Reserves & Production
Fossil Fuels

Agenda

- World & US primary fossil fuel (FF) reserves, (coal, oil & gas) production & consumption
  Cost of electricity

- U.S. geological FF mining areas
  U.S. Oil & gas security (abundance)
  Oil refinery products (fractional distillation) (feedstock, new fuels)
  Liquid natural gas production, terminals

- Fuel mining/production technologies
  Modern coal mining techniques
  Hydraulic fracturing (fracking) technique
  Steam Assisted Gravity Drainage (oil sands)

- Clathrates

Reading weeks Nov 17-20: Lecture Notes 4.1, 4.2
Andrews & Jelley: Chapters 3.6-3.12

Fossil Fuels: Proven World Reserves & Production

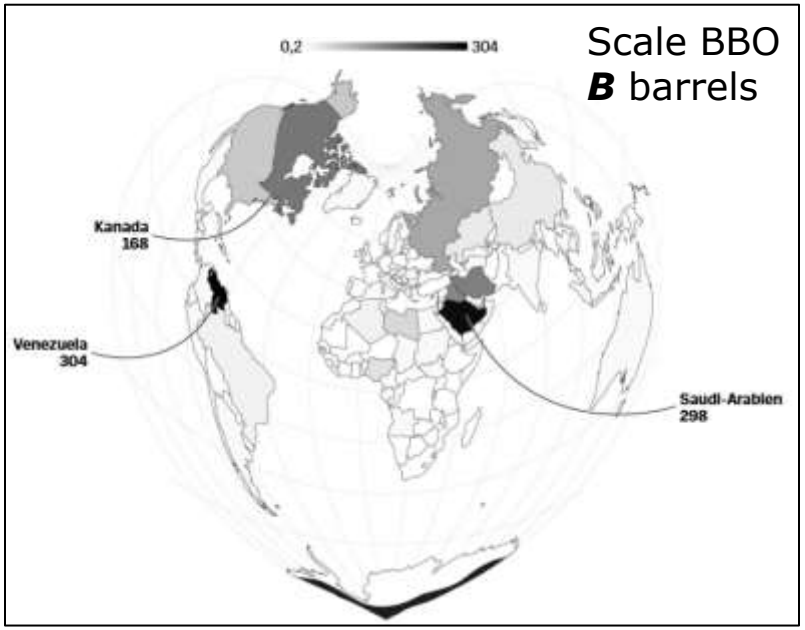
Region/Country	Anthracite Bituminous	Lignite Subbituminous	Total
United States	123,834	143,478	267,312
North America	128,608	147,491	276,100
Central & South America	8,489	13,439	21,928
Western Europe	1,571	34,918	36,489
Europe	19,558	46,203	65,762
Eurasia	104,183	146,322	250,505
Middle East	462	0	462
Africa	55,294	192	55,486
Asia & Oceania	212,265	114,999	327,264
World Total	528,860	468,646	997,506

Coal Reserves

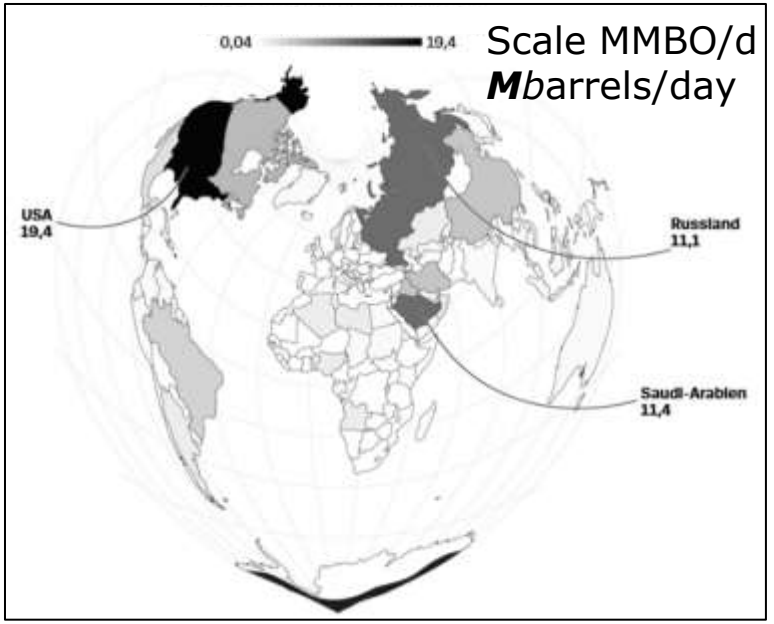
1 short ton = 0.907mt

Very different coal quality (heating value, contaminants, e.g., S,…As,…U.)
Anthracene-to-bitumen

Oil Reserves



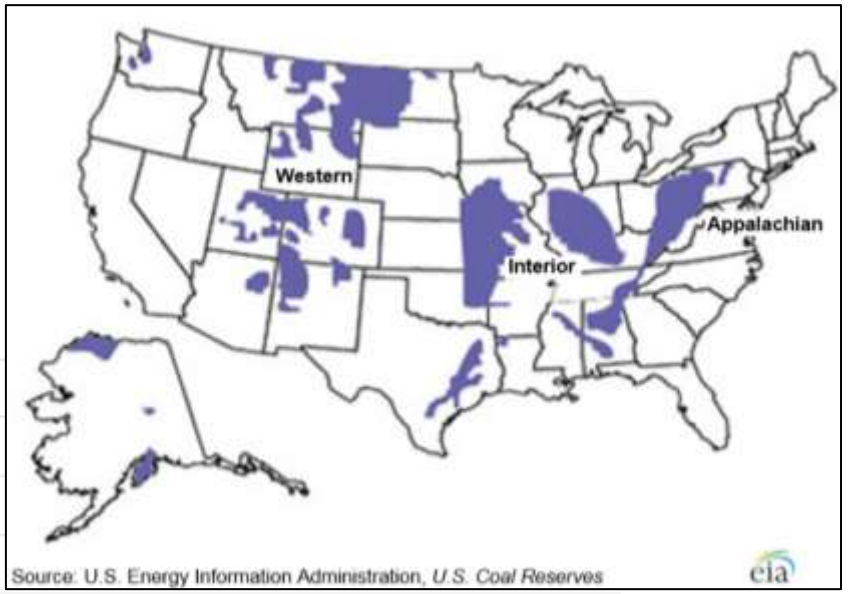
Oil Production



U.S. Coal Reserves 2023

2021:US daily consumption: 1.6 MMst

1 short ton = 0.907mt

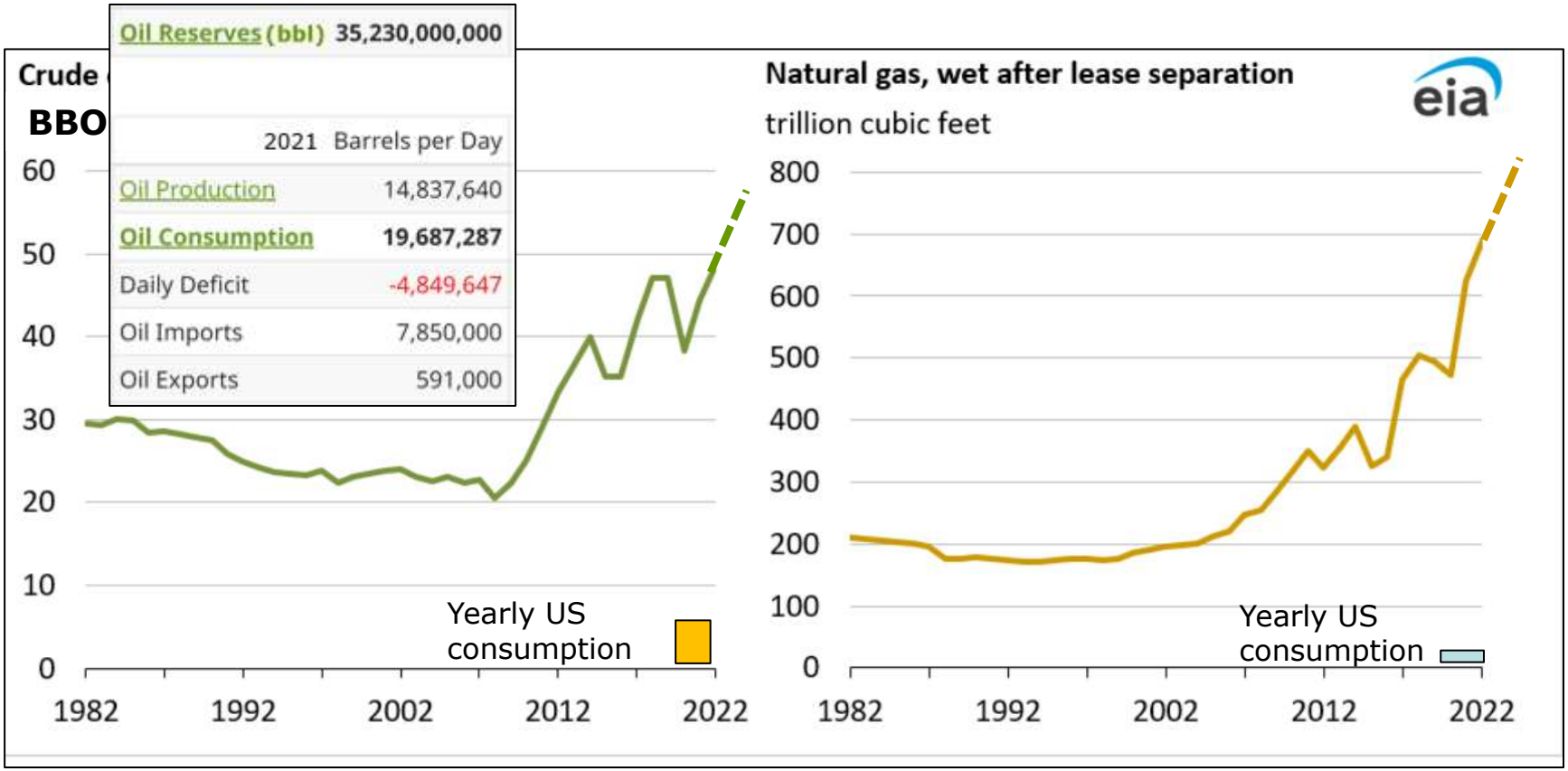


- Montana—25%
- Illinois—22%
- Wyoming—12%
- West Virginia—6%
- Kentucky—6%
- Pennsylvania—5%

Reserves @ now (2022) producing U.S. mines

2022 U.S. coal production = 0.594 billion short tons → recoverable coal reserves would last about 422 years, and recoverable reserves at producing mines would last about 20 years.

U.S. Proven Oil & Gas Reserves (2023)

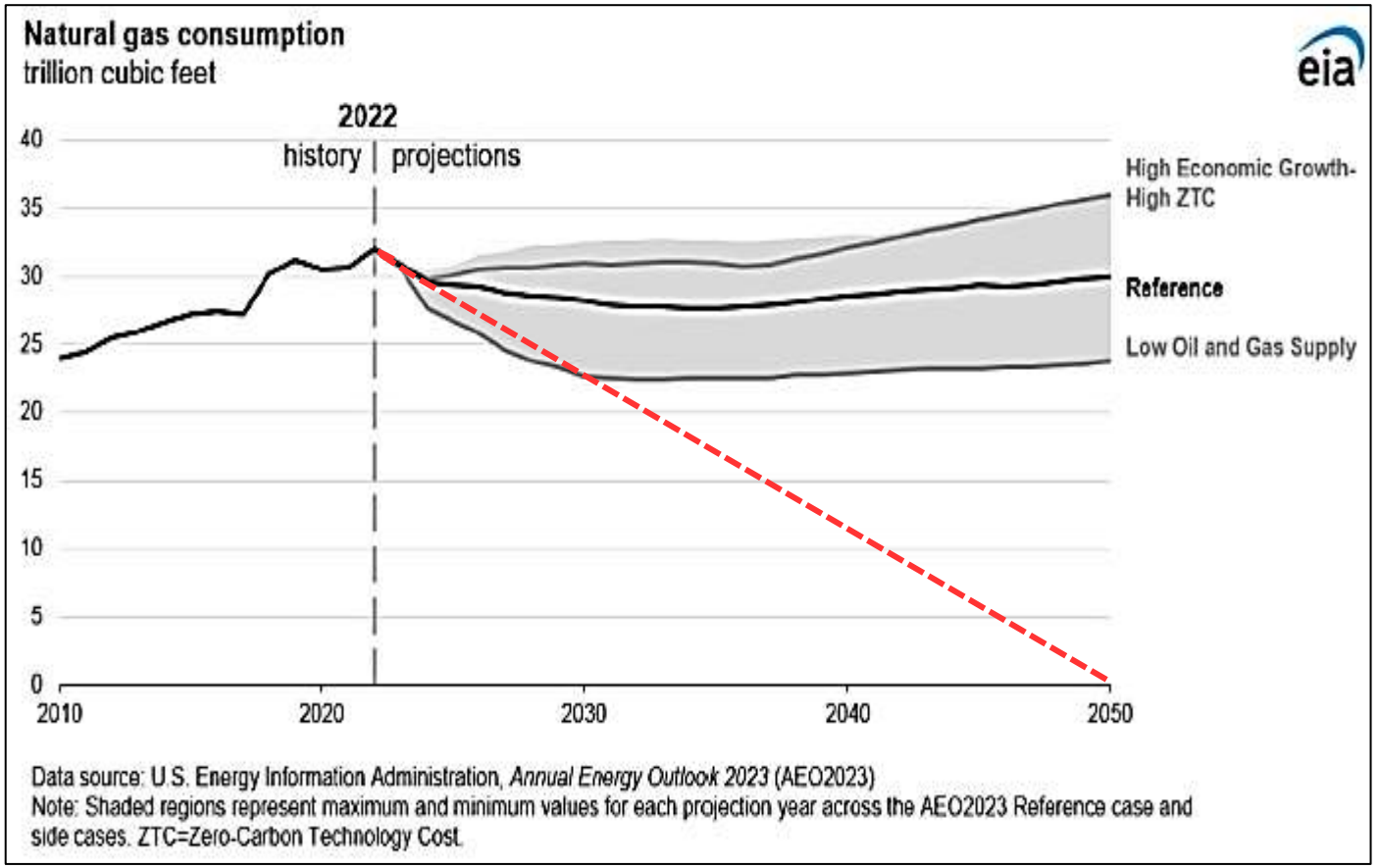


Reserves increased since 2006 (shale plays) and are expected to increase further:

- New discoveries
- Thorough appraisals of existing fields
- Existing reserves production
- New and improved techniques and technologies

Reserves will last for >10a Crude
>100a nat Gas

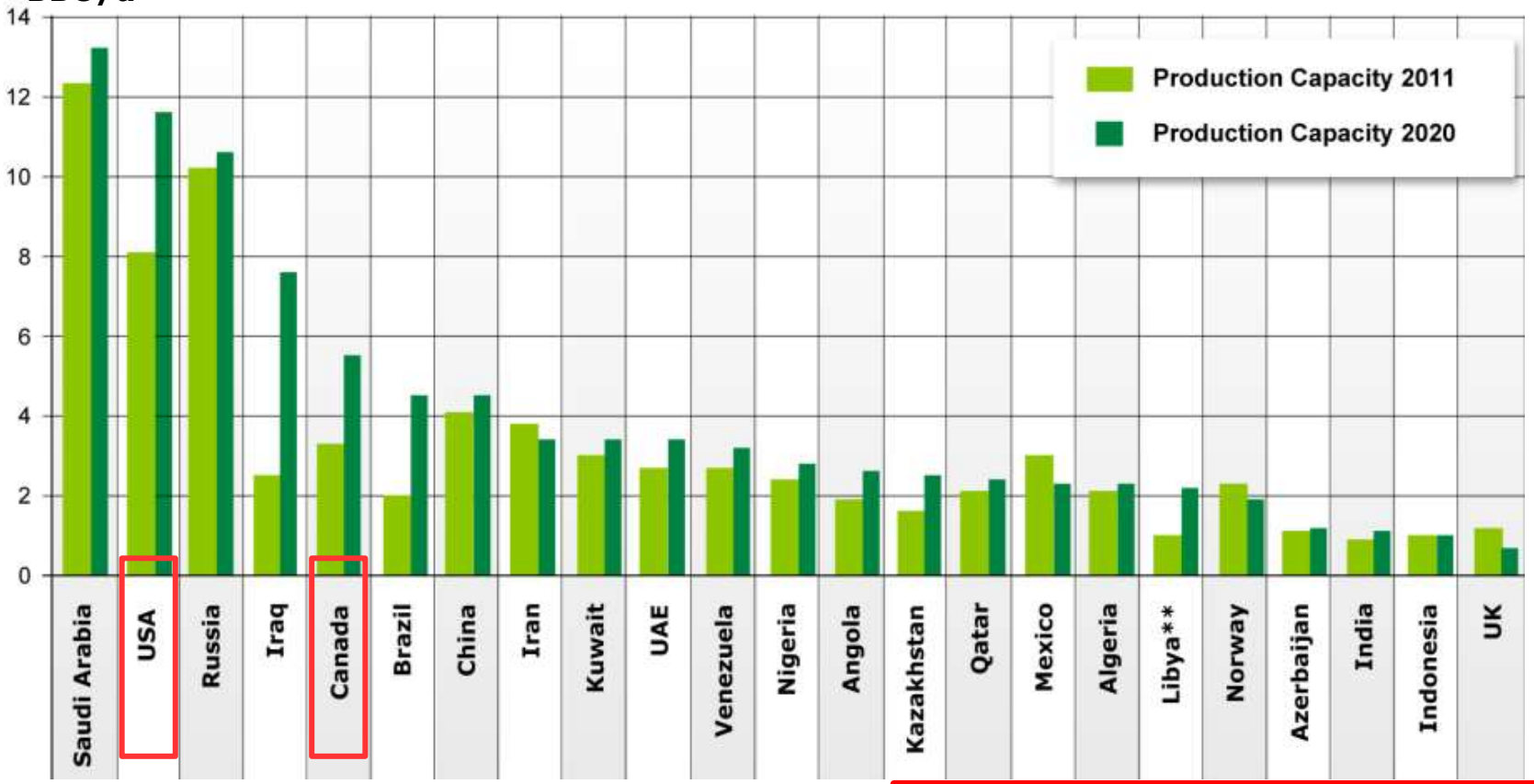
U.S. Gas Consumption 2022 & Outlook



Outlook in conflict with Paris Agreement and stated policies (U.S., EU,…) of net zero emissions by 2050.

Crude Oil & Gas Abundance

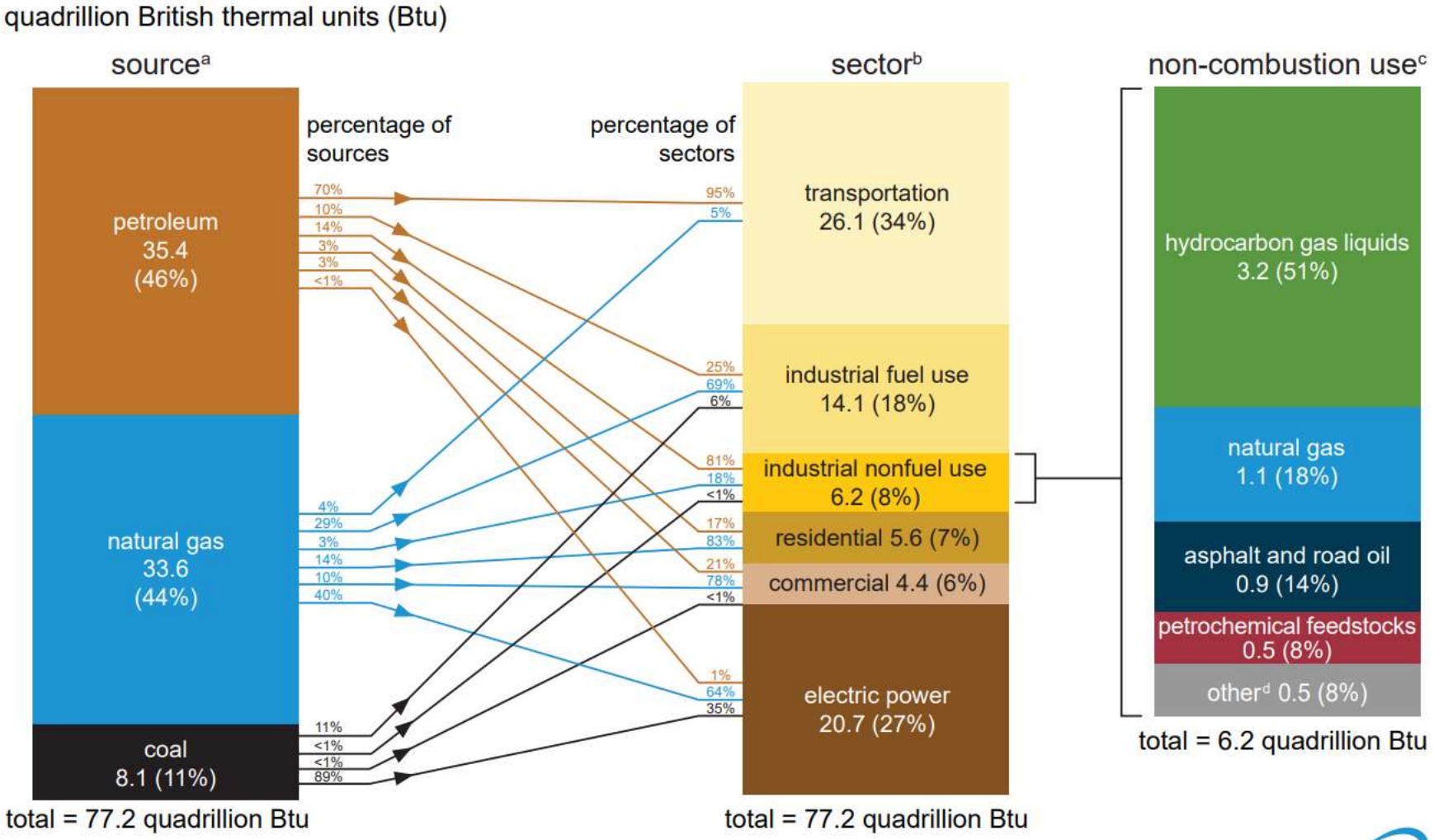
Independent analysis: world oil reserves exceed demand, can accommodate demand increase Δ ≤1.6%/a to forecast horizon (>2020). Profitable for > $(50-65)/bbl.



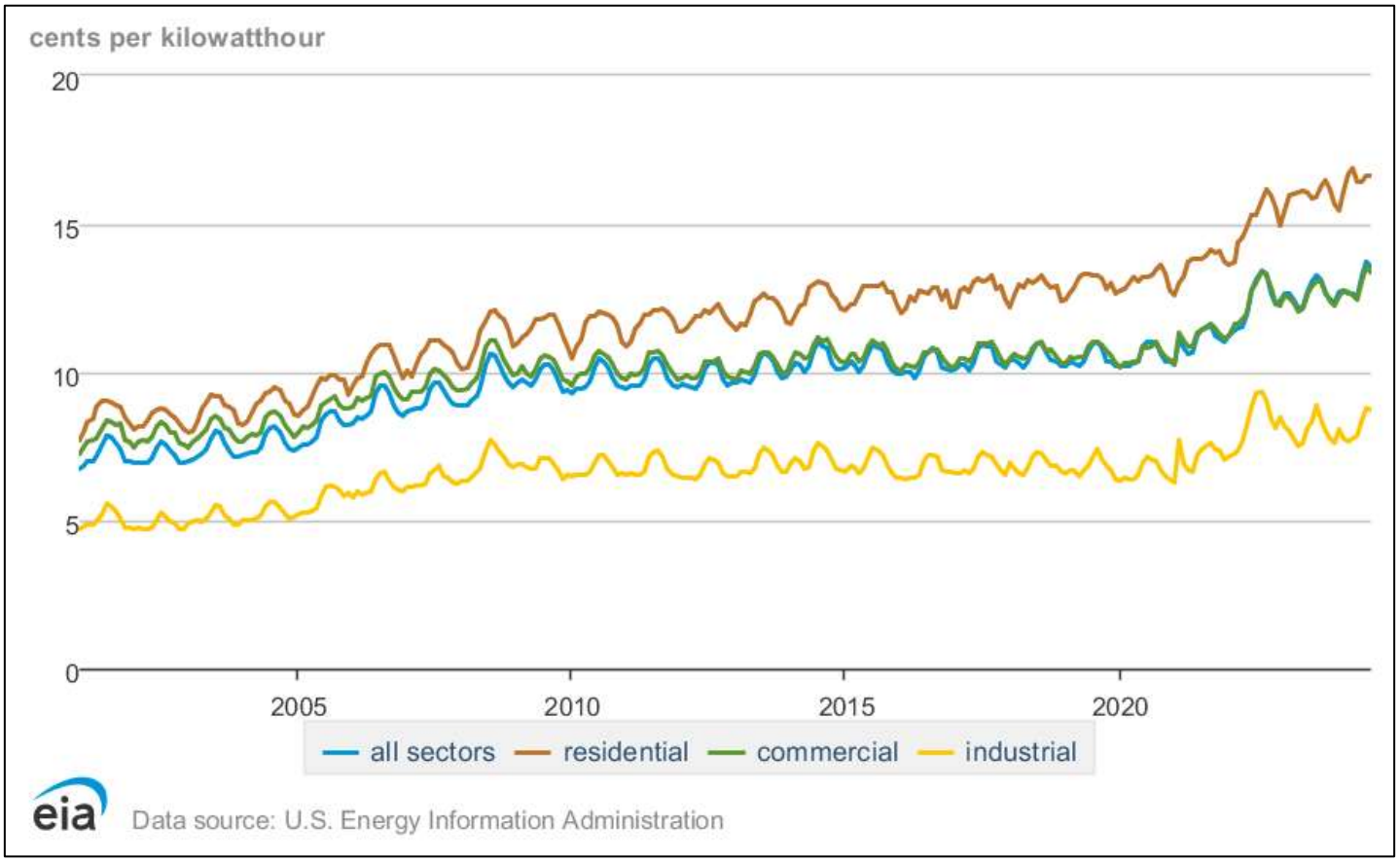
U.S. 2011 **oil consumption**:6.87 Billion barrels/a =18.83 M bbl/day→19.4 Mbbl/day (2023)
Possible hurdles: insufficient transportation infrastructure (pipelines, RR, roads,…), public attitudes. U.S. with Canada almost oil self sufficient, → export oil/gas.

Leonardo Maugeri, Harvard Kennedy School,
http://belfercenter.ksg.harvard.edu/files/Presentation%20on%20Oil-%20The%20Next%20Revolution.pdf

2023 U.S. Fossil Fuel Consumption



U.S. Average Price of Electricity



Electricity generated FF=60%, Nucl=20%, Hydro= 15%, PV Sol+Wind=8%

Cost of Electricity by Generation

Representative Cost for Power Generation Technologies in 2015					
All Costs in Constant Dec. 2010$	*Nominal Plant Capacity, MW*	*Capacity Factor*	*Total Plant Cost $/kW*	*Total Capital Required $/kW*	*Levelized Electricity Cost $/MWh*
Coal: PC	750	80%	2,000 - 2,300	2,400 - 2,760	54 - 60
Coal: IGCC	600	80%	2,600 - 2,850	3,150 - 3,450	68 - 73
Natural Gas: NGCC	550	80%	1,060 - 1,150	1,275 - 1,375	49 - 79
Nuclear	1,400	90%	3,900 - 4,400	5,250 - 5,900	76 - 87
Biomass, Bubbling Fluid-ized Bed	100	85%	3,500 - 4,400	4,000 - 5,000	84 - 147
Wind: Onshore	100	28 - 40%	2,025 - 2,700	2,120 - 2,825	75 - 138
Wind: Offshore	200	40%	3,100 - 4,000	3,250 - 4,200	130 - 159
Solar: Concentrating Solar Thermal (CST)	100 - 250	25 - 49%	3,300 - 5,300	4,050 - 6,500	151 - 195
Solar: Photovoltaic (PV)	10	15 - 28%	3,400 - 4,600	3,725 - 5,050	242 - 455

Source: Electric Power Research Institute Program on Technology Innovation: Integrated Generation Technology Options, June 2011.

LCOE: Capital investment at the start, ongoing Fuel cost, Non-fuel O&M, Waste & decommissioning costs,..

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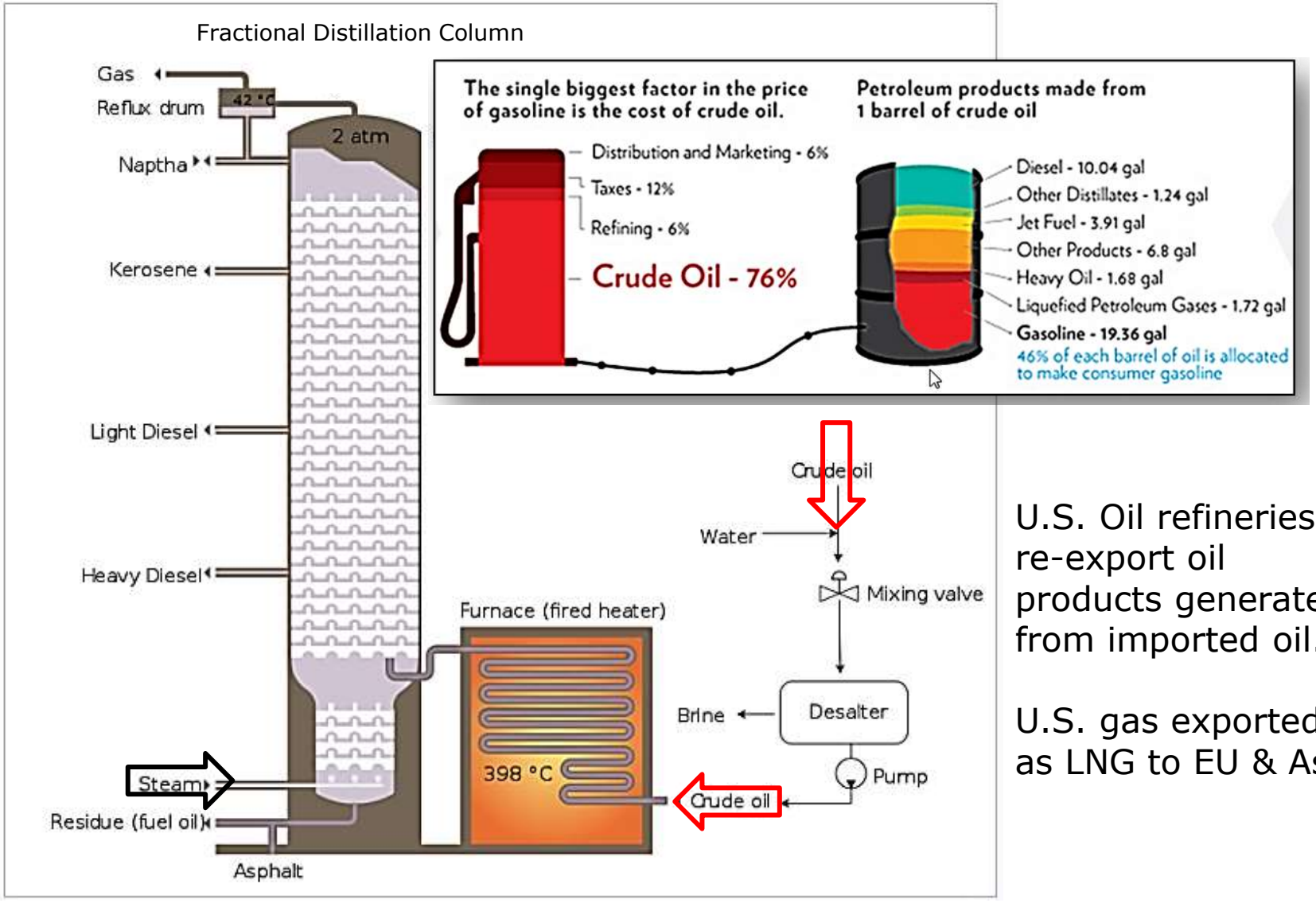
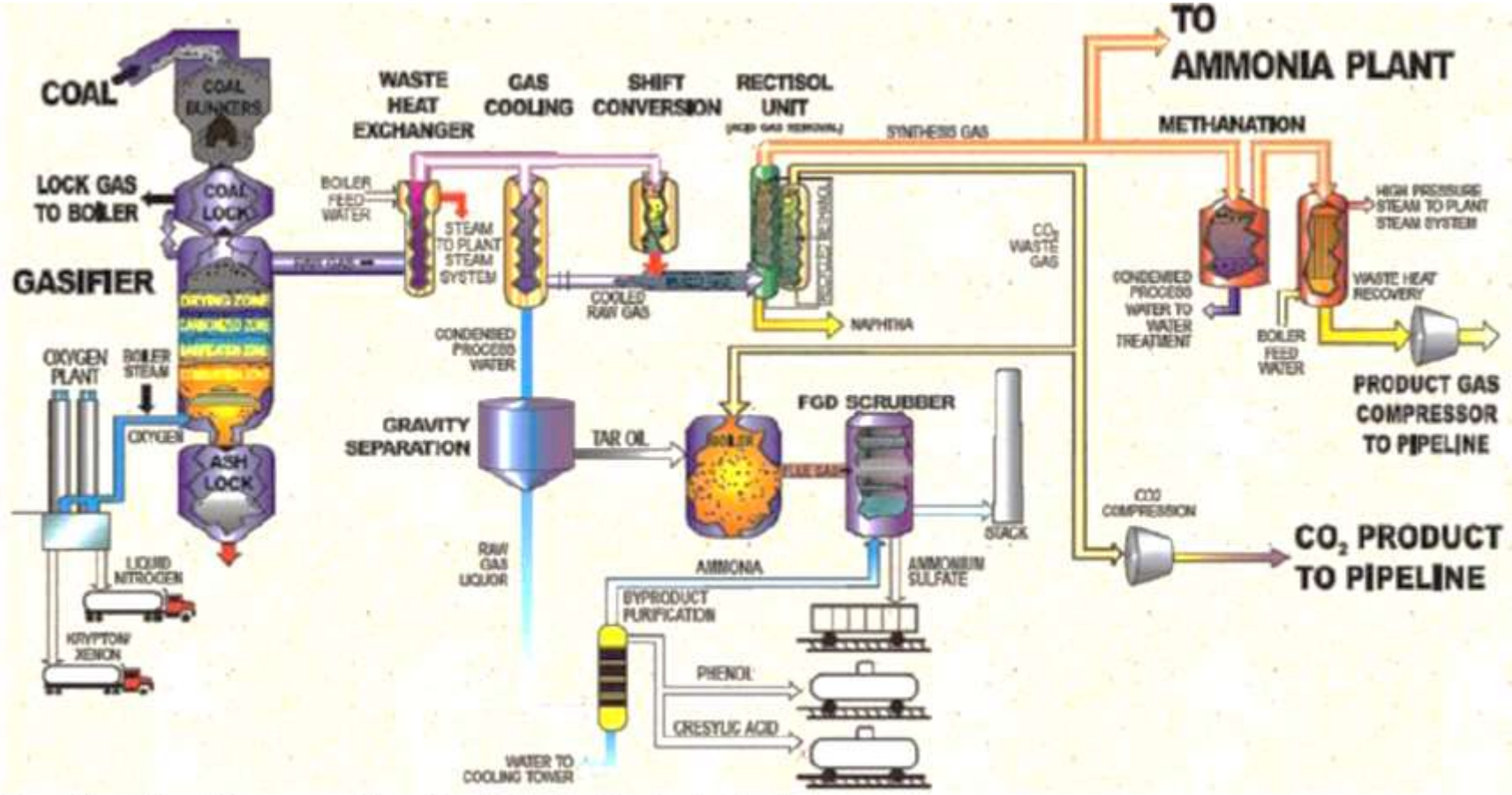
Fractional Distillation of Crude Oil



U.S. Oil refineries re-export oil products generated from imported oil.

U.S. gas exported as LNG to EU & Asia

Coal Gasification/Chemical Feedstock



Simplified Plant Process at the Great Plains Synfuels Plant

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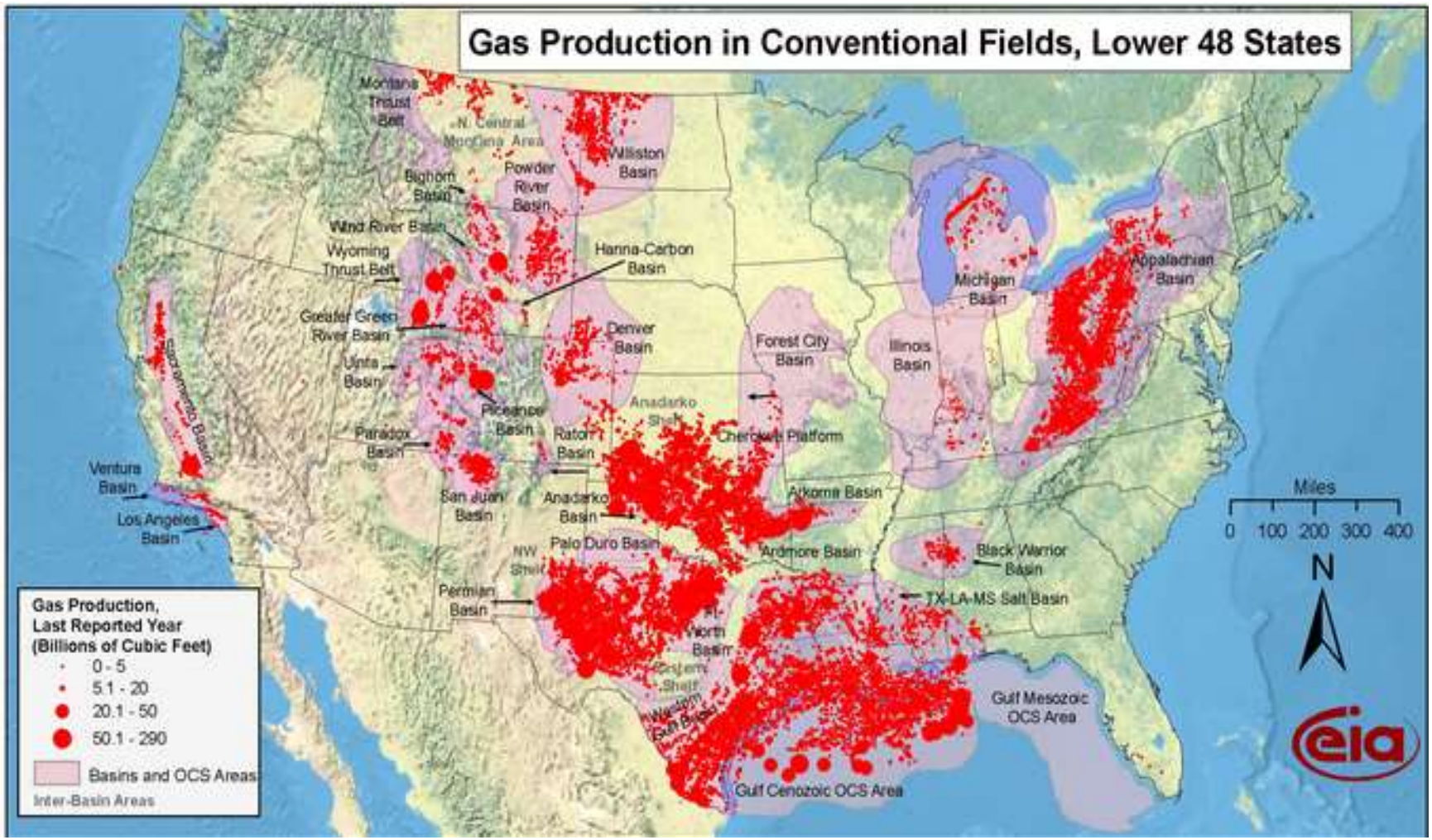
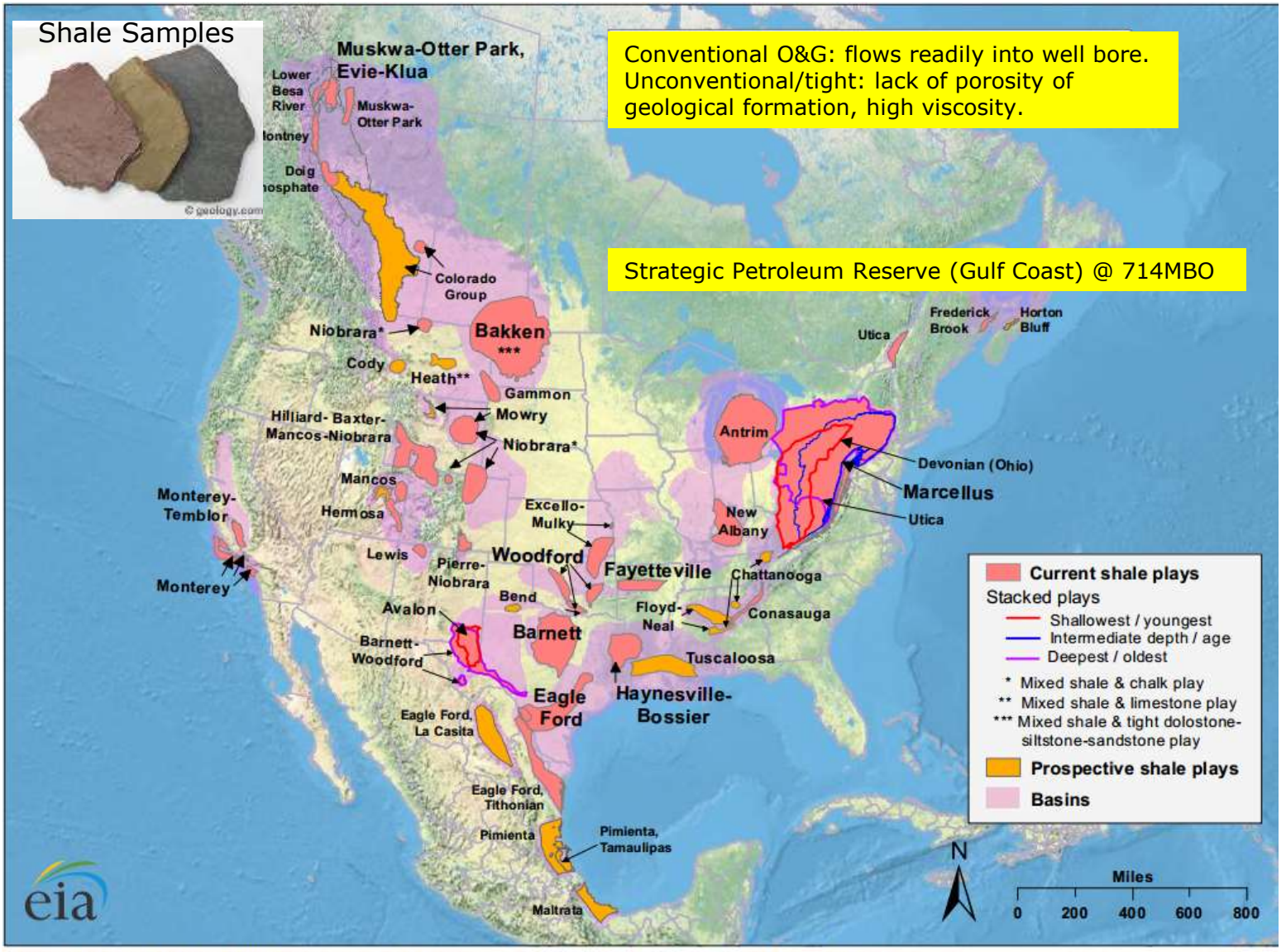
U.S. Natural Gas Fields



OCS=Outer Continental Shelf

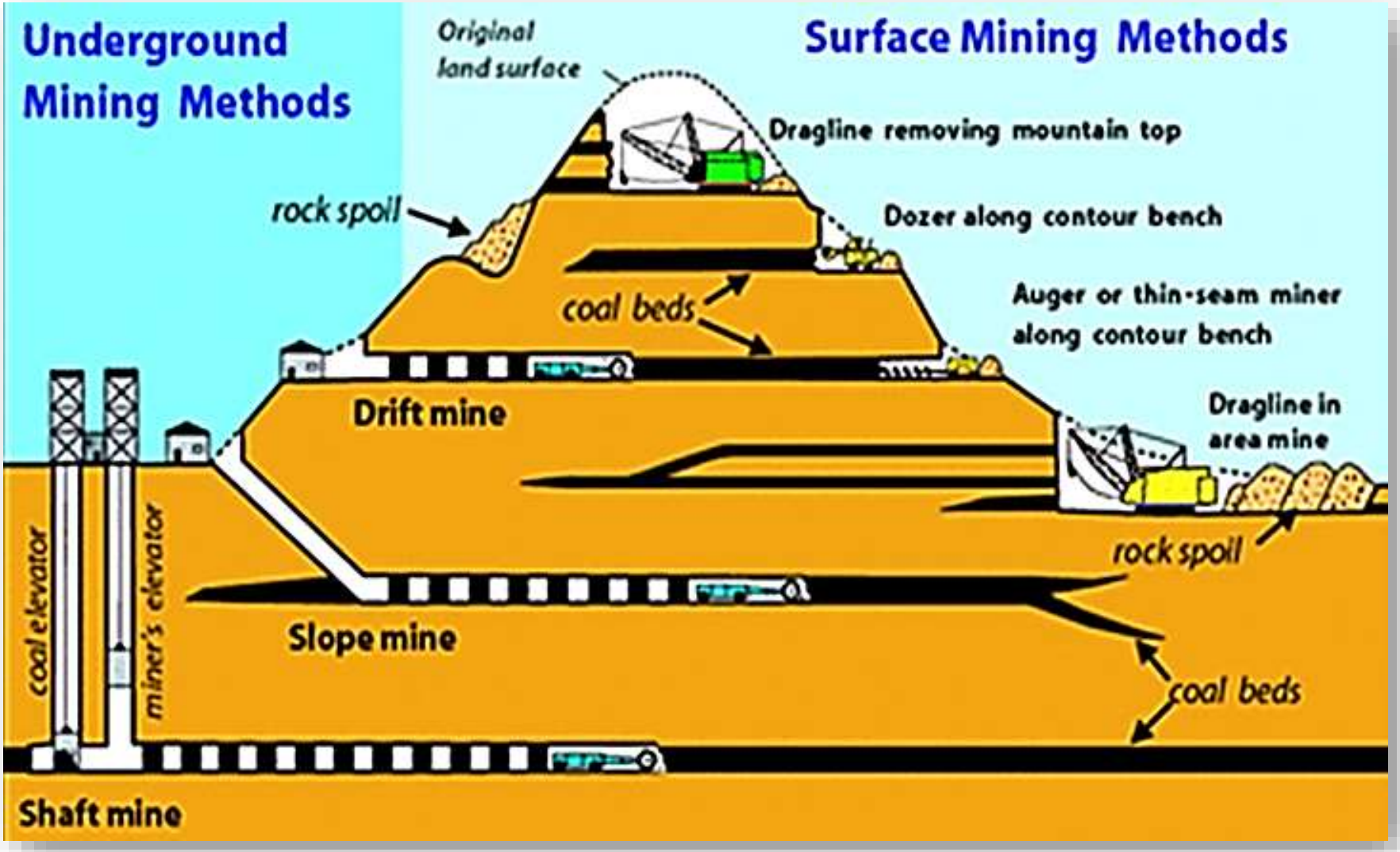
U.S. Shale Gas & Oil Reserves



Source: U.S. Energy Information Administration based on data from various published studies. Canada and Mexico plays from ARI.
Updated: May 9, 2011

Coal Mining Technologies

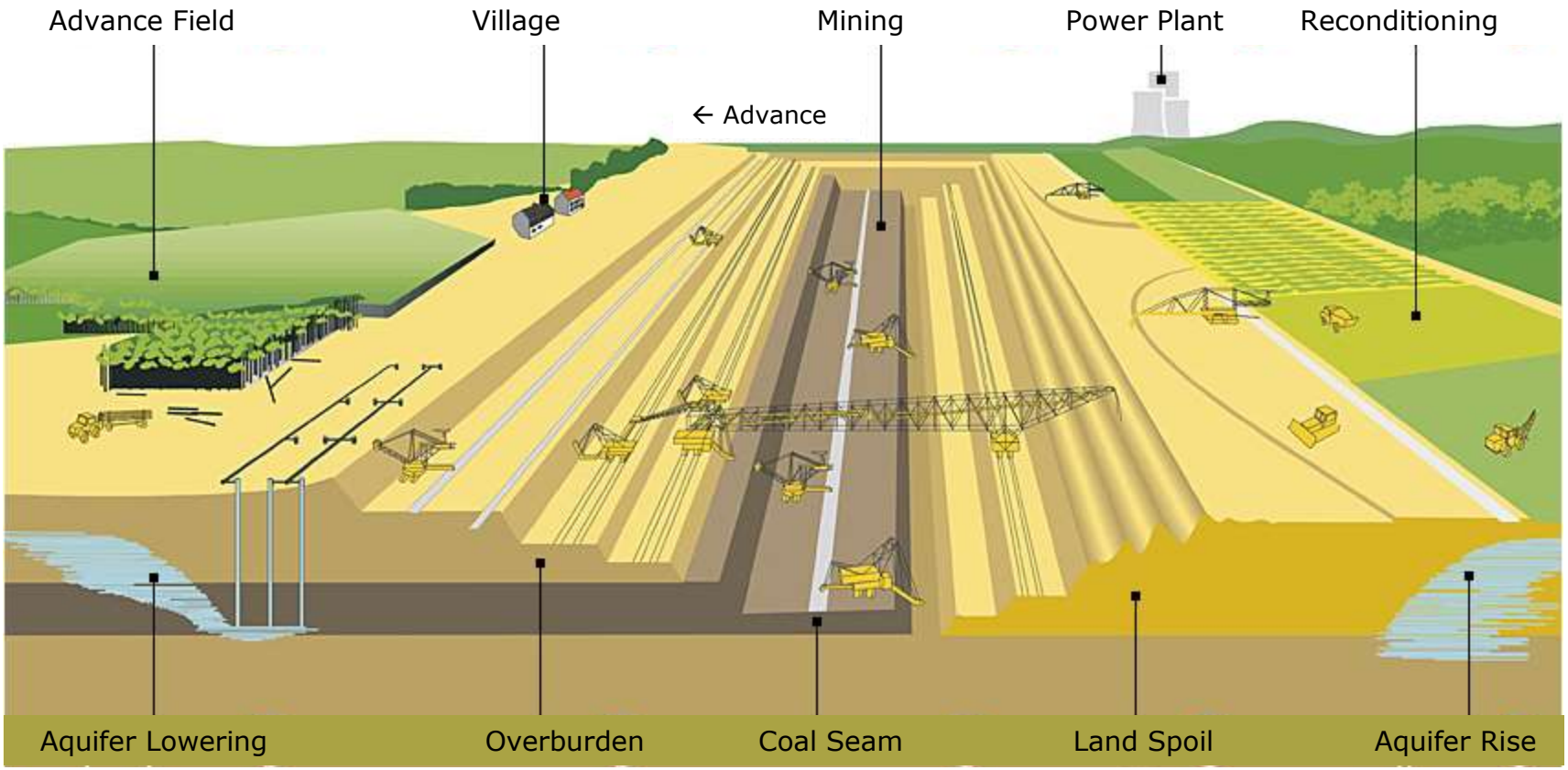
Underground mining down 33% → massive surface/open pit mining
→ fewer fatalities, but mountain top removal → lakes with toxic sludge.



Mountain Top Removal in Surface Coal Mining

Coal Surface (Strip) Mining on Flatland

Surface mining → major changes in environment:
Deforestation, destruction of habitat, demolition of villages, resettlements



Bitumen mining, Hambach/D

Coal Surface Mining (Germany)

Traditional Oil Production: Oil Wells in Baku

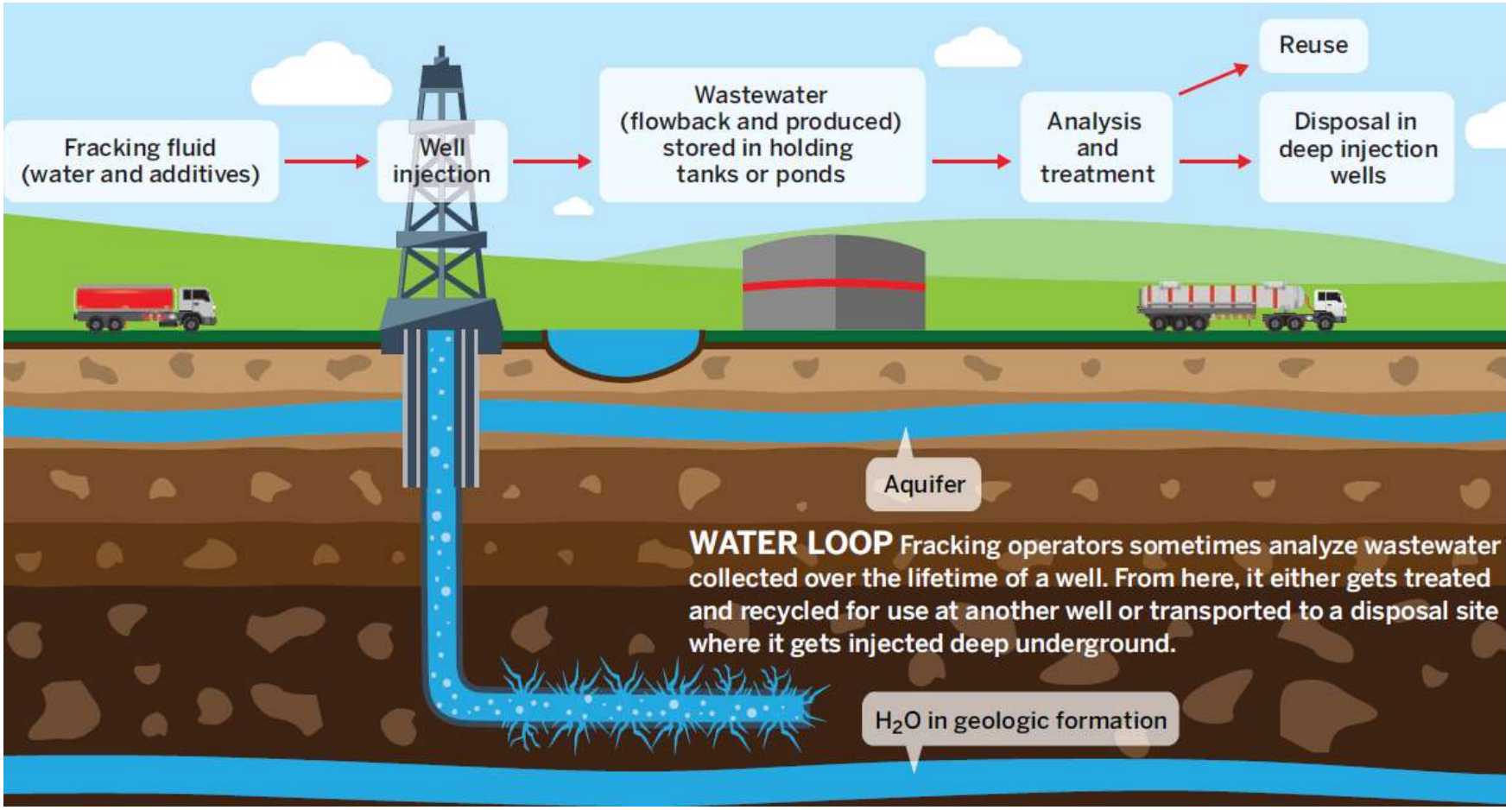
Ölfeld in Baku: Die Energiewende ist bisher nicht mehr als eine Ankündigung Foto: Tobias Schwarz / AFP

30,000 Feet Under the Sea (The Drilling Fields)

Chevron's deep-sea drilling in the Gulf of Mexico
> 6 miles drill

Cost several B$/platform
Several years to bring on line
5-7 Gbblo
~1 year U.S. demand)

Oil & Gas Fracking Revolution



New Technology: Hydrofracking

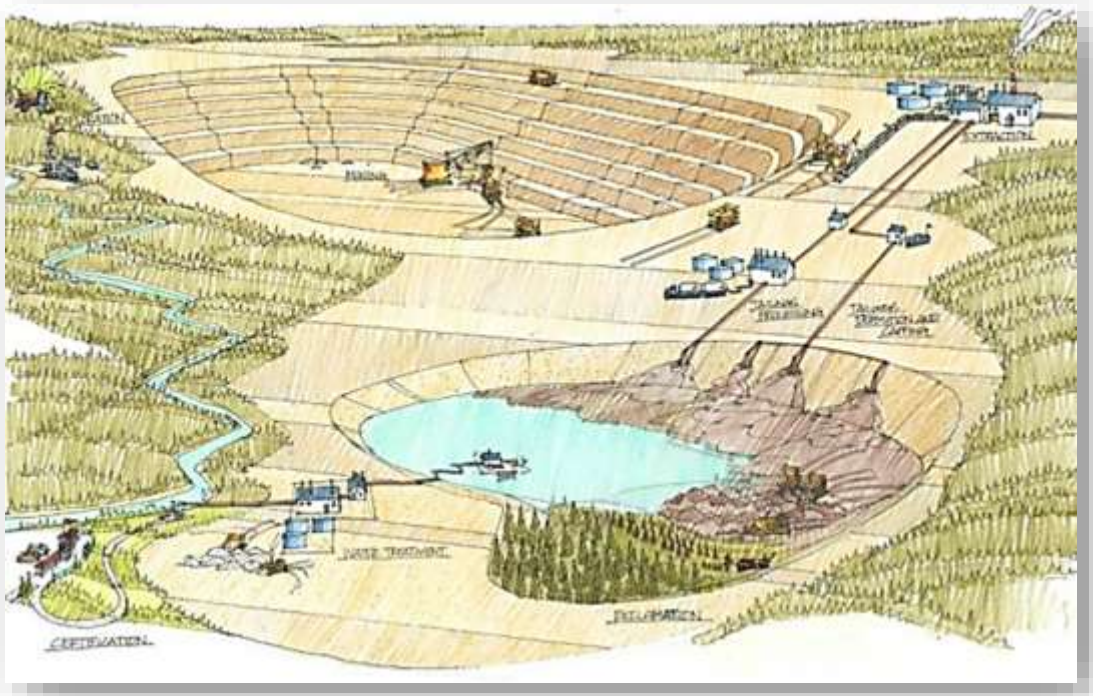
Vertical drill down for several 1,000’ then turn horizontal, create fissures in shale rock by injecting high-pressure water/chemical fluids. Oil and gas migrates to well opening, distributed via local gathering pipeline.

Well is protected by several layers of steel and concrete casing.

Complaints: leakage of gas into aquifers, small earthquakes.

→ EPA files

Surface-Mining Oil Sands



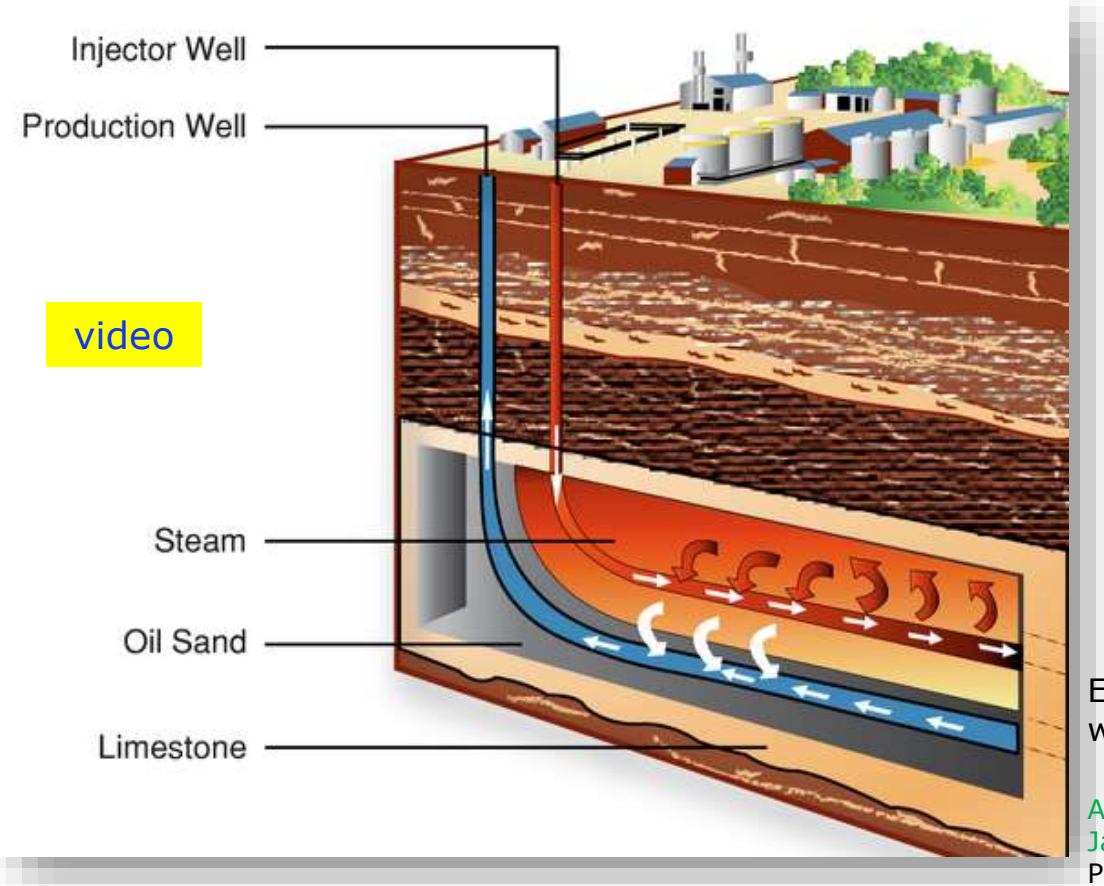
Alberta's boreal forest (381,000 km^2)

Oil sands surface mineable area (4,800 km^2), field contains 170 B bbl

Oil sands mineable area cleared or disturbed (2012: 767 km^2)

Alberta Chamber of Resources (Canada), January 2004. Canadian Association of Petroleum Producers (CAPP).

On-Site Steam Assisted Gravity Drainage



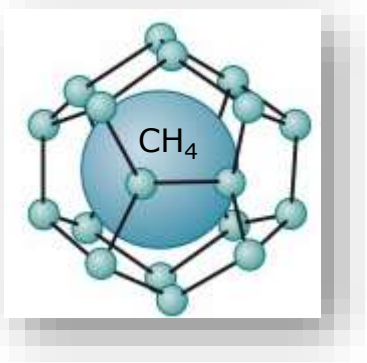
Essentially all oil sands are mineable with SAGD technology.

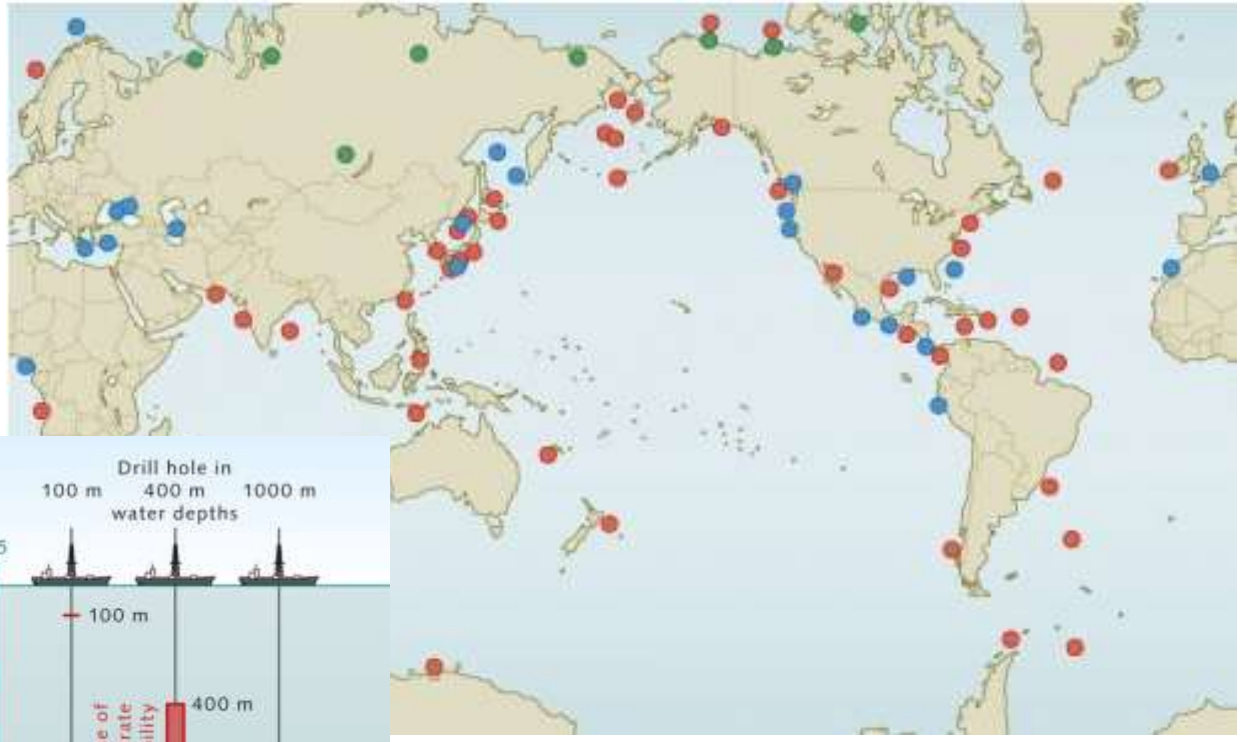
Alberta Chamber of Resources (Canada), January 2004. Canadian Association of Petroleum Producers (CAPP).

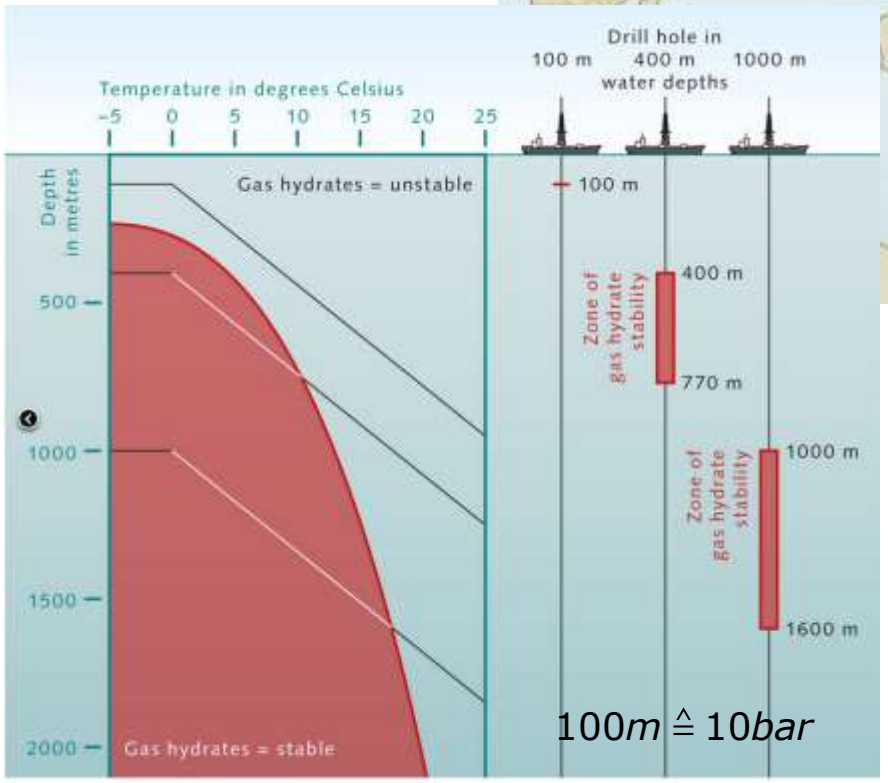
Pair of horizontal wells drilled into formation (5 m spacing).
Low-pressure steam in "Steam Chamber"
@ upper wellbore → heat oil sand, lower viscosity of oil
Oil drains via gravity into producer wellbore →
Toxic/oily "tailing lakes" remain (endangered wildlife)

Nat gas produced in the SAGD process is typically flared → CO_2.

Methane Hydrates (Clathrates)







Hydrates occur when sufficient methane is produced by organic matter degradation on the sea floor @ low T, high P.
→ @ Continental boundaries.

Looming problem for climate!

End
Fossil Fuels