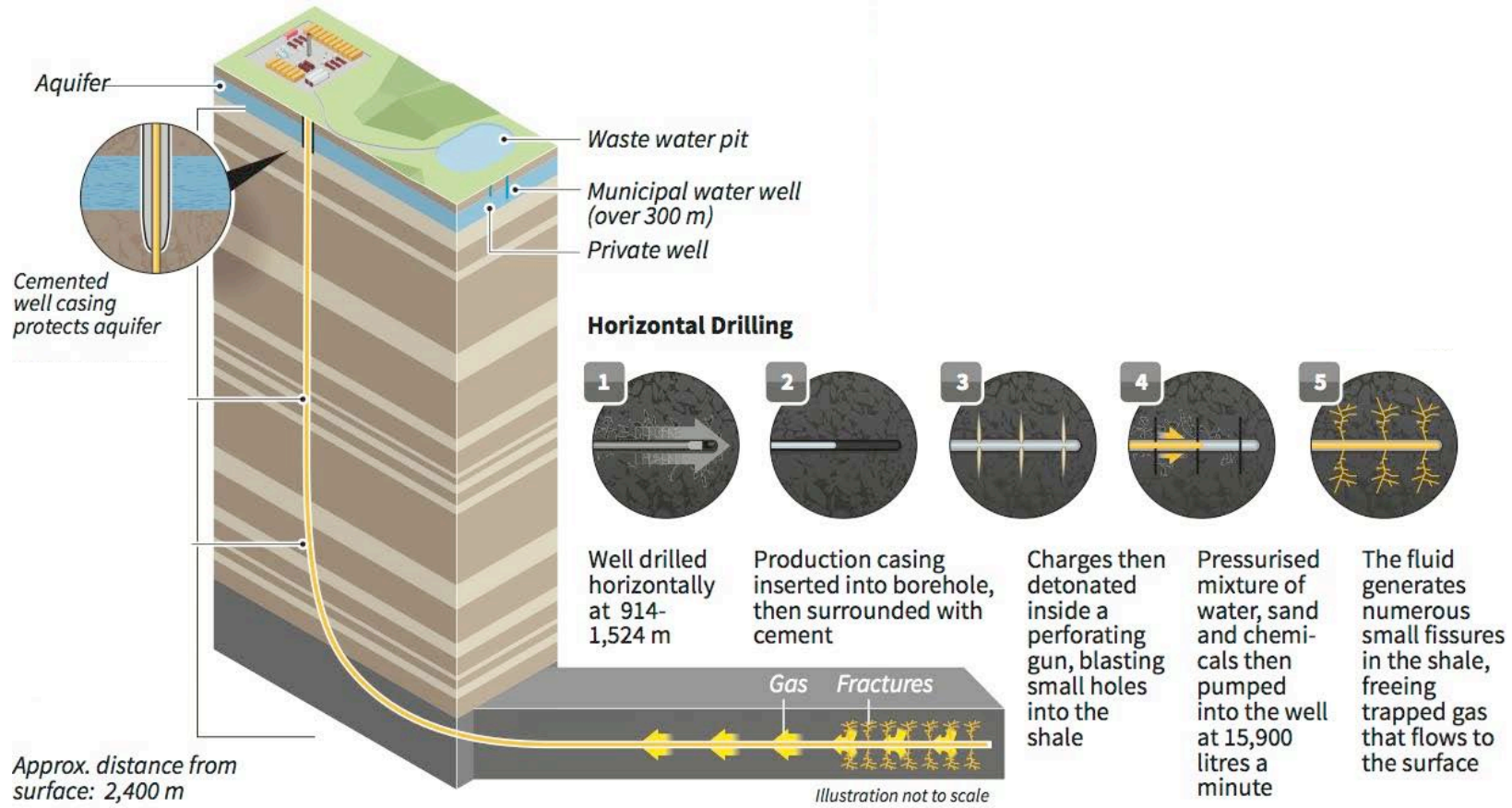
Horizontal drilling and fracking

Microseismic monitoring



Sources: National Geographic, Chesapeake Energy, EIA., USGS , Stanford Department of Geophysics

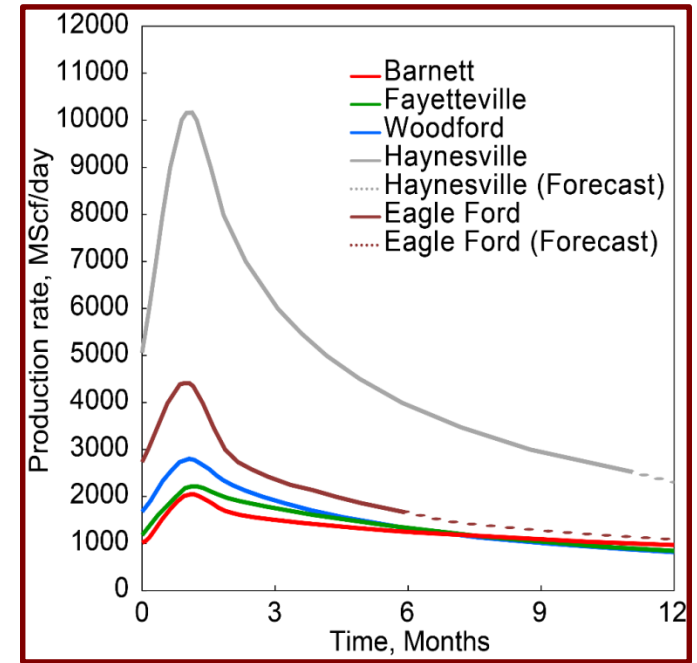
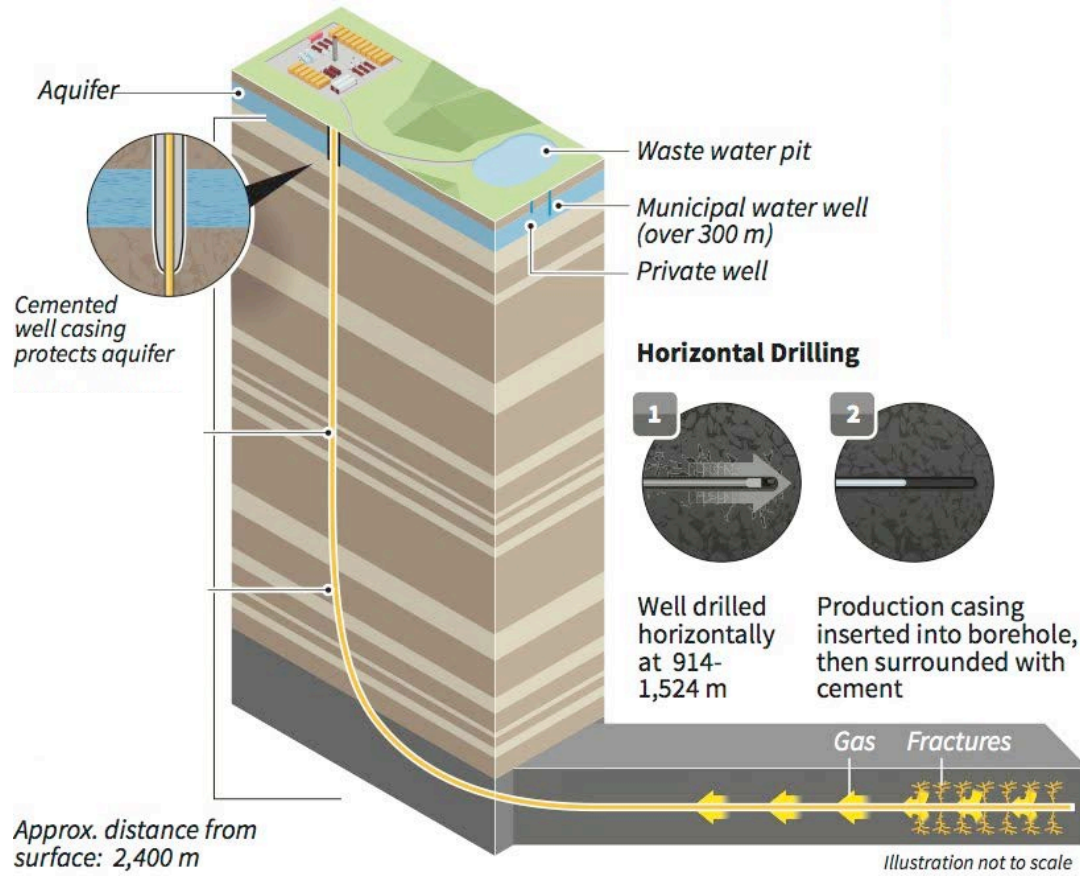
Horizontal drilling and fracking



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Horizontal drilling and fracking

Same technology is used for producing *tight oil*



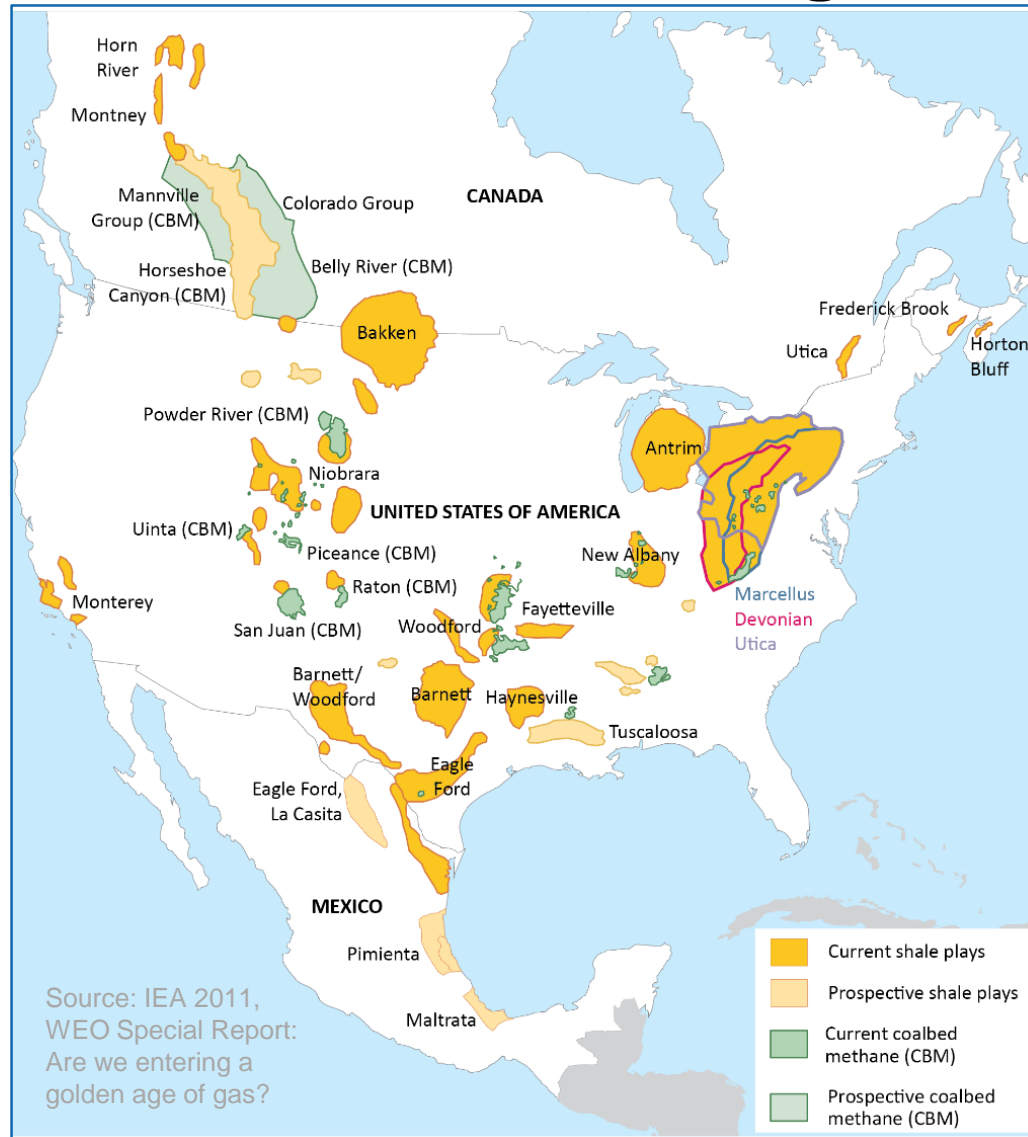
Average absolute gas production rate per day per well

Sources: National Geographic, Chesapeake Energy, EIA., USGS

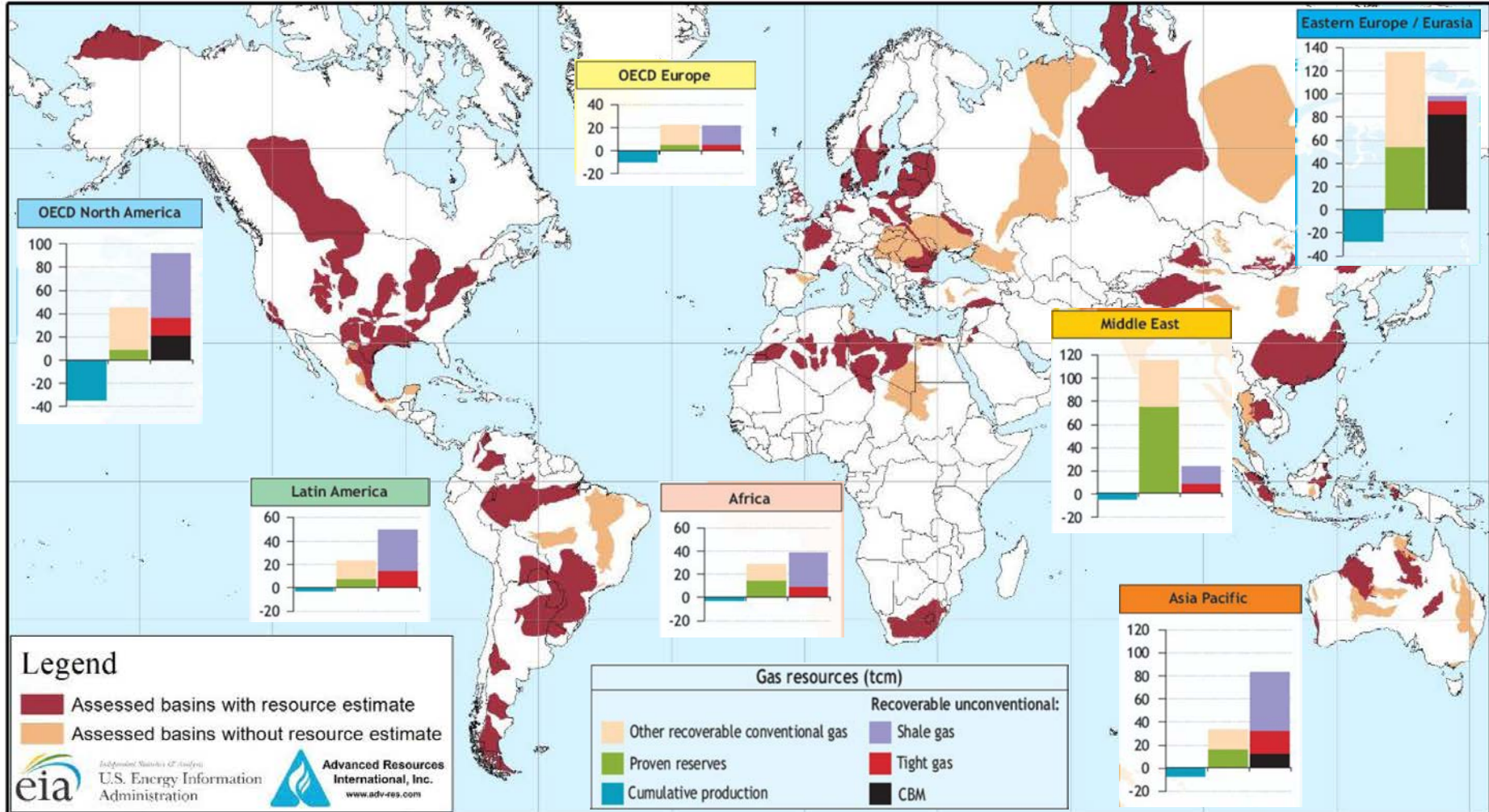
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North-American unconventional gas resources

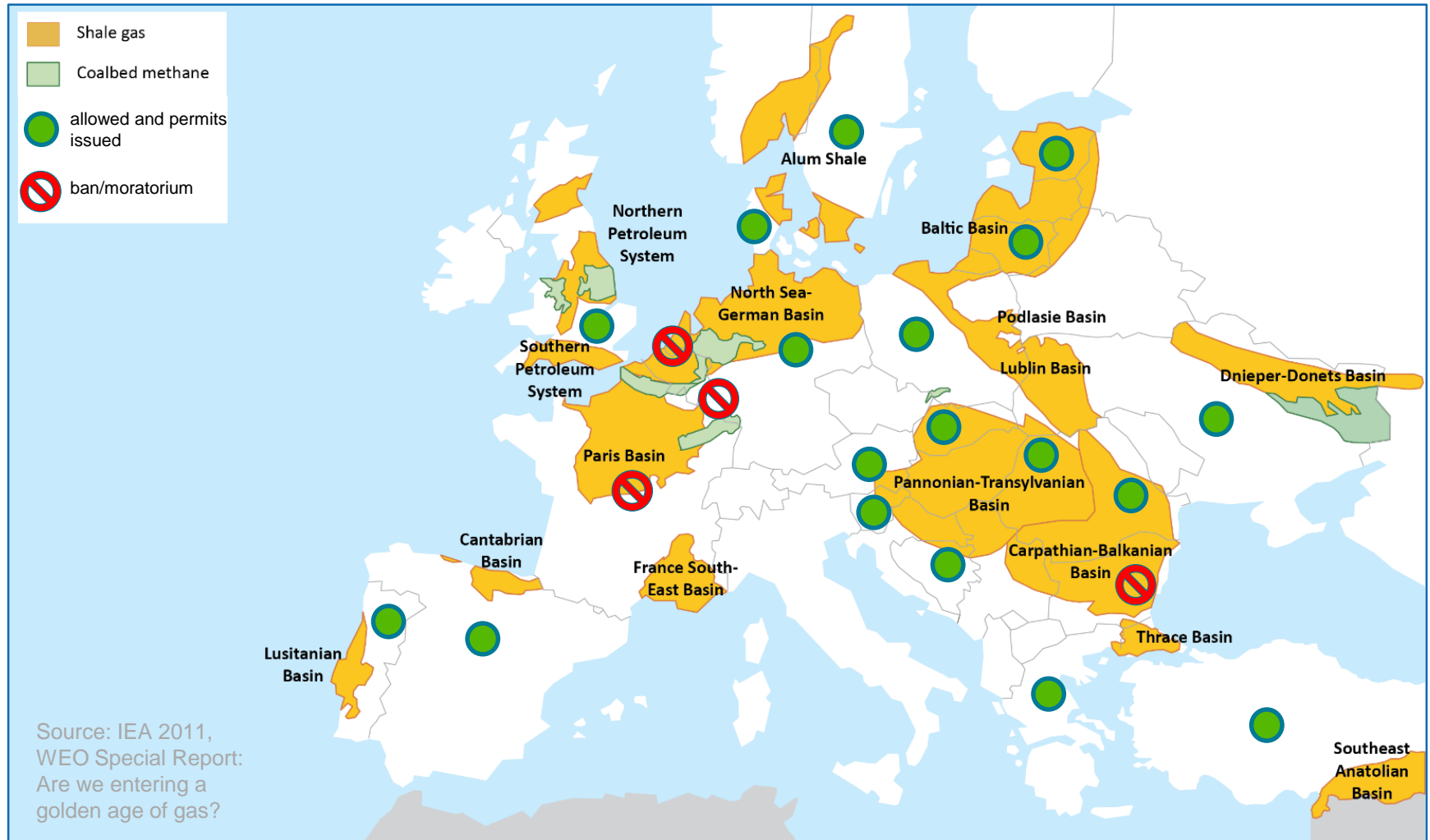


Basins with assessed shale oil/gas formations

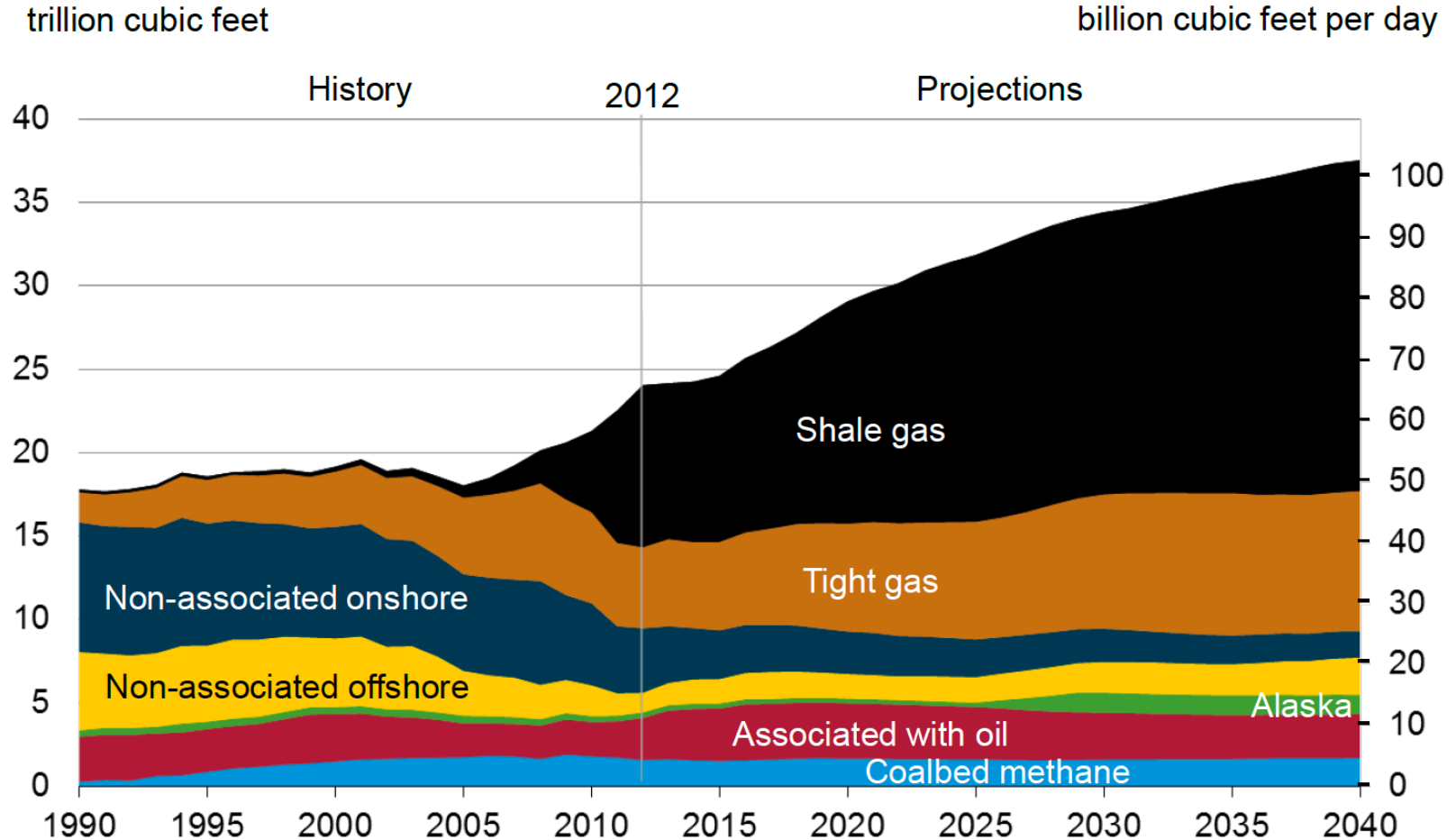


Source: IEA 2011, WEO Special Report: Are we entering a golden age of gas?

European unconventional gas resources

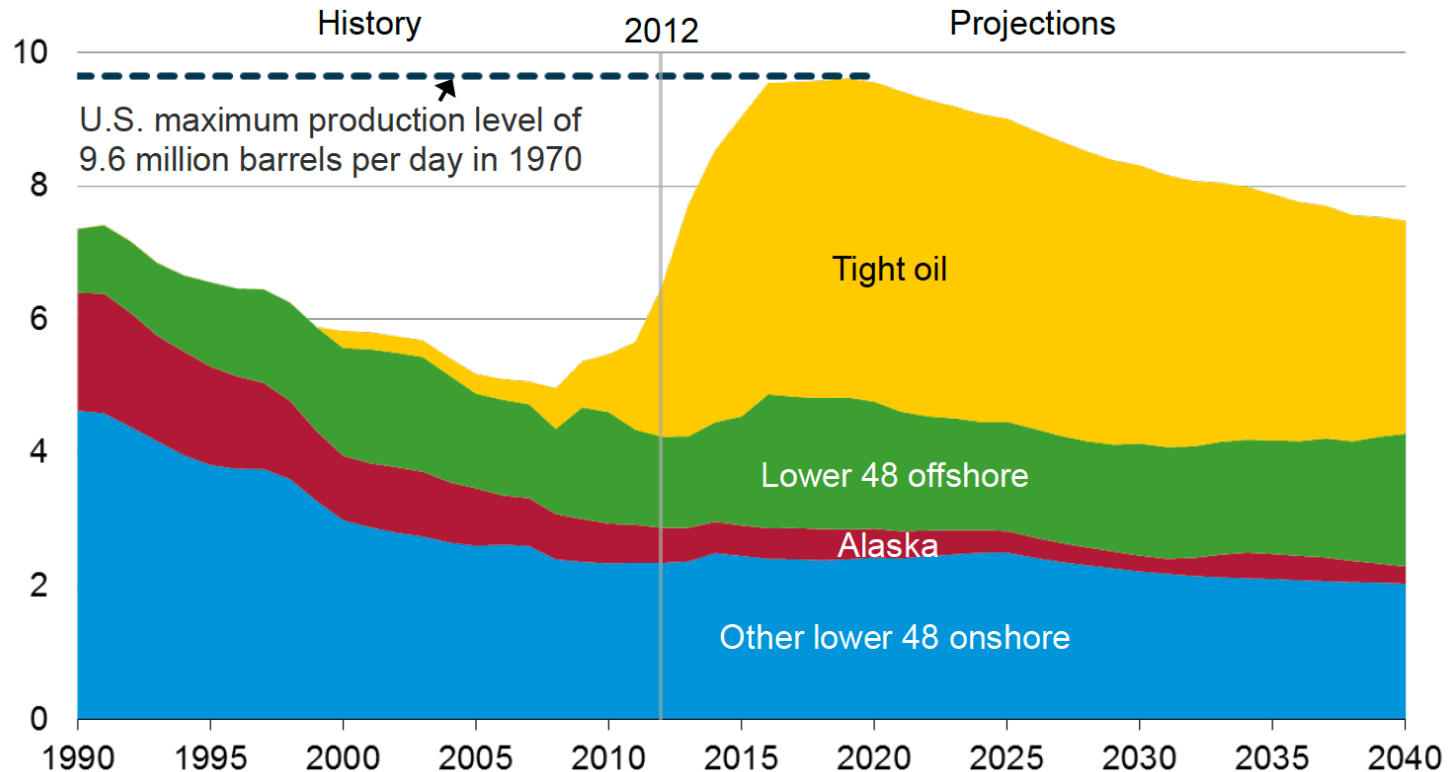


US natural gas production (EIA 2013)



Source: EIA, Annual Energy Outlook 2014 Early Release

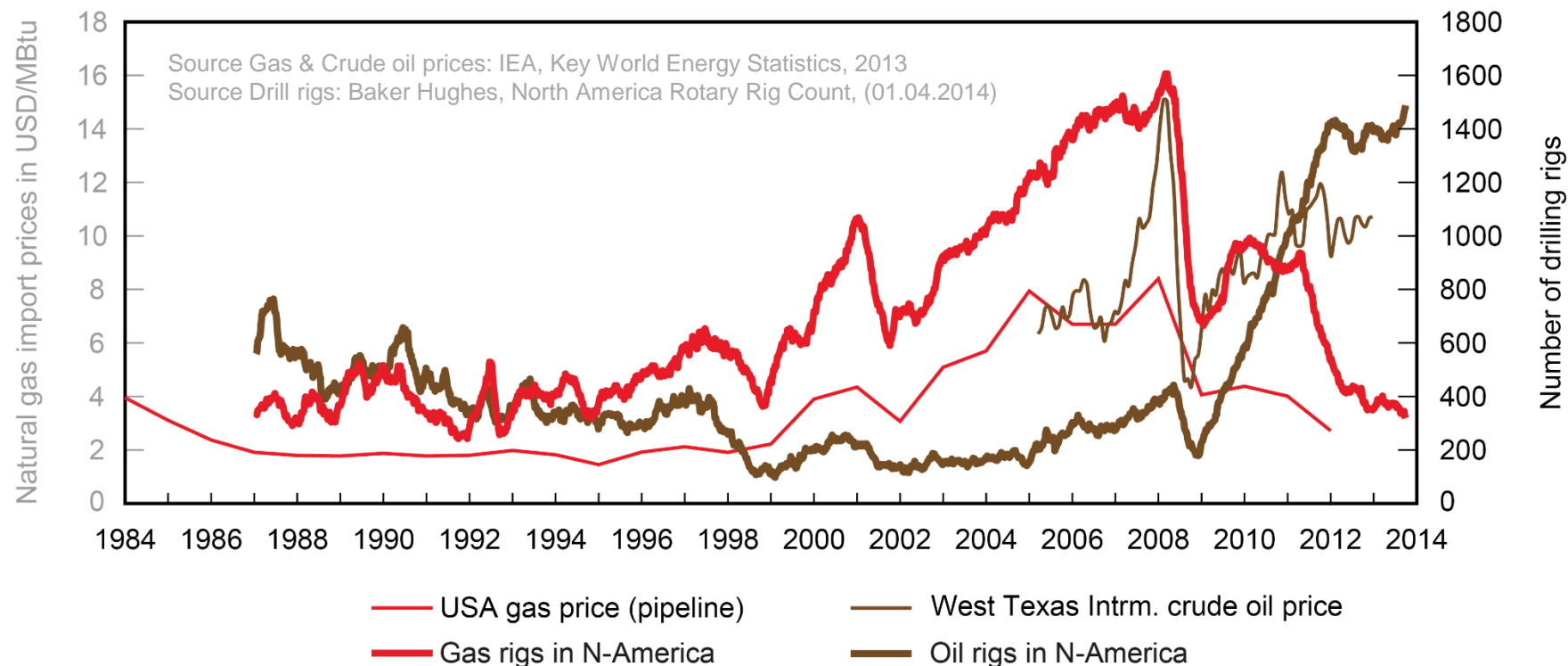
US crude oil production (EIA 2013)



Source: EIA, Annual Energy Outlook 2014 Early Release

“US expected to become largest producer of oil and gas” (EIA, 4.10.2013). Thus overtaking both Saudi Arabia (oil) and Russia (gas).

Development of fossil fuel prices (IEA, 2013)



- NG prices are aligned globally until 2006 when US shale gas starts.
- Oil and NG prices track each other until 2009 when NG boom led to oversupply.
- Prices crashed for both during the recession as demand fell globally.
- Oil prices recovered after 2009, while NG supply exceeds national demand.
- High NG prices and new tech trigger a gas drilling boom in the early 2000s.
- After 2009 high oil prices and low NG prices cause major shift in rig activity.

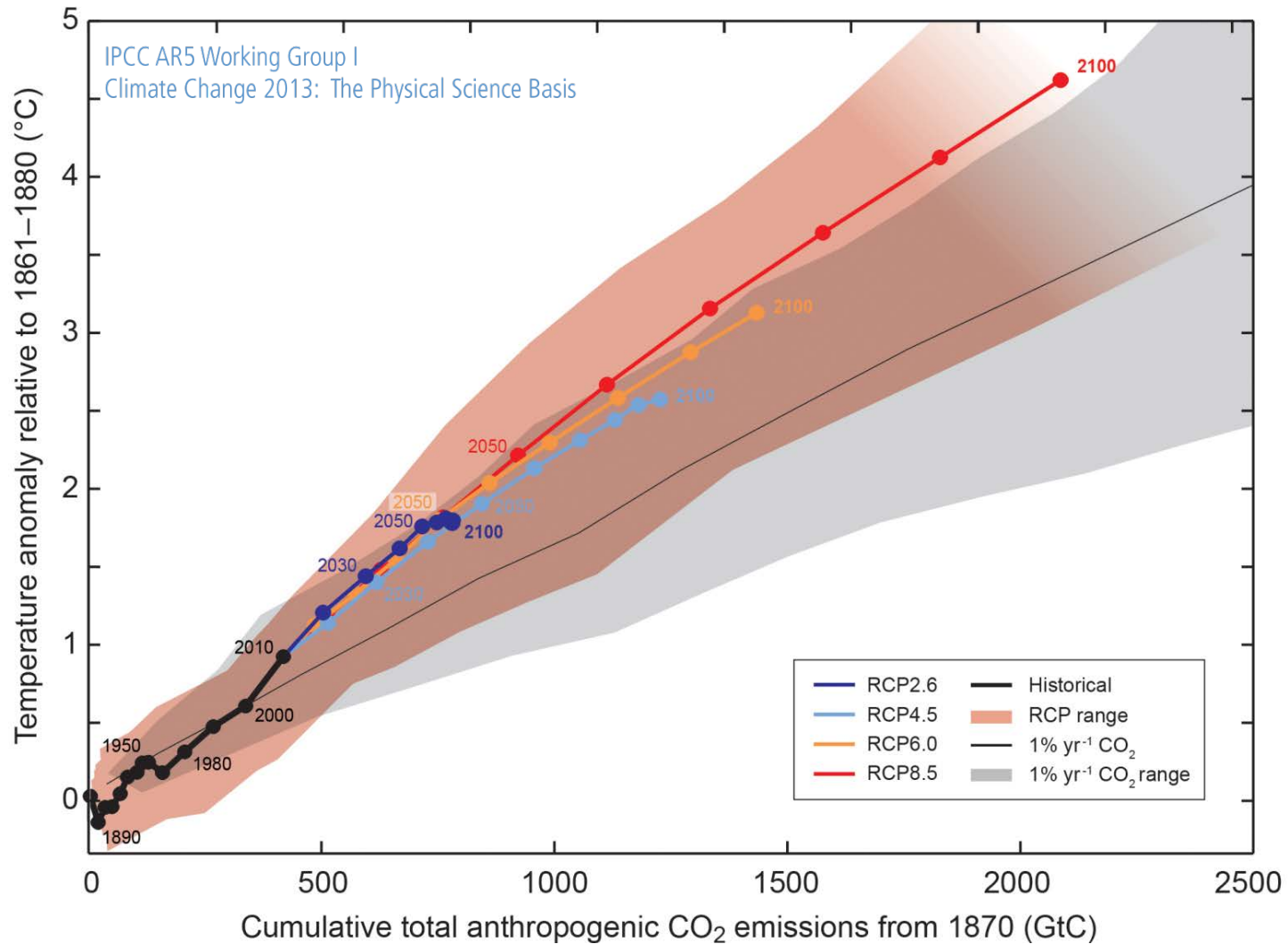
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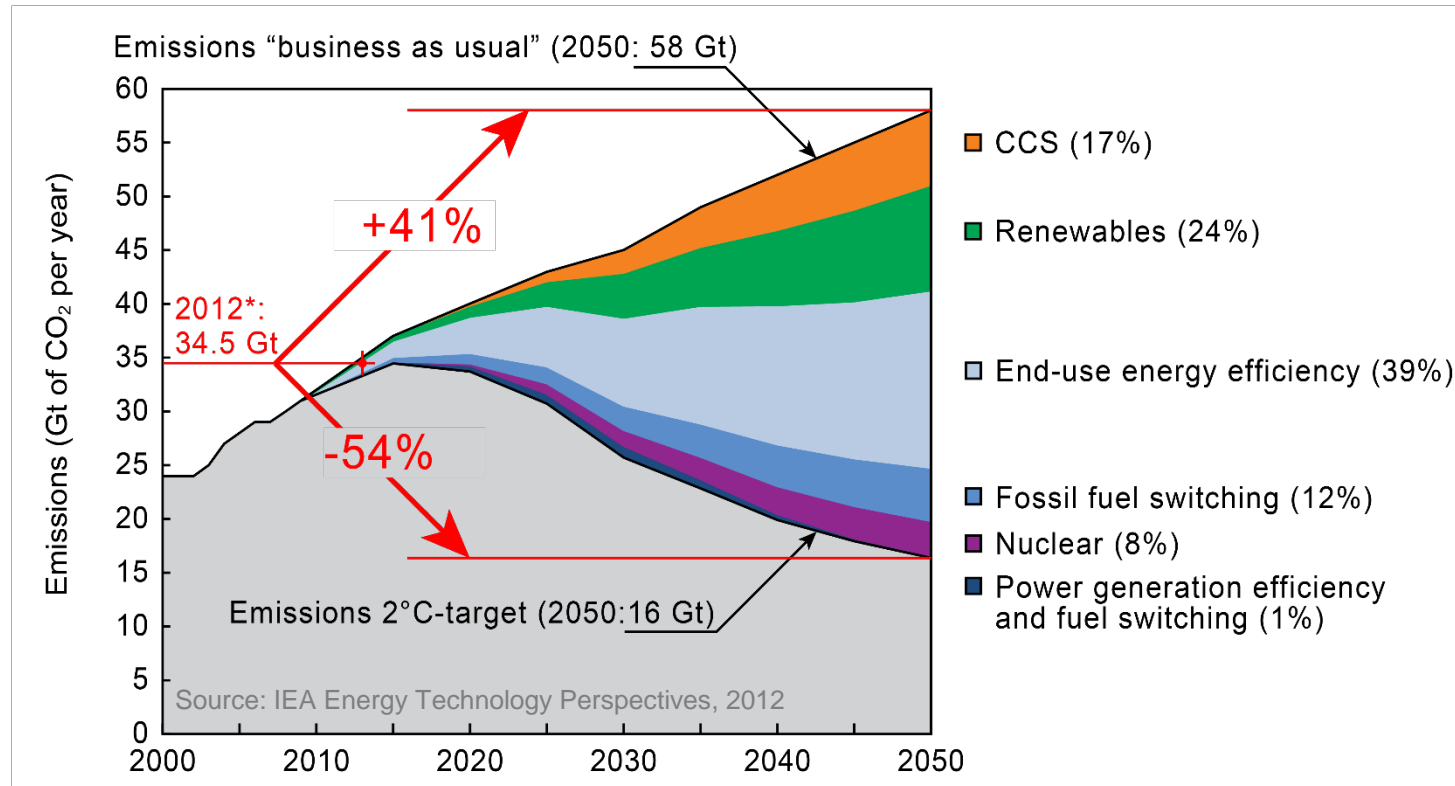
Too much of a good thing?

- Water management
- Land use
- Emissions
- Life cycle assessment
- Induced seismicity
- Economics of shale gas
- Energy independence
- Public perception
- Potential for Switzerland (and Europe)

Global warming and CO₂ emissions (IPCC, 2013)



CO₂ emission reduction by technology

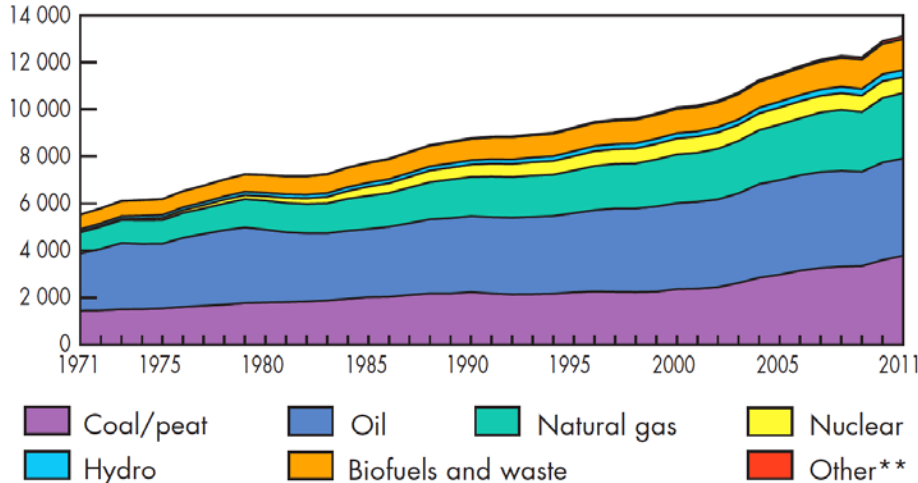


*) PBL, Trends in Global CO₂ emissions: 2013 Report, EUR 26098 EN

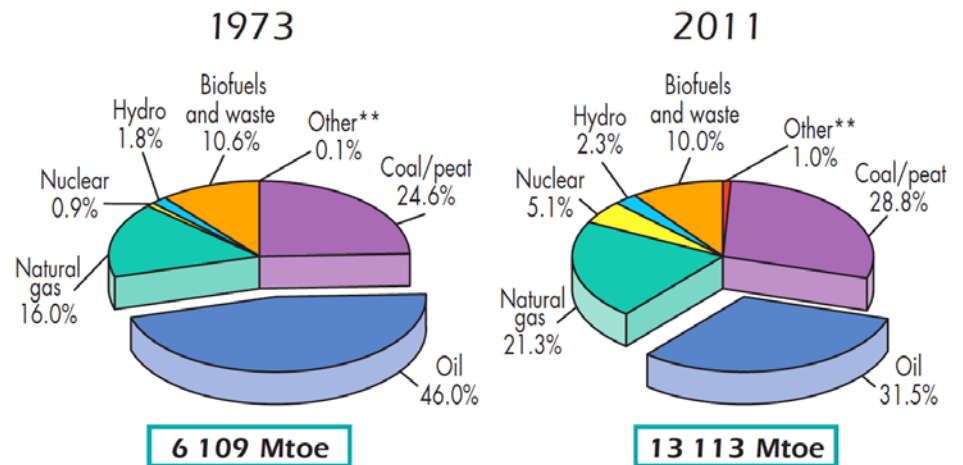
- There is no *silver bullet*
- All measures are needed, including CO₂ capture and storage (CCS) and fossil fuel switching

Total primary energy supply by fuel (IEA, 2013)

World* total primary energy supply from 1971 to 2011 by fuel (Mtoe)

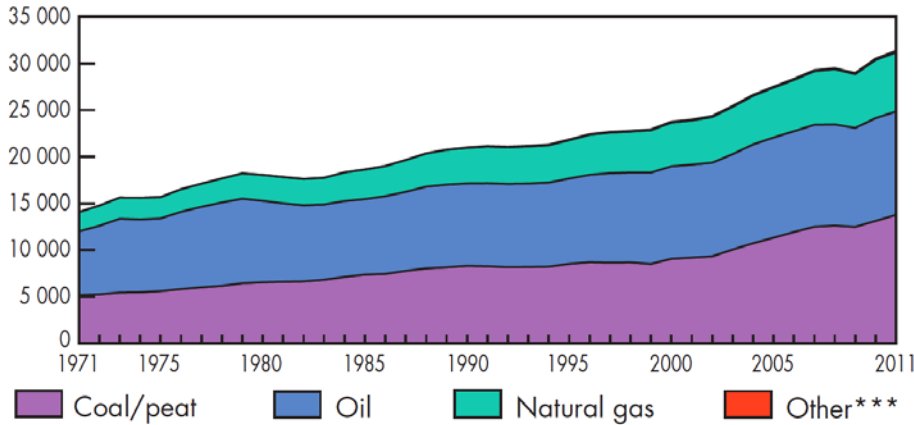


1973 and 2011 fuel shares of TPES

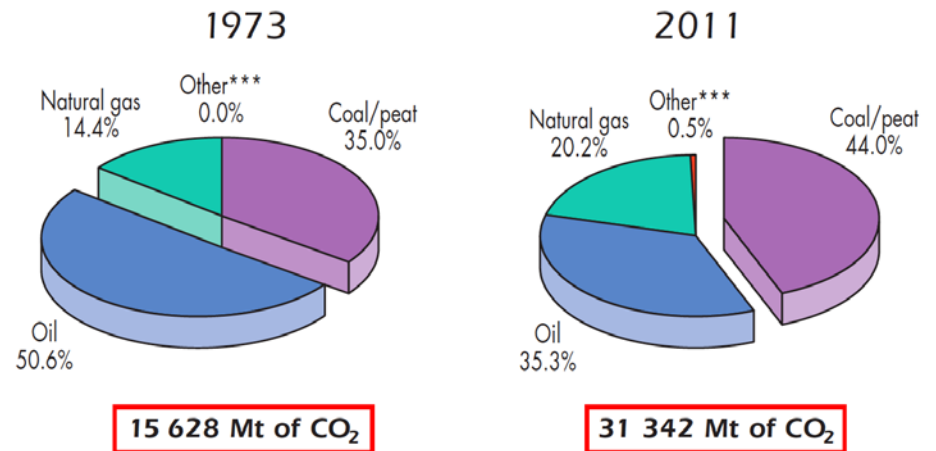


CO₂ emissions by fuel (IEA, 2013)

World* CO₂ emissions** from 1971 to 2011
by fuel (Mt of CO₂)

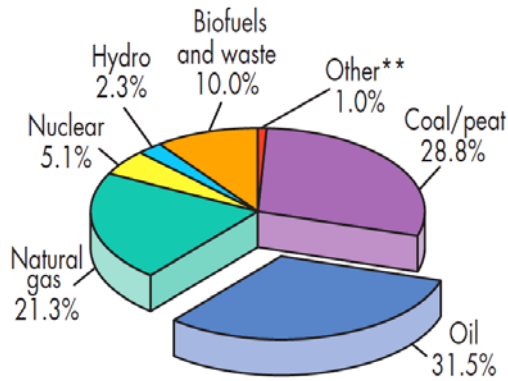


1973 and 2011 fuel shares of CO₂ emissions**



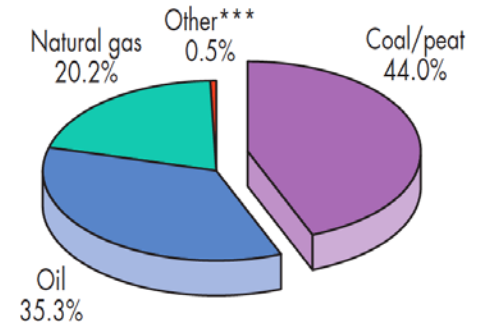
Potential of fossil fuel switching

- 2011 fuel shares of TPES



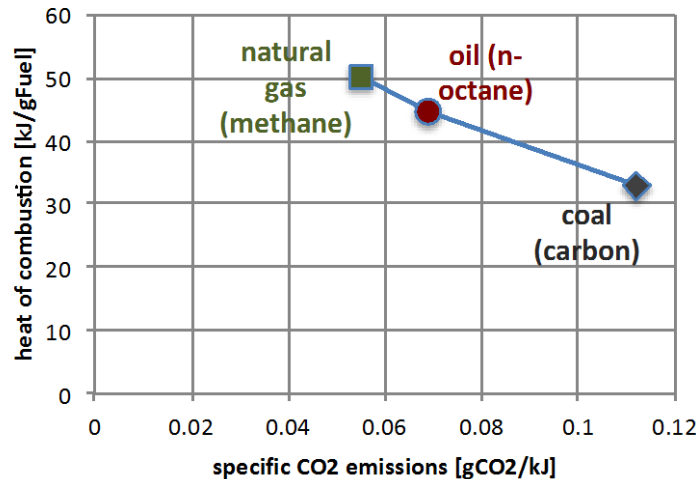
13 113 Mtoe

- 2011 fuel shares of CO₂ emissions



31 342 Mt of CO₂

Properties of fossil fuels



Too much of a good thing?

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- Land use
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- **Transparent and stringent rules of the game!**