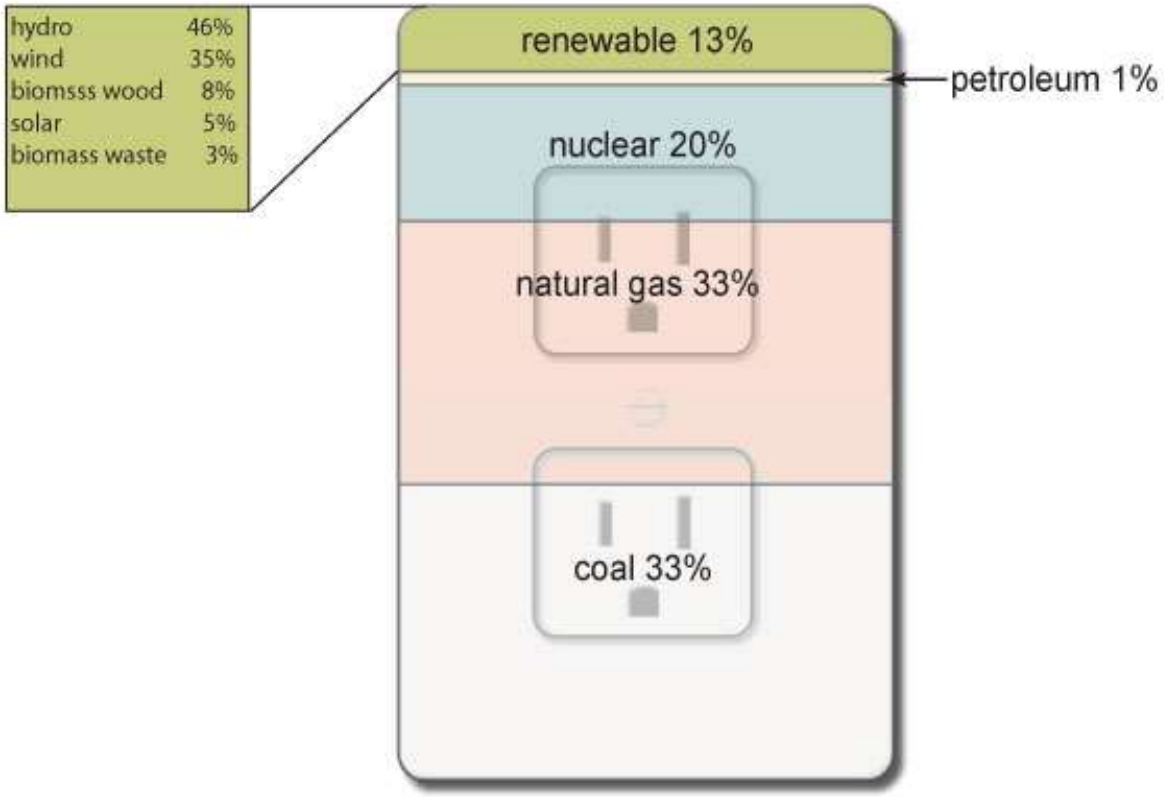
Technologies→ electricity

- Photovoltaic (pv) cells
- Batteries (lead acid, cadmium, lithium-ion)
- Hydrogen fuel cells
- Each rely on chemical reactions and properties → electron flow

- Steam generators
- Wind turbine
- Water powered turbine
- Each rely on spinning a coil of wires around a magnet

Sources of U.S. electricity generation, 2015

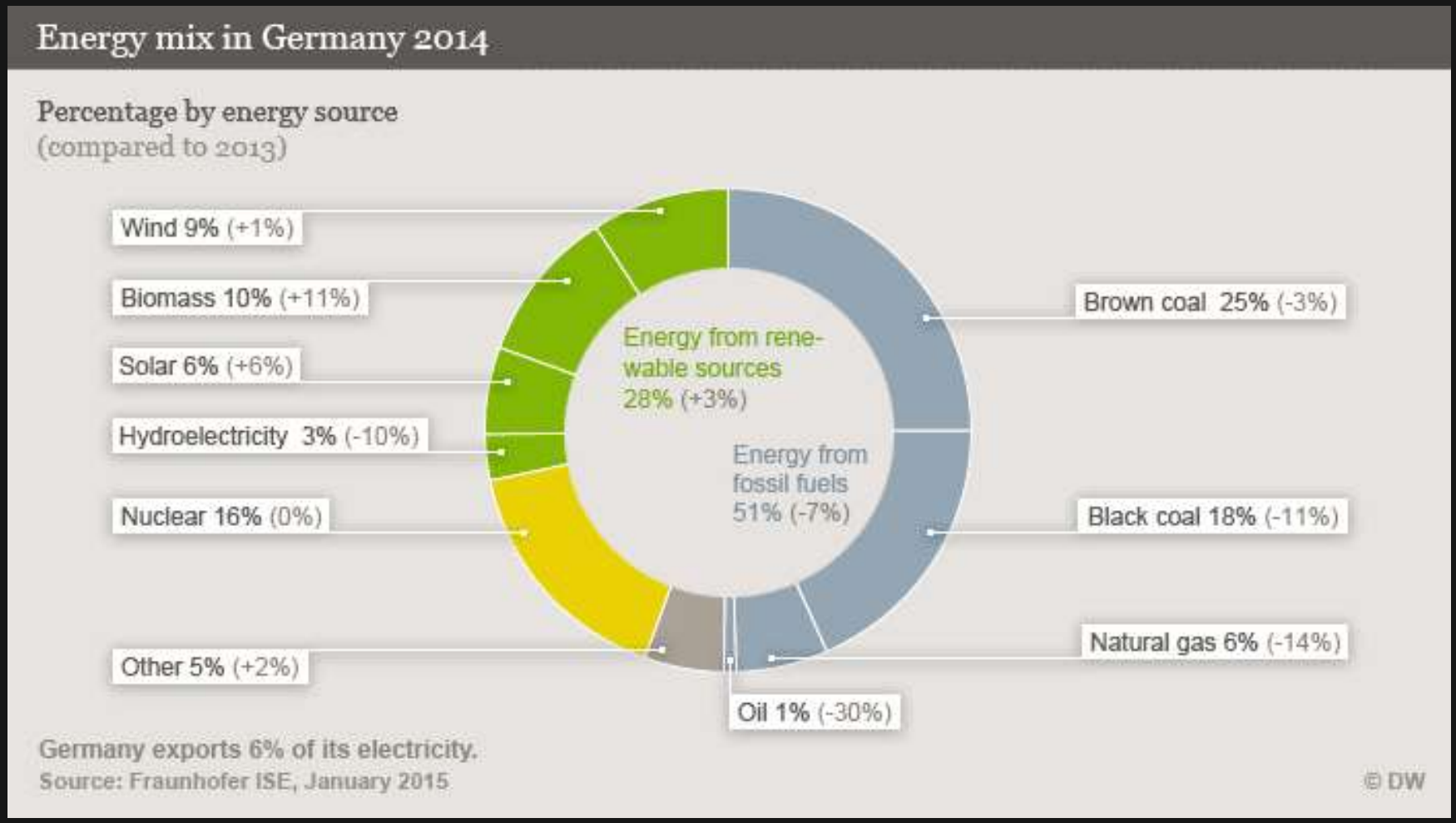


Source: U.S. Energy Information Administration, *Electric Power Monthly*, February 2016. Preliminary data for 2015

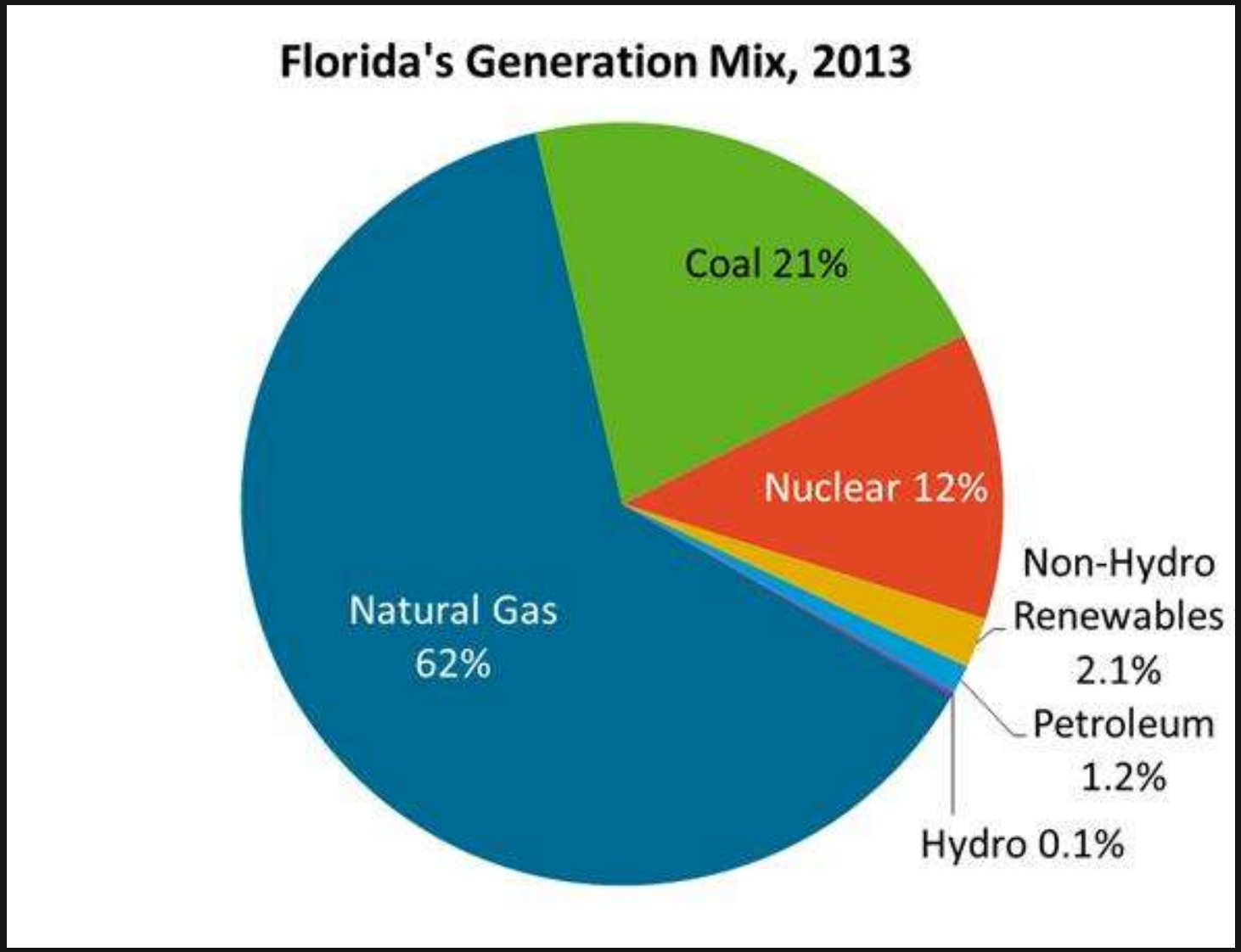
Note: Sum of components may not equal 100% due to independent rounding.

eia

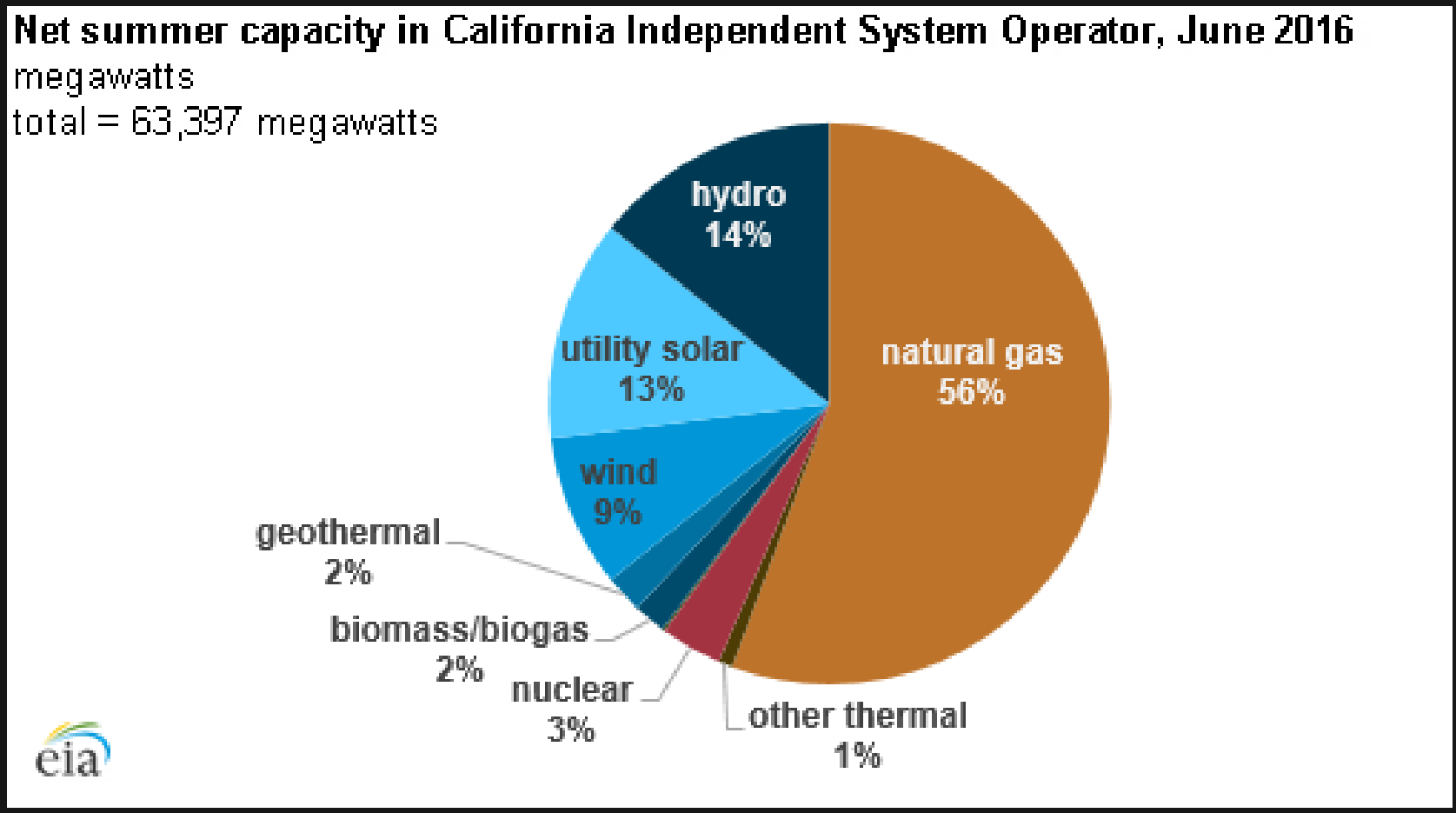
Renewables → 28% Germany's electricity (2014)



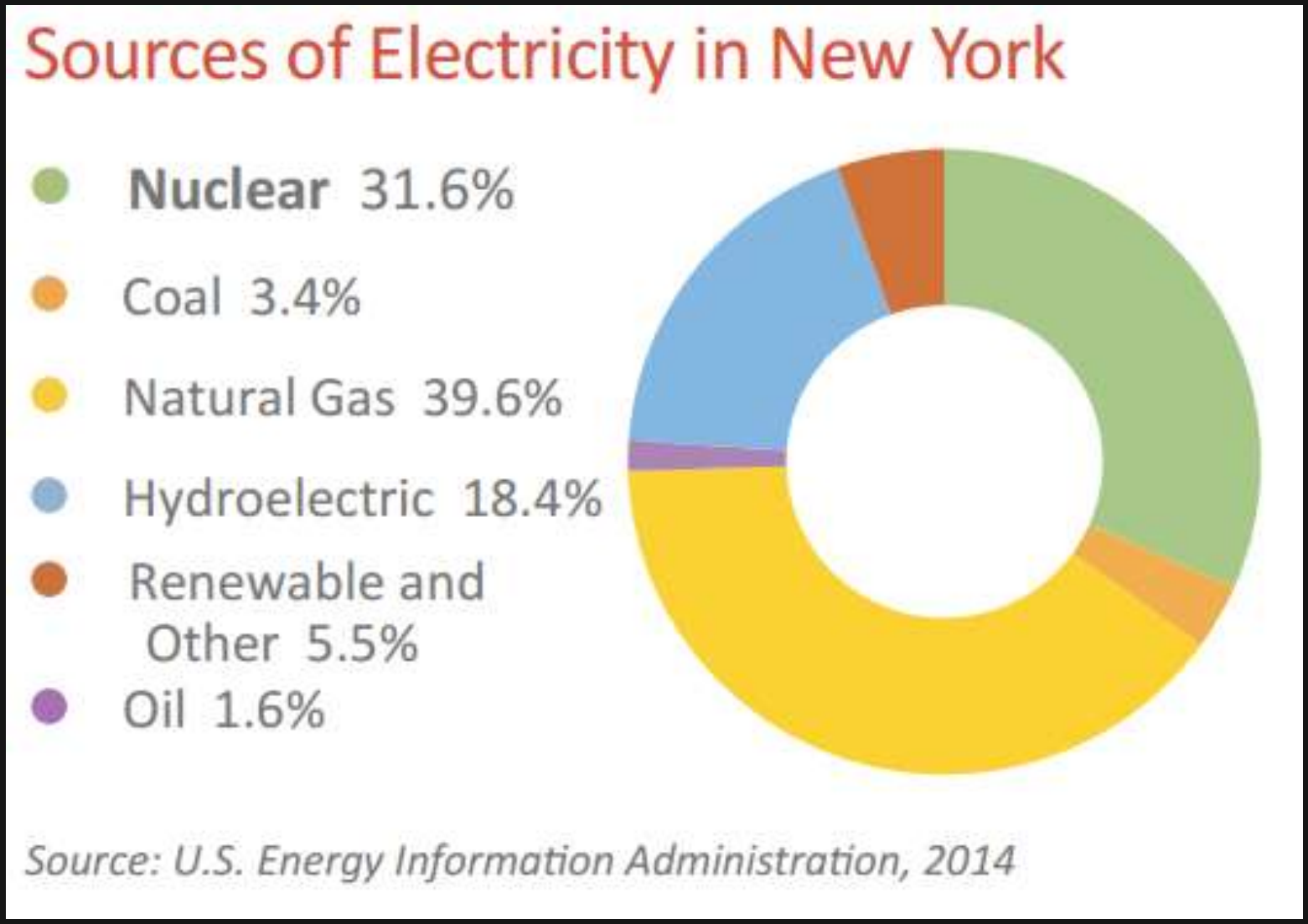
2.2%


Florida's Generation Mix, 2013
Coal 21%
Nuclear 12%
Non-Hydro Renewables 2.1%
Petroleum 1.2%
Hydro 0.1%
Natural Gas 62%

40%

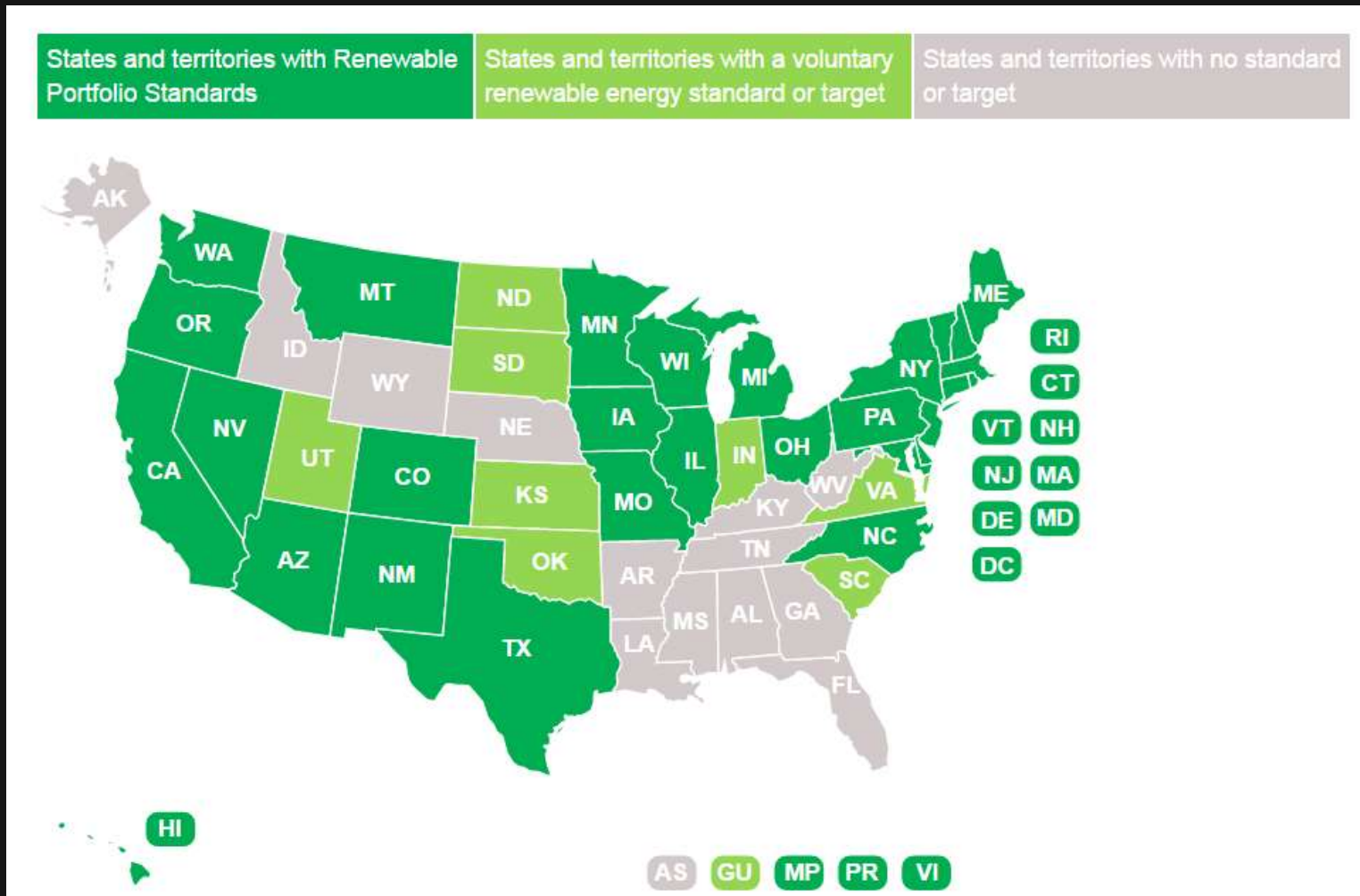

Net summer capacity in California Independent System Operator, June 2016
megawatts
total = 63,397 megawatts
hydro
14%
utility solar
13%
natural gas
56%
wind
9%
geothermal
2%
biomass/biogas
2%
nuclear
3%
other thermal
1%
eia

23.9%


Sources of Electricity in New York
Nuclear 31.6%
Coal 3.4%
Natural Gas 39.6%
Hydroelectric 18.4%
Renewable and Other 5.5%
Oil 1.6%
Source: U.S. Energy Information Administration, 2014

What is necessary → states and governments transition to renewable electric generation?

- Renewable energy portfolios and standards
- Renewable energy credits (RECs)
- Production tax credits
- Economic Incentives


States and territories with Renewable Portfolio Standards
States and territories with a voluntary renewable energy standard or target
States and territories with no standard or target
AK
WA
OR
CA
NV
ID
MT
WY
UT
AZ
CO
NM
ND
SD
NE
KS
OK
TX
MN
IA
MO
AR
LA
WI
IL
MS
MI
IN
KY
TN
AL
OH
WV
GA
FL
SC
NC
VA
PA
NY
ME
RI
CT
VT
NH
NJ
MA
DE
MD
DC
HI
AS
GU
MP
PR
VI

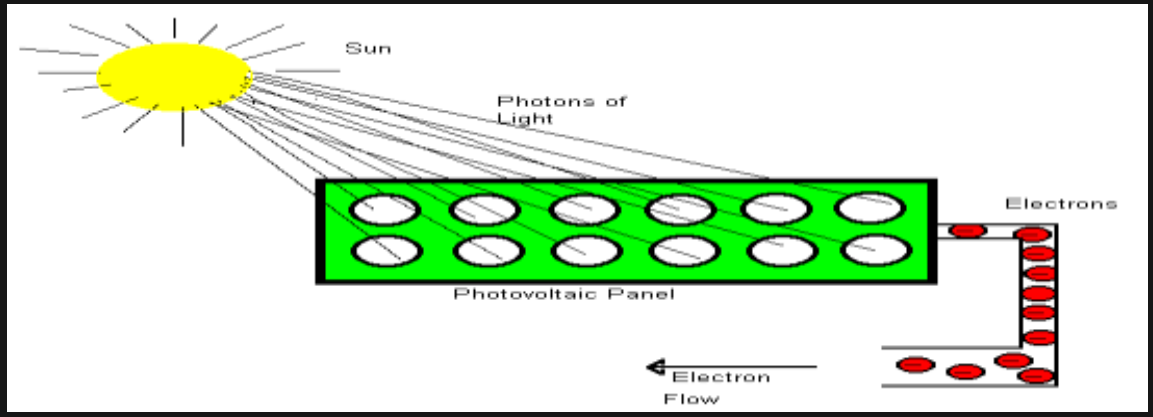
Florida does not have a renewable portfolio standard

California	Renewables Portfolio Standard	33% by 2020 40% by 2024 45% by 2027 50% by 2030	2013 amendment allows the California Public Utilities Commission to adopt additional requirements.	Cal. Public Utilities Code §399.11 et seq.; Cal. Public Resources Code §25740 et seq.; CA A 327 (2013)

New York	Renewable Portfolio Standard; Reforming the Energy Vision (REV)	29% by 2015; 50% by 2030 (REV- *currently in process*)	Distributed Generation: 8.4% of annual incremental requirement.	NY PSC Order Case 03-E-0188; 2015 New York State Energy Plan

Photovoltaics

- Requires a semi-conductor (Si)
- Creates a direct current (DC) which can
  - Be stored in batteries
  - Or converted to a conventional alternating current (AC)
  - Or used to split water (electrolysis) → Hydrogen gas (stored fuel for fuel cells)
- Typical PV cell has a 15-20%



Batteries

- Electrochemical reaction → flow of electrons
- REDOX reactions
- Electrons flow from negative (anode) terminal to positive (cathode)

Photovotaics and batteries → DC current

- Direct current
- Electrons flow in 1 direction

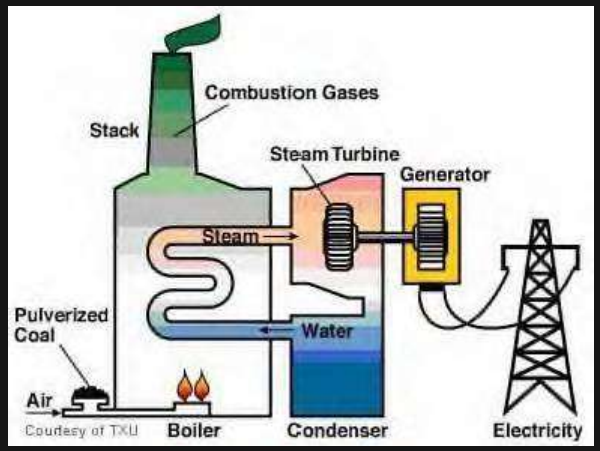
NiCd battery

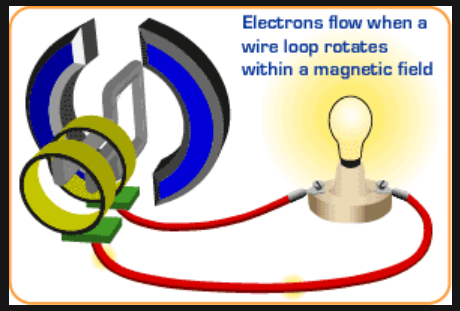
- Cathode = nickel oxide
- Anode = cadmium compound
- Electrolyte = potassium hydroxide (alkaline = strong base)
- Pros = rechargable
- Cons = Cd is toxic heavy difficult to dispose safely

Lithium-ion battery

- Cathode = lithium-cobalt oxide ($LiCoO_2$) or, in newer batteries, from lithium iron phosphate ($LiFePO_4$).
- Anode = graphite (carbon)
- Electrolyte = varies from one battery to another
- Pros =
- Most energy dense battery on the market today
- Cons =
- Less toxic but can overheat and catch on fire

Turbine - Generator





- Steam turns turbine
- Turbine spins wire loop in a magnetic field
- → flow of electrons

9 ways → turn a turbine → electricity

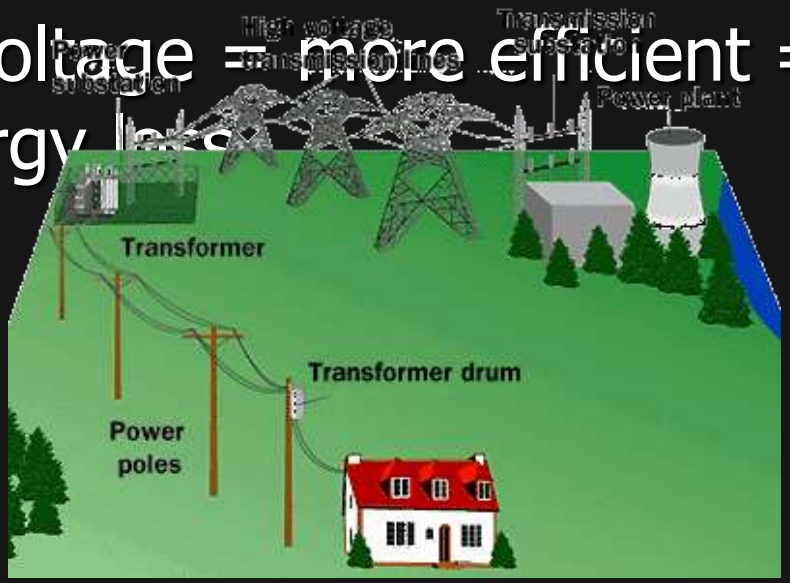
- Nonrenewable
  - Nuclear reaction
  - Coal
  - Natural gas
  - oil
- Renewable
  - Wind
  - Hydro
  - Solar thermal generation
  - Biomass (wood, biogas…)
  - Geothermal

Most powerplants →AC current

- Alternating
- Advantage = easier to step up or step down current with transformers

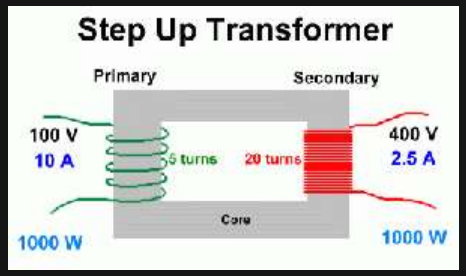
Electric power transmission

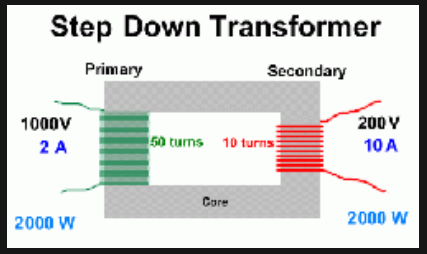
- AC current is converted to high voltage (10^6volts)
- Higher voltage = more efficient = less energy lost



Transformers increase and decrease voltage

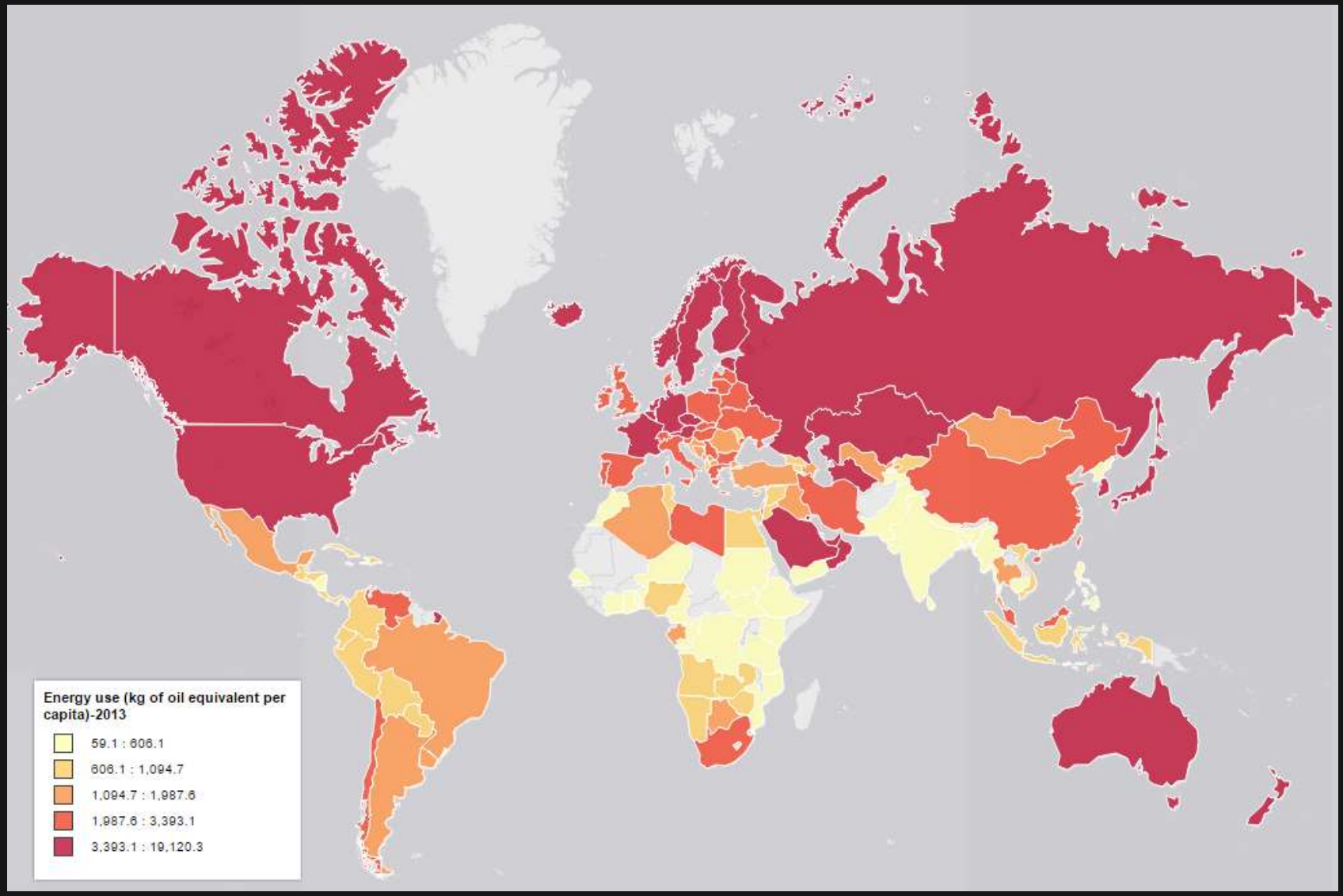
- Voltage is decreased to about 1000 volts at a substation for transmission
- Then down to 120 volts in homes



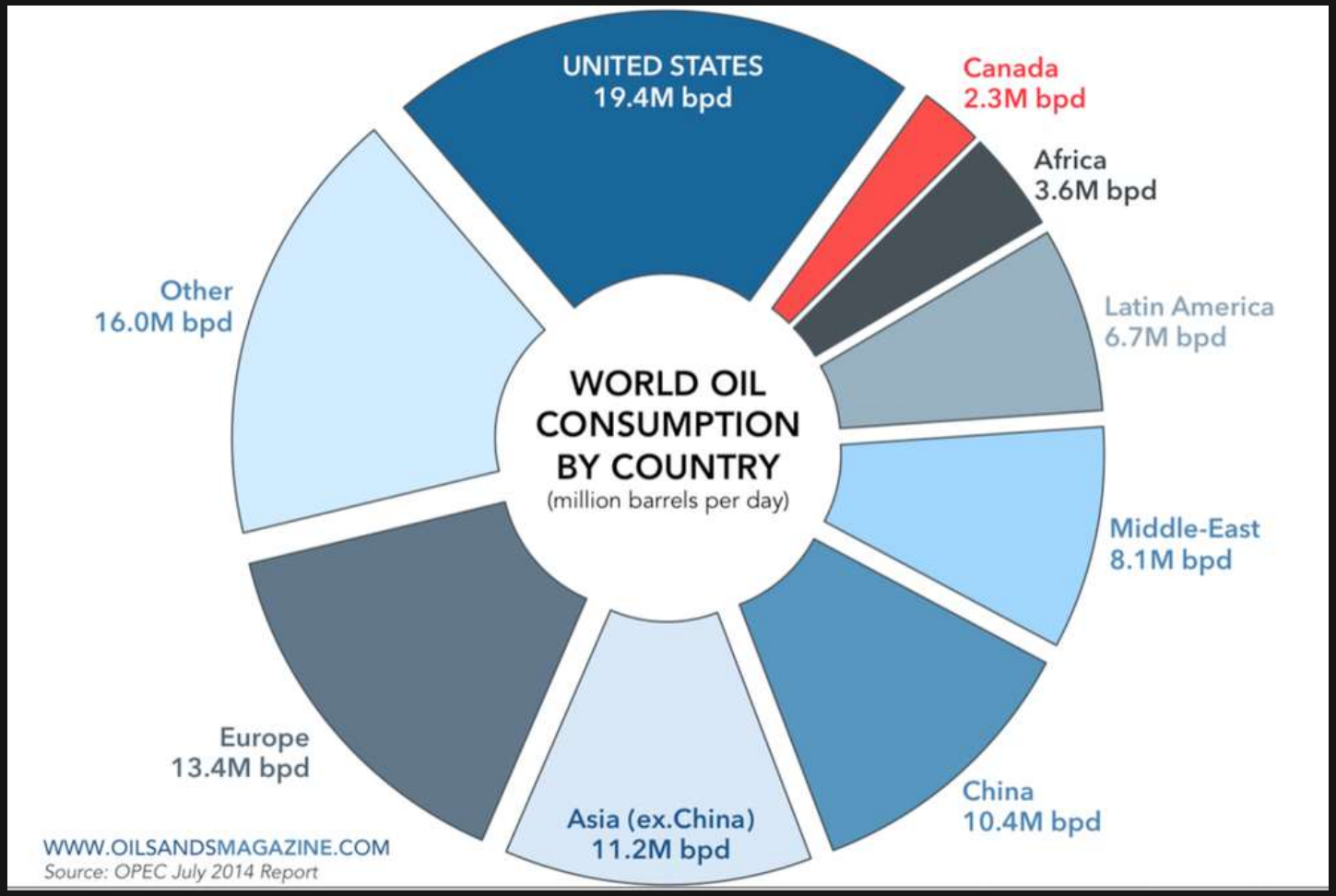


Nonrenewable Fossil Fuels Part 1 Coal

People in highly developed countries consume more energy than humans in developing countries



US consumes more energy than any other nation



Energy around the world

- Industrial nations and urban areas rely on industrial fuels
  - energy dense fossil fuels (coal, oil, natural gas)
- Rural communities in developing nations rely on subsistence fuels =
  - wood, charcoal, biomass

How fossil fuels were formed

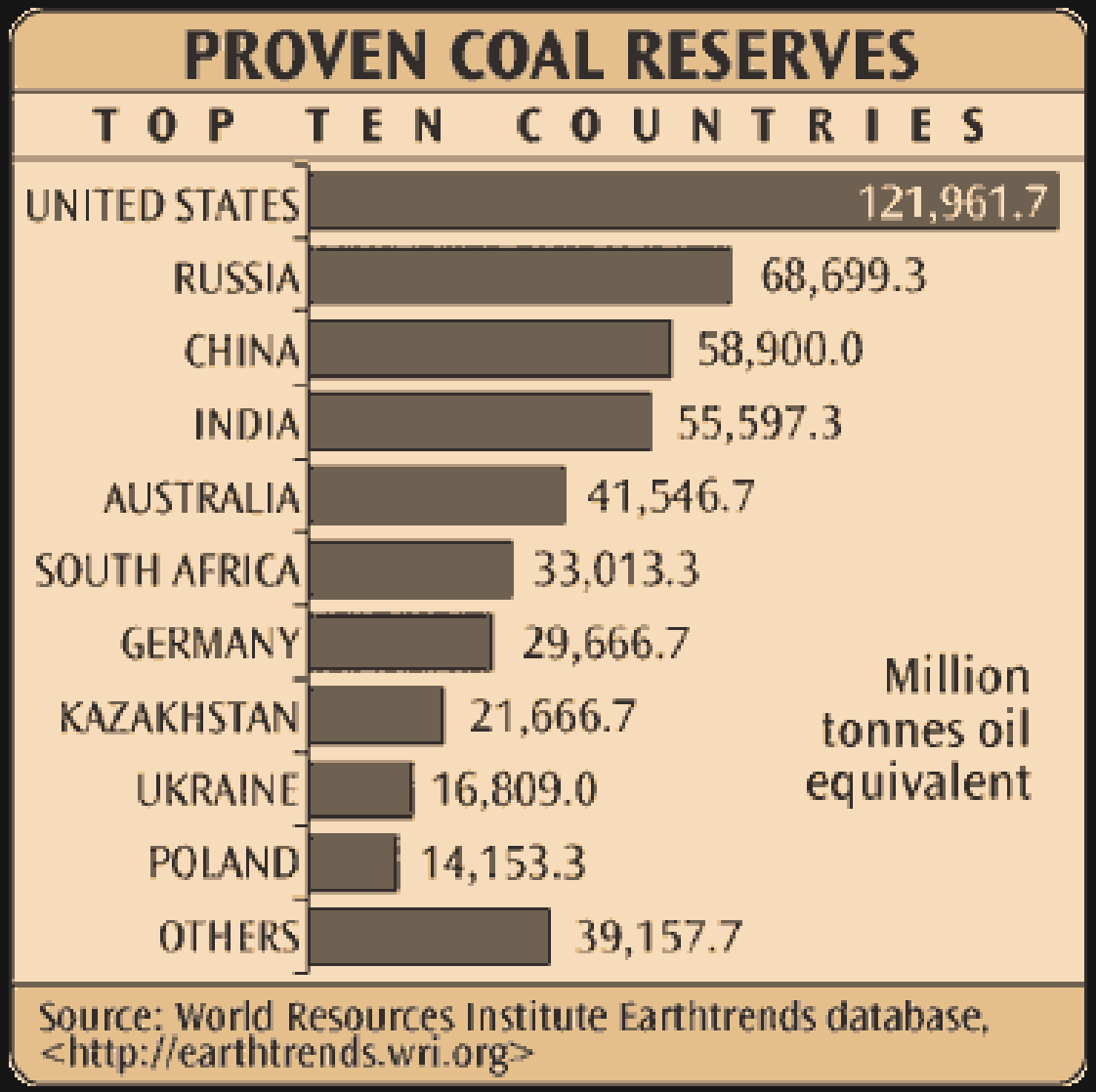
- Organic sediment underwater decomposes slowly because
- **anaerobic conditions → slow decomposition**

- Fossil fuels are formed when:

1. Dead organic material underwater gets covered by layers of sediment
2. **Heat** and **pressure** → **carbon rich rocks (coal), liquid (petroleum), and natural gas**

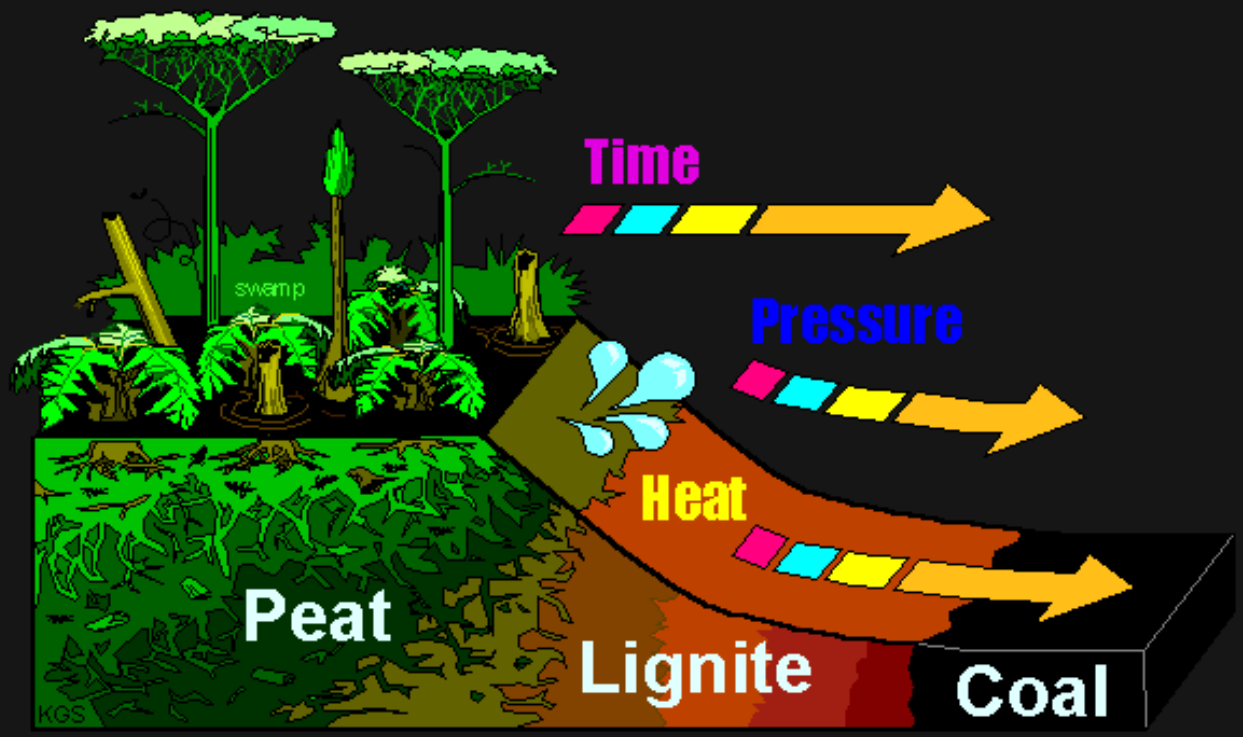
Coal

- Fueled the Industrial Revolution of the 1800's
- Today used mainly → <u>electricity</u>
- <u>US, Russia, and China</u> have <u>largest coal reserves</u>



Coal formation

http://www.uky.edu/KGS/coal/coalform.htm



- Peat forms when living remains get buried by sediment in swampy (anaerobic) areas
- Coal forms when peat is chemically changed by heat and pressure

Peat supplies heat and electricity in Ireland

https://www.youtube.com/v/ufwvFOXUCnc

https://www.youtube.com/v/EwK48eD5lYs

Coal

- 3 types of coal
  - Lignite
  - Bituminous
  - Anthracite

http://www.consumerenergyreport.com/research/coal/coal-mining-and-processing/

http://www.astecindustries.com/images/photos/Coal_Hands.jpg

http://newsimg.bbc.co.uk/media/images/41047000/jpg/_41047334_coal_fire_203.jpg

Lignite

- Soft and brown
- Not very efficient
- Found in Western US (esp. North Dakota)
- → 7,000 BTU/lb

(*Note: BTU = British Thermal Unit*)

www.mchenry.edu/…/eas170/ rocks/lignite.jpg

Bituminous

- Harder than lignite but still soft
- Most common
- High in sulfur content
- Found in the Appalachians, Mississippi Valley, and Central Texas
- →12,000 BTU/lb

www.uwm.edu/Course/422-100/ bituminous.coal1.jpg

Anthracite

- Black, hard coal
- Was exposed to extremely high temperatures during formation
- High energy, cleanest burning coal (least amount of sulfur)
- → 14,000 BTU/lb

www.evsc.virginia.edu/tours/rockmin/ images/anthracite.jpg

Powder River Basin = Largest coal producing region in the US

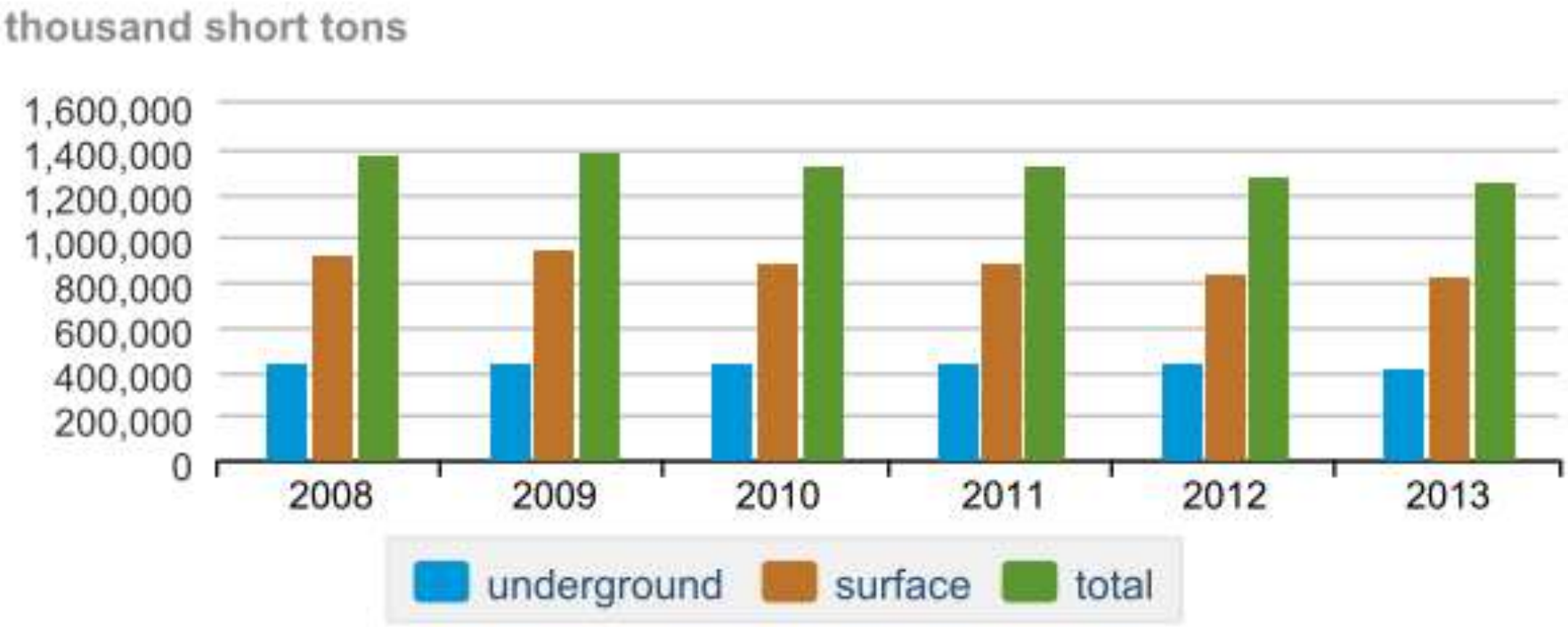
2 types of coal mining

- Surface

- Subsurface

Productive capacity of coal mines by mine type, 2008-13

Most coal mines = surface mines



eia Source: Annual Coal Report Table 11.

Surface Mining

Pros:

- Cheaper
- Safer for miners
- Common on mountaintops

Surface Mining

Cons:

- Disrupts and pollutes streams
- Destroys habitat
- Increases erosion
- Spoils and tailings = leftover rock → may contain heavy metals and acids → contaminate water supplies

Legislation

- Surface Mining Control and Reclamation Act of 1977 requires restoration of all surface coal mines
  - Reclamation = put it back to original state (restore vegetation)
- The unstable land around the coal pits = unsuitable for agriculture and → safety hazards without restoration.

Poker Flats reclamation project (Healy, Alaska)

Controversial practices in surface mining

- https://www.youtube.com/v/p5RcbPZXUZo
- Mountaintop removal →
- Valley fill
- Mountain removed and left over rock fills in valleys
- No federal law prevents this
- Many ongoing lawsuits trying to use Clean Water Act to fight this

Read Mountaintop removal article→ Environmental Problems w/ coal mines

General mining law 1872

- Opened all federal land to mining (discoverers rights → gold rush)

1977 Surface mining control and reclamation act

- Federal regulation → required reclamation of surface coal mines
- Created tax on coal to help pay for reclamation of lands stripped prior to ’77

Mine reclamation = creating useful landscapes from mined land.
Includes: fill placement, stabilizing, capping, regrading, placing cover soils, revegetation, and maintenance.

In the US, Mine reclamation is a regular part of modern coal mining practice due to Surface mining control and reclamation act

Coal mining

2. **Subsurface mines**

- 40% of US mines
- Pros =
- Does not disturb the surface
- Less erosion and habitat loss

historytogo.utah.gov/ brhistory.html

http://www2.illinoisbiz.biz/coal/virtualtour/index.html

Virtual tour of a subsurface mine

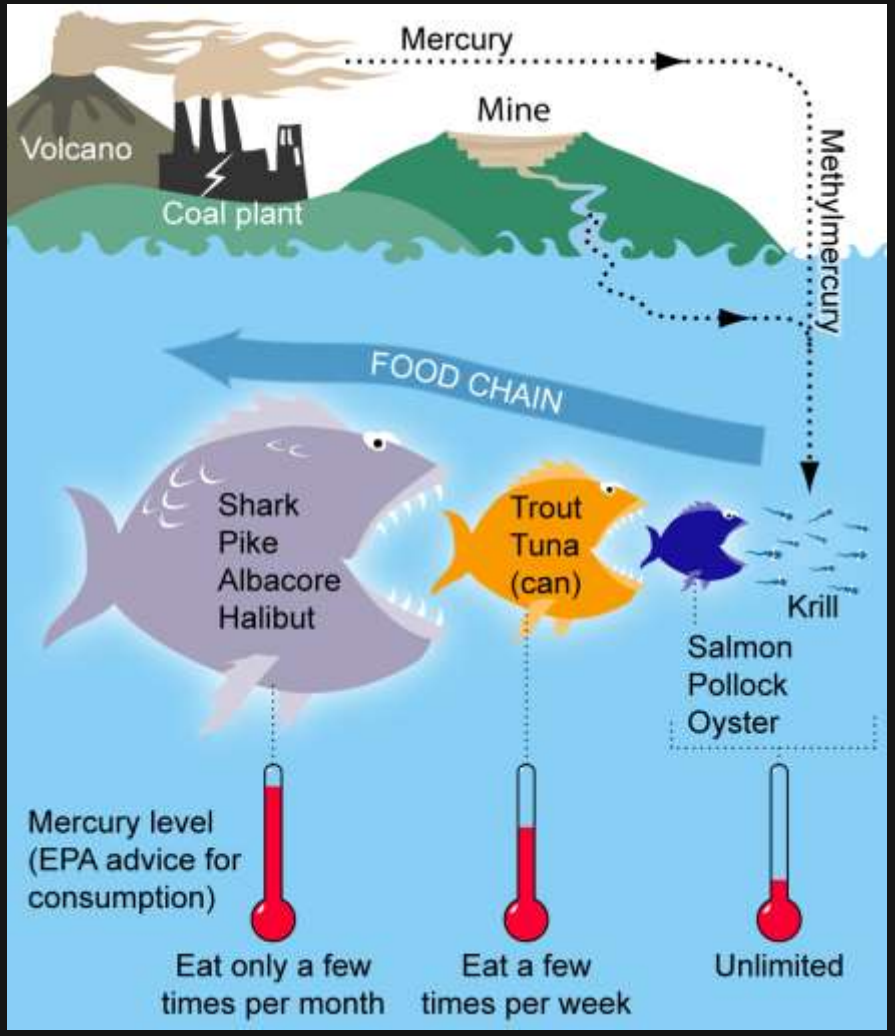
Problems associated with subsurface coal mining

- More expensive
- Hazardous to workers health
  - → black lung disease and lung cancer
  - Accidents
- Environmental effects =
  - Acid mine drainage

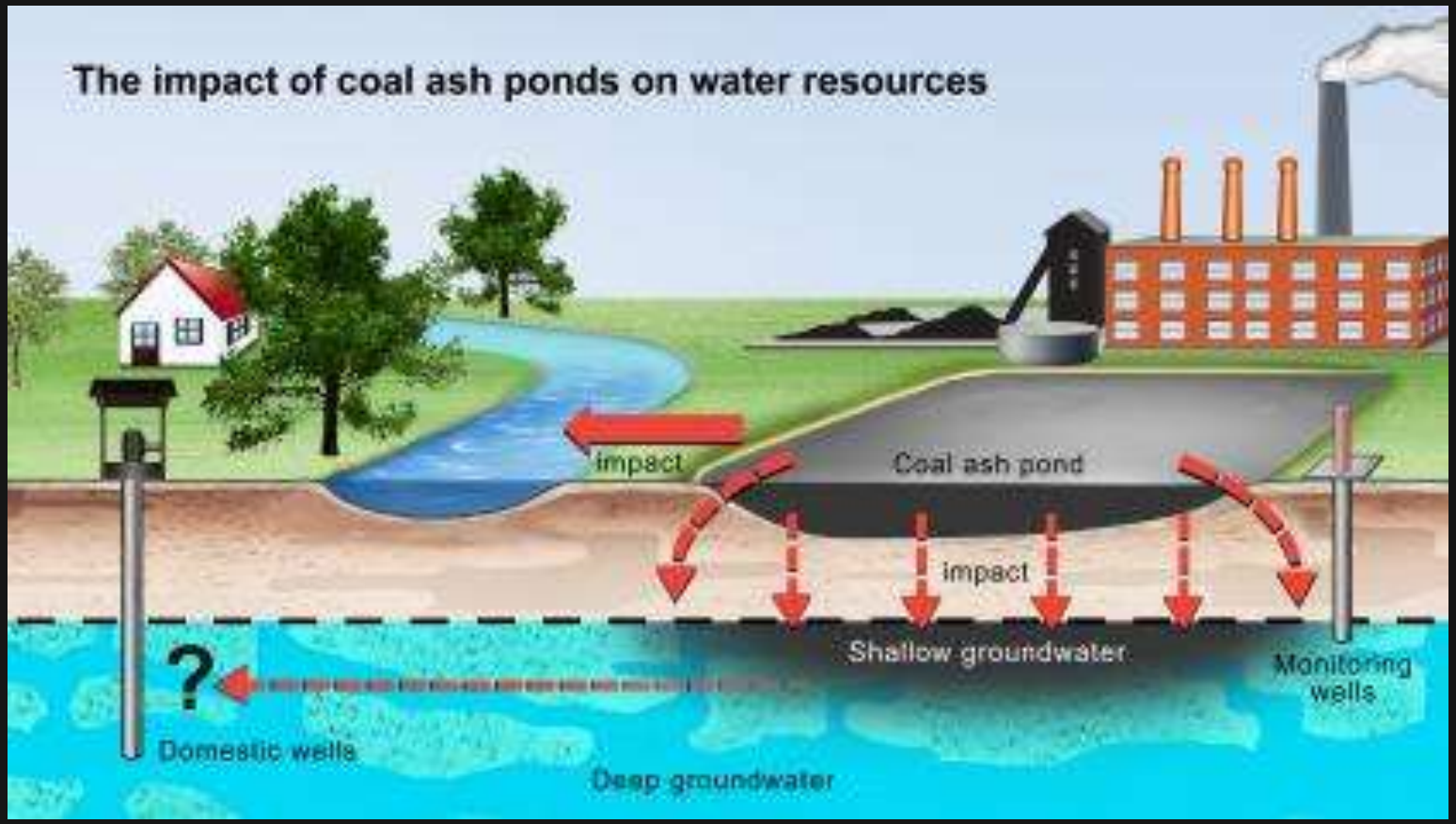
Environmental effects of burning coal

- Releases CO_2 (#1 greenhouse gas) → global warming
  - (Kyoto protocol, Copenhagen and Paris COP21 = Global efforts to decrease CO_2 emissions)
- Releases sulfur containing compounds →
- acid rain
- Releases particulate matter →
- smog

- Releases mercury, Hg (a heavy metal) →
- (bioaccumulates → neurological problems



Burning coal → fly ash and bottom ash → held in ash ponds



Tennessee Sludge dam Break 12/24/08

- A billion gallons of sludge (water and fly ash) from a coal burning steam plant in Tenn. Swamped 300 acres of mostly private property when a dike on a retention pond collapsed Dec. 24, 2008
- Residents were evacuated on Christmas Eve
- Homes, railroad tracks, roadways and river systems were damaged
- Unsafe levels of arsenic were found in the fly ash

http://www.cnn.com/2009/US/01/02/tennessee.sludge/index.html?iref=nextin#cnnSTCVideo

http://www.cnn.com/2009/US/01/02/tennessee.sludge/index.html?iref=nextin#cnnSTCVideo

Tenn. Sludge dam break

Federal Legislation and technologies to minimize impacts

- Clean Air Act Amendments

  Control point sources of NOx, SO_2, and PM (particulate matter) (does not limit CO_2)

- Scrubbers =

  chemicals react with pollutants → precipitate out as sludge

- Fluidized bed combustion =

  Crushed coal mixed with limestone → remove SO_2

- Electrostatic precipitators =

  Remove particulate matter

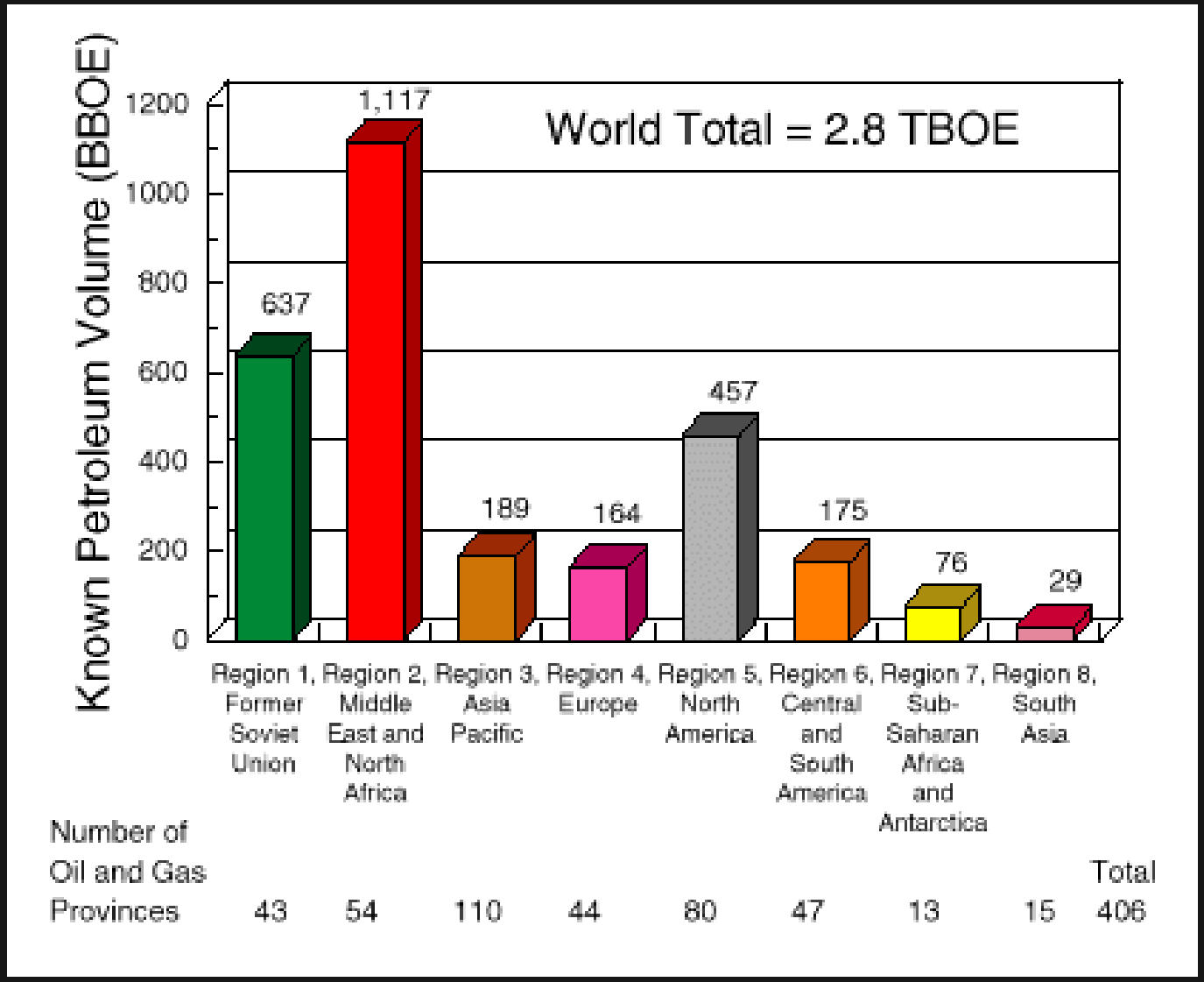
Nonrenewable Fossil Fuels Part 2 Oil

http://www.nrdc.org/land/use/gastank/intro.asp

Crude oil = Petroleum

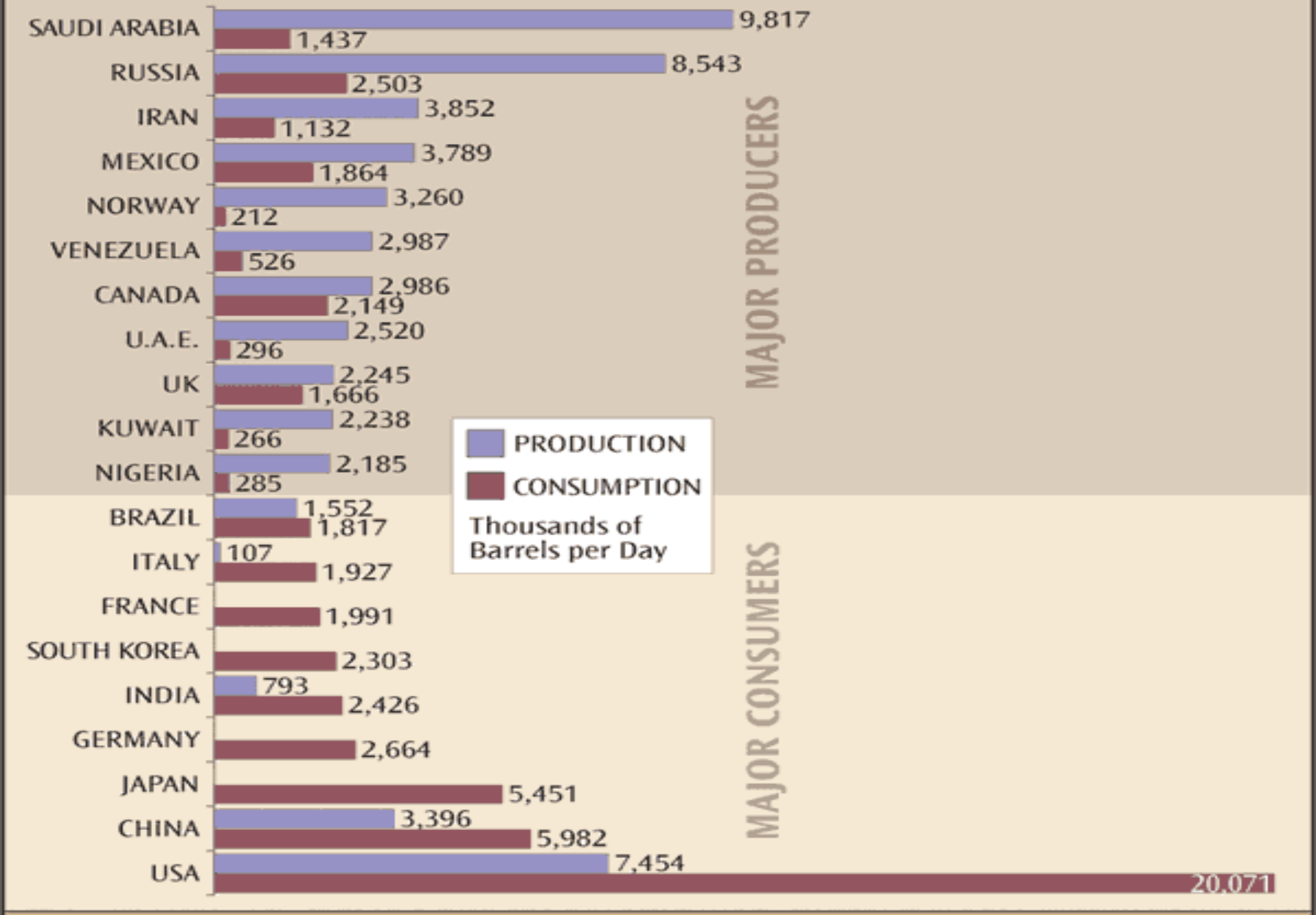
- Made up of lots of different hydrocarbons
- Formed from decaying plants and animals in areas that used to be sea-beds millions of years ago.

World petroleum distribution



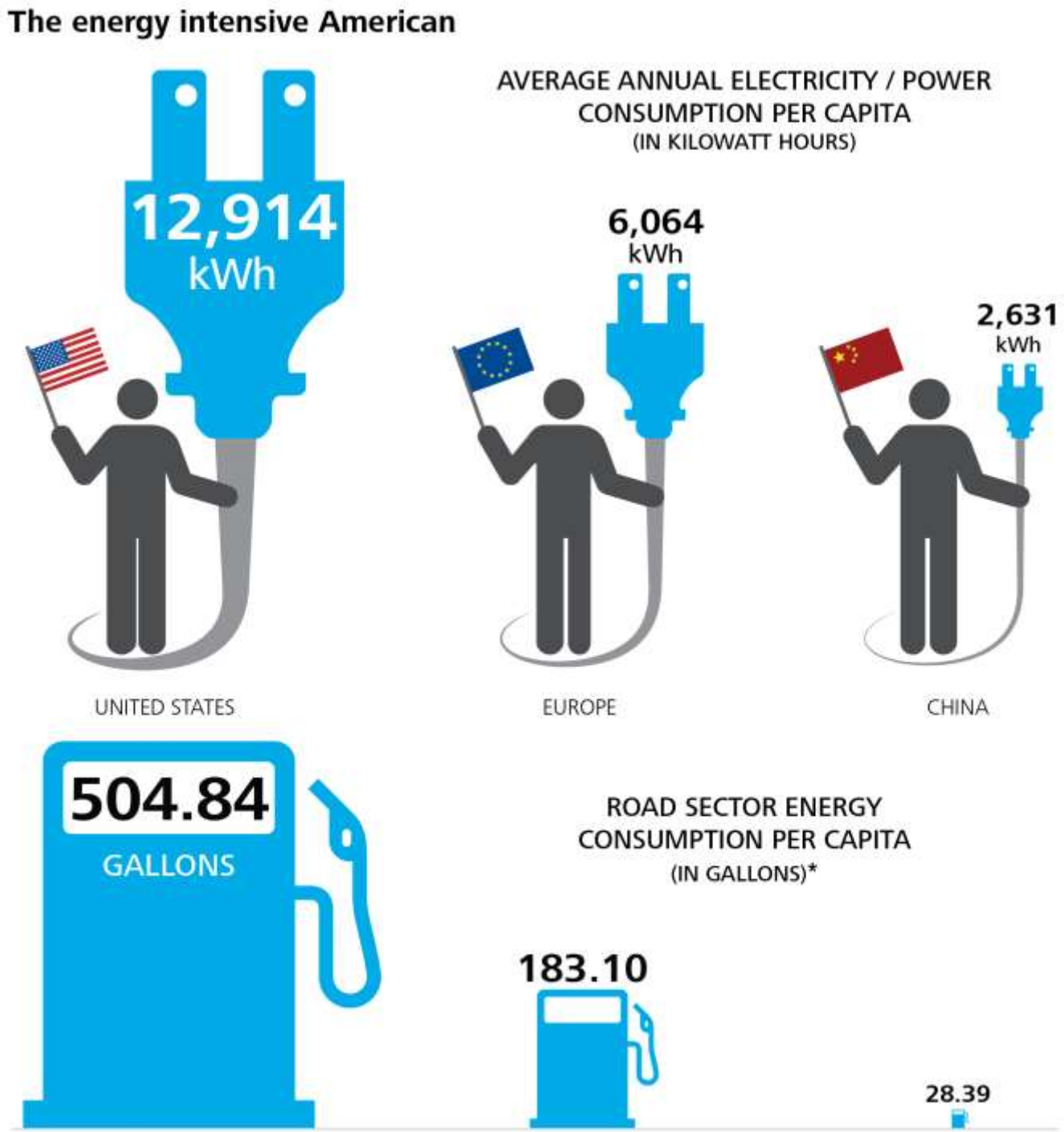
U. S. Department of the InteriorGeological Survey Open-File Report 97-463

MAJOR OIL PRODUCERS AND CONSUMERS



Source: BP Statistical Review of World Energy 2004 <http://www.bp.com/statisticalreview2004>

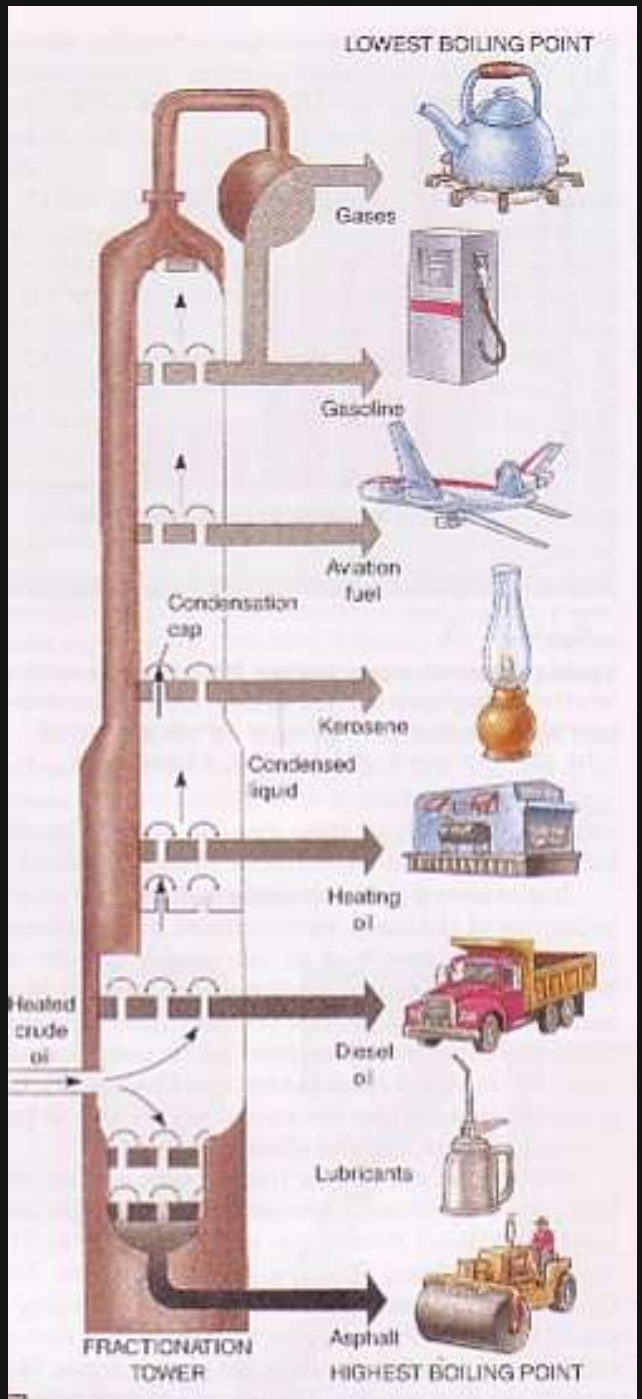
The energy intensive American



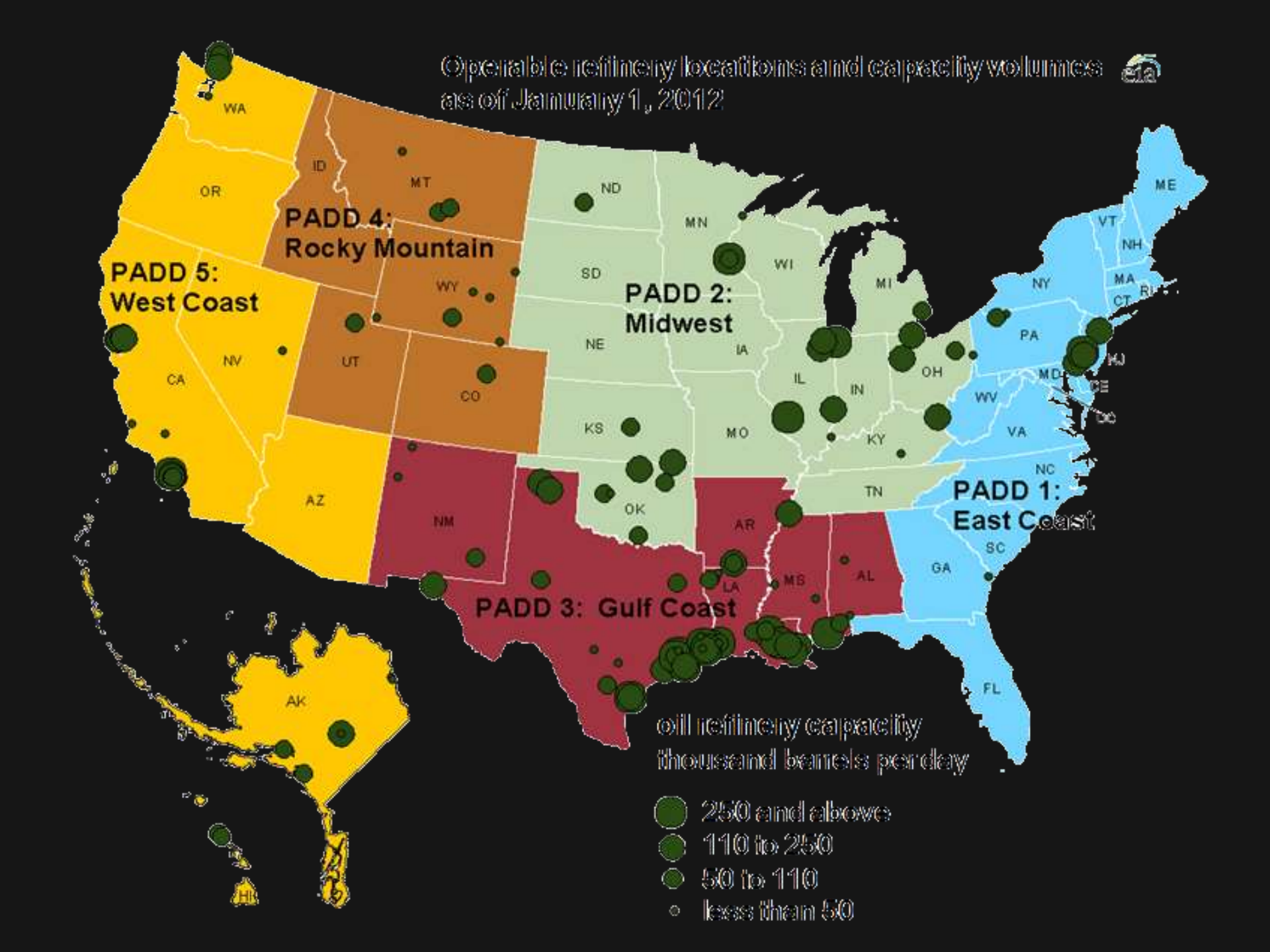
Petroleum is refined

- Crude oil is separated into different components in a **fractionation tower = use different boiling points to separate fuels**

https://www.youtube.com/v/s9Pzz44fAoE



Most US refineries are in Texas and Louisiana


Operable refinery locations and capacity volumes as of January 1, 2012
eia
PADD 5: West Coast
PADD 4: Rocky Mountain
PADD 2: Midwest
PADD 1: East Coast
PADD 3: Gulf Coast
WA
OR
CA
ID
NV
MT
WY
UT
AZ
CO
NM
ND
SD
NE
KS
OK
TX
MN
IA
MO
AR
LA
WI
IL
MS
MI
IN
KY
TN
AL
OH
WV
VA
NC
SC
GA
FL
PA
NY
MD
DE
NJ
CT
RI
MA
VT
NH
ME
AK
HI
oil refinery capacity
thousand barrels per day
250 and above
110 to 250
50 to 110
less than 50

History

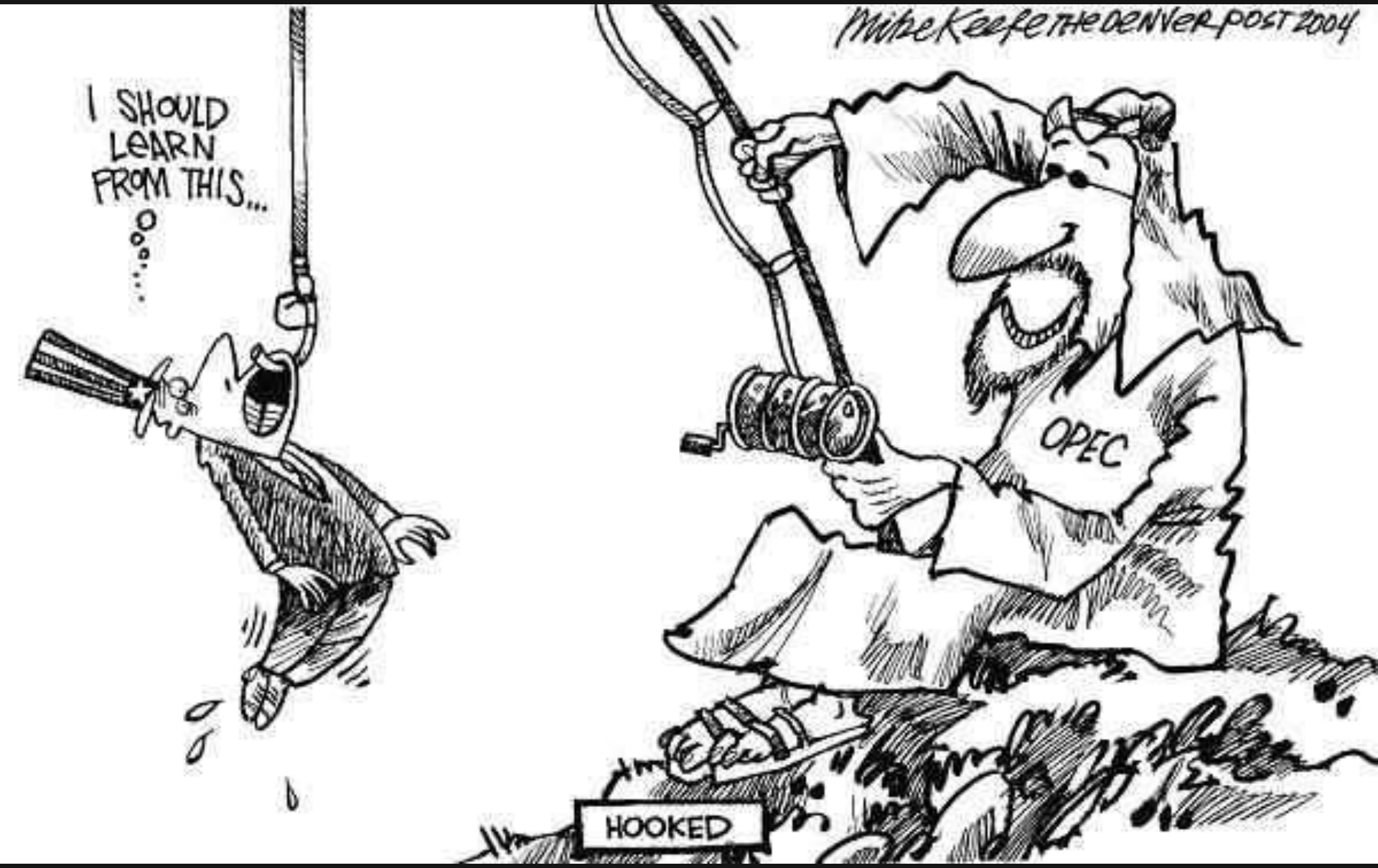
- 1950 – present = The US economy became dependant upon oil (primarily because of automobiles)
- 1960 = OPEC was formed (Organization of Petroleum Exporting Countries) by Iran, Iraq, Kuwait, Saudi Arabia, and Venezuela
- 1970 Domestic (crude oil and natural gas) production in US peaked → Most of our oil is imported from foreign companies

Oil and the Economy

- 1973 US supports Israel in the Arab-Israeli War.
- OPEC cut oil supplies → Recession

Oil and the Economy

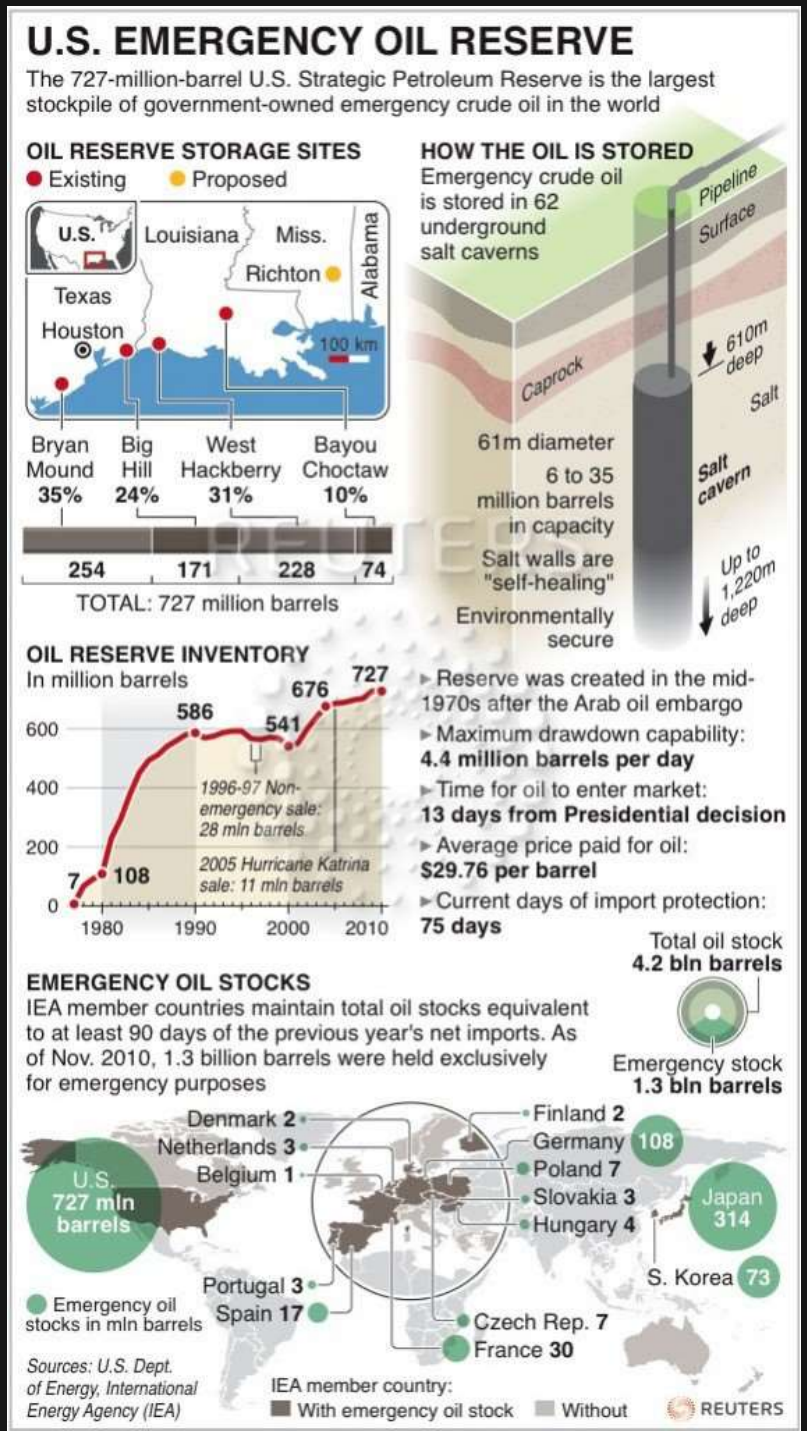
- 1979 The overthrowing of the Shah in Iran (a friend of the West) → Oil Crisis
- Crude went from $13 - $34 /barrel → Recession


I SHOULD LEARN FROM THIS...
Mike Keefe THE DENVER POST 2004
OPEC
HOOKED

Legislation

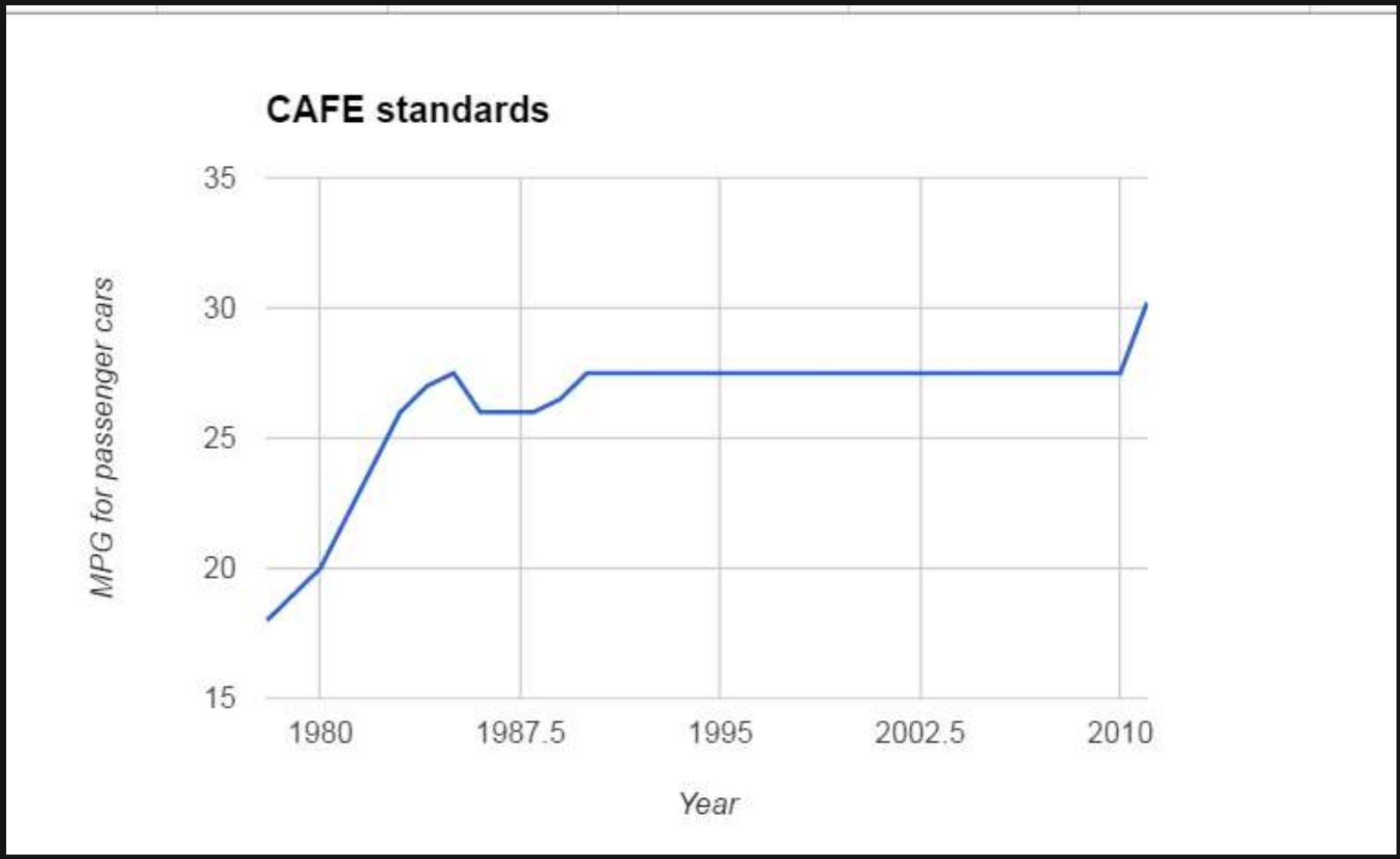
- Presidents Nixon and Ford →
- Energy Policy and Conservation Act (1975)
  - Strategic petroleum reserves
  - CAFE standards
  - Daylight savings
  - Changed federal speed limit to 55mph

Strategic reserves → ~75 days

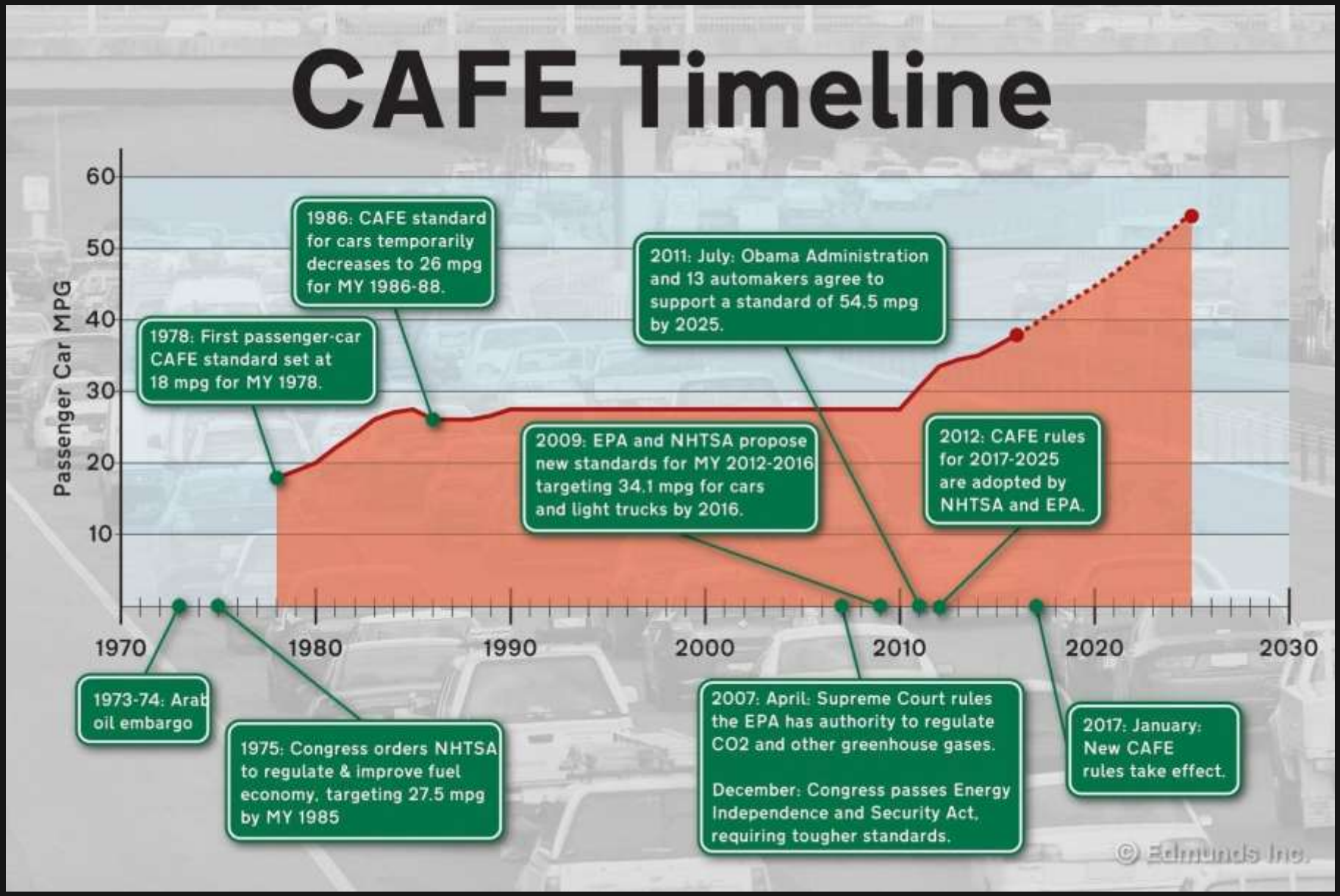


CAFE Standards

- Corporate average fuel economy standards



CAFE Timeline



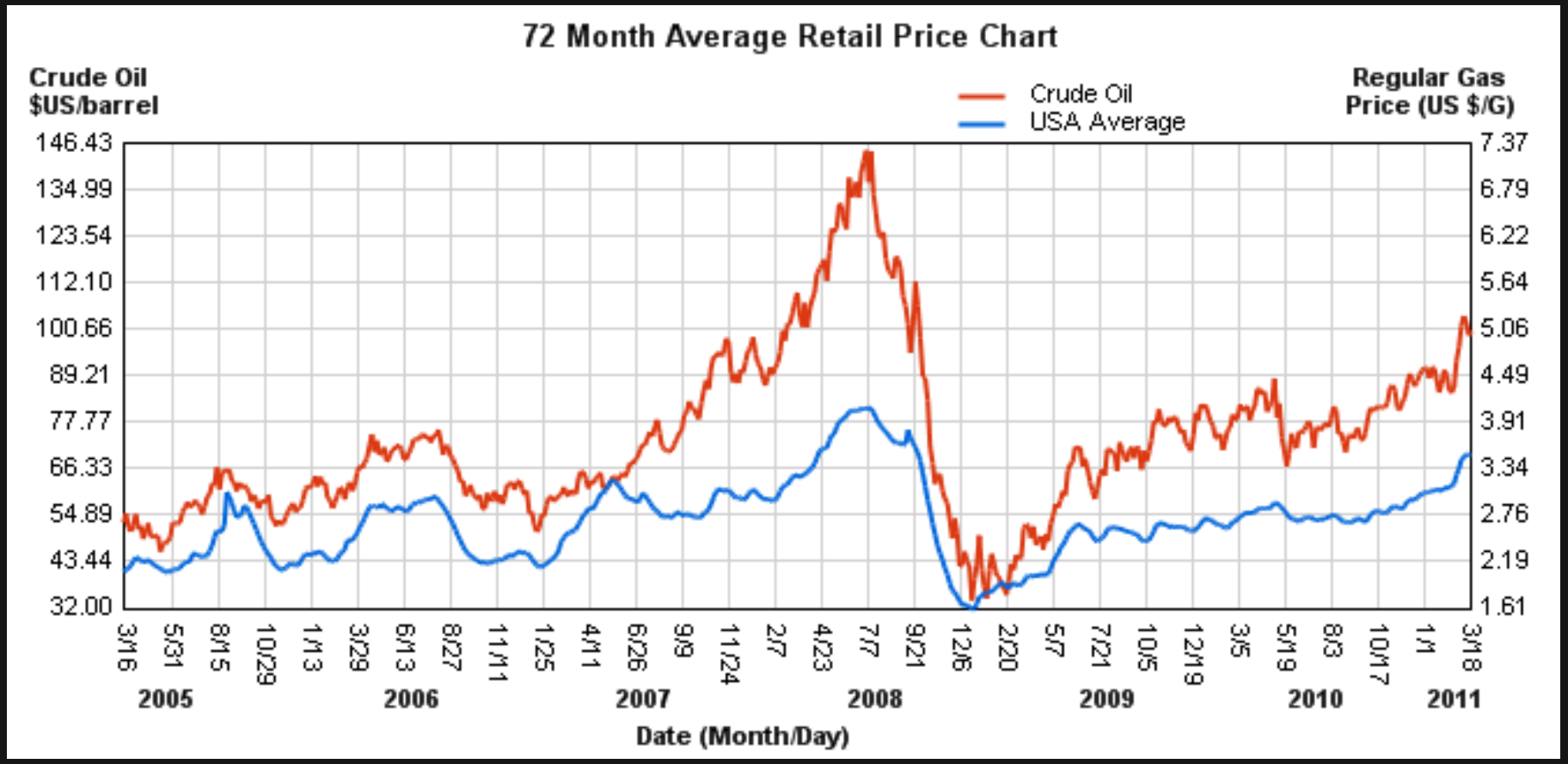
1990's and early 2000's

- US petroleum consumption continued to rise due to increase in automobiles and SUV's
- Foreign oil imports have more than doubled (Leading suppliers = Can., Saudi Arabia, Venezuela, Mexico, and Nigeria)

2005

- Record hurricane season caused massive damage to US oil and gas production infastructure
- ISSUE =
- Most of US oil refineries are in the Gulf region
- Unstable gas prices

2008 → more competition



Followed by global recession

(EISA) Energy Independence and Security Act 2007

- Increased renewable fuel standards (RFS) for transportation fuels (ex: ethanol for gasoline engines, and biodiesel)
- (10%) at the pumps and up to 85% for flex fuel vehicles

Sources of ethanol

- Corn in the US and
- Sugar cane in Brazil
- More sustainable options for the future
- Cellulosic ethanol (from grasses and woody biomass)

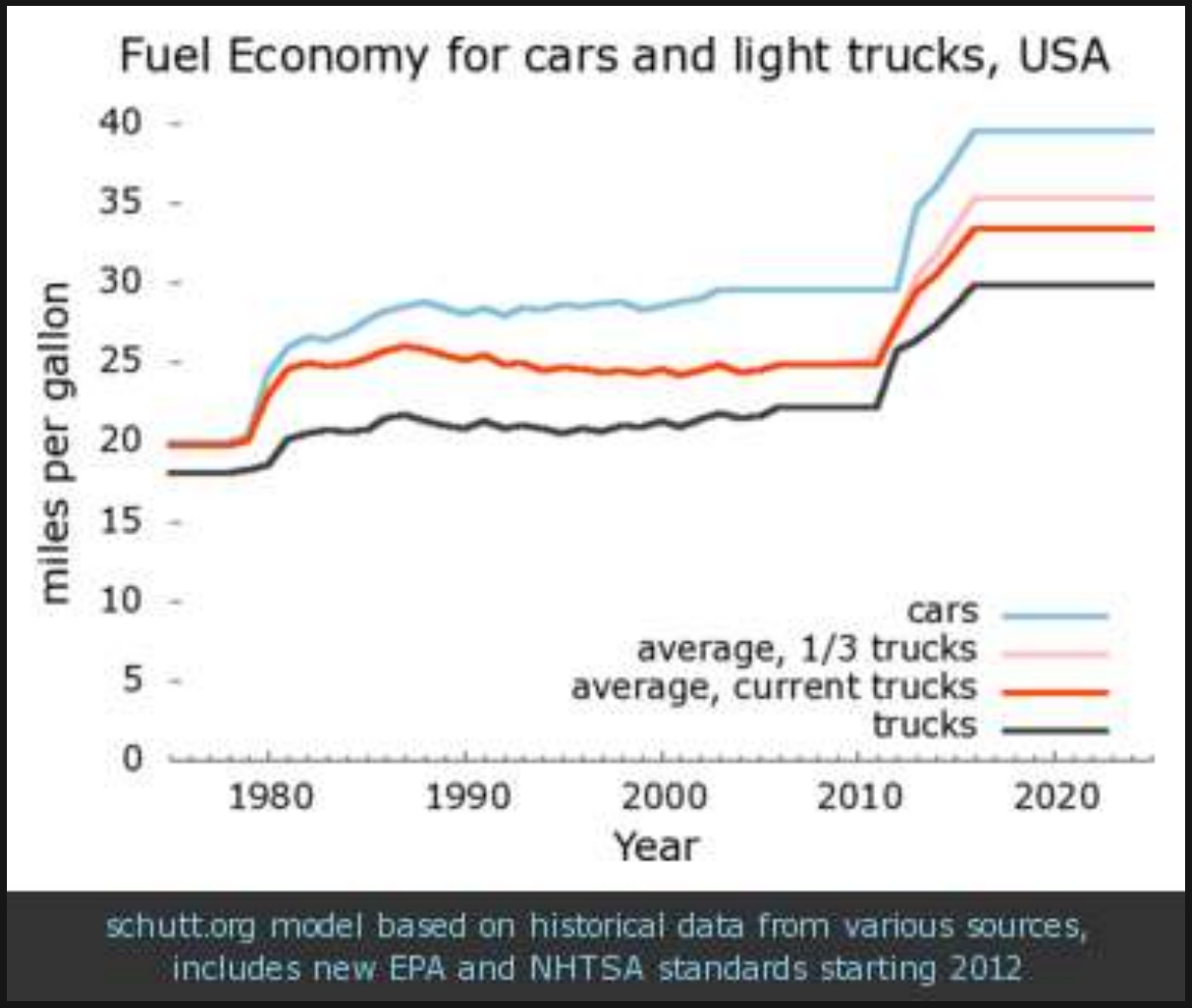
Ethanol issues

- Most ethanol in US comes from corn
- = dependent on fossil fuels and
- Need lots of arable land and water → corn.
- Need to develop ethanol from cellulosic feedstocks (ex: crop residuals, switch grass, wood chips…)
- https://www.youtube.com/watch?v=AzqLJF-uq6o&t=56s

RFS apply to biodiesel as well

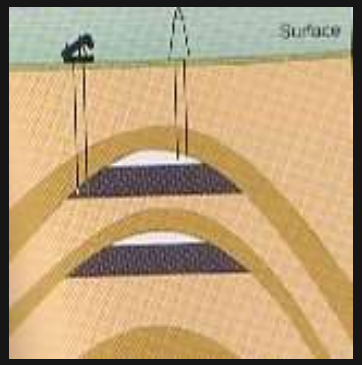
- Biodiesel can be made from oily crops, waste oil, or microalgae.

2011 Obama → new CAFE standards

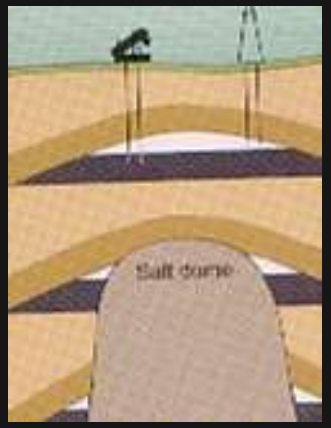


Finding oil and natural gas deposits

- Anticlines = upward layering of rock



- Salt Domes = underground columns of salt



Easy Oil = a thing of the past

- Extracting oil is becoming more and more difficult and expensive

- Technologies that used to be too expensive and difficult are becoming common place
  - Deep well offshore drilling
  - Tar sands

Heavy Oils from Oil Sand and Oil Shale:

- Heavy and tarlike oils increase supplies but there are environmental tradeoffs
  - High sulfur content.
  - Extracting and processing produces:
    - Toxic sludge
    - Uses and contaminates larges volumes of water
    - Requires more energy to produce

Oil Shales

- Oil shales contain a solid combustible mixture of hydrocarbons called ***kerogen***.

Figure 16-9

Heavy Oils

- It takes about 1.8 metric tons of oil sand to produce one barrel of oil.

Figure 16-10

Synthetic fuels or synfuels

- Derived from coal and other naturally occurring sources
  - Include:
    - Tar sand, oil shales, gas, hydrates,
    - liquid coal and coal gas (a way to use coal as an alternative to gasoline, cleaner than burning regular coal)
  - Energy intensive to make → more expensive
  - Same problems with other fossil fuels

Alberta tar sands

Tradeoff = drilling and transporting crude → spills and accidents

- https://www.youtube.com/watch?v=QiF-X-Ez9Bs
- http://video.foxbusiness.com/v/4249607689001/california-oil-spill-a-setback-for-the-keystone-pipeline/?#sp=show-clips

Historic accidents

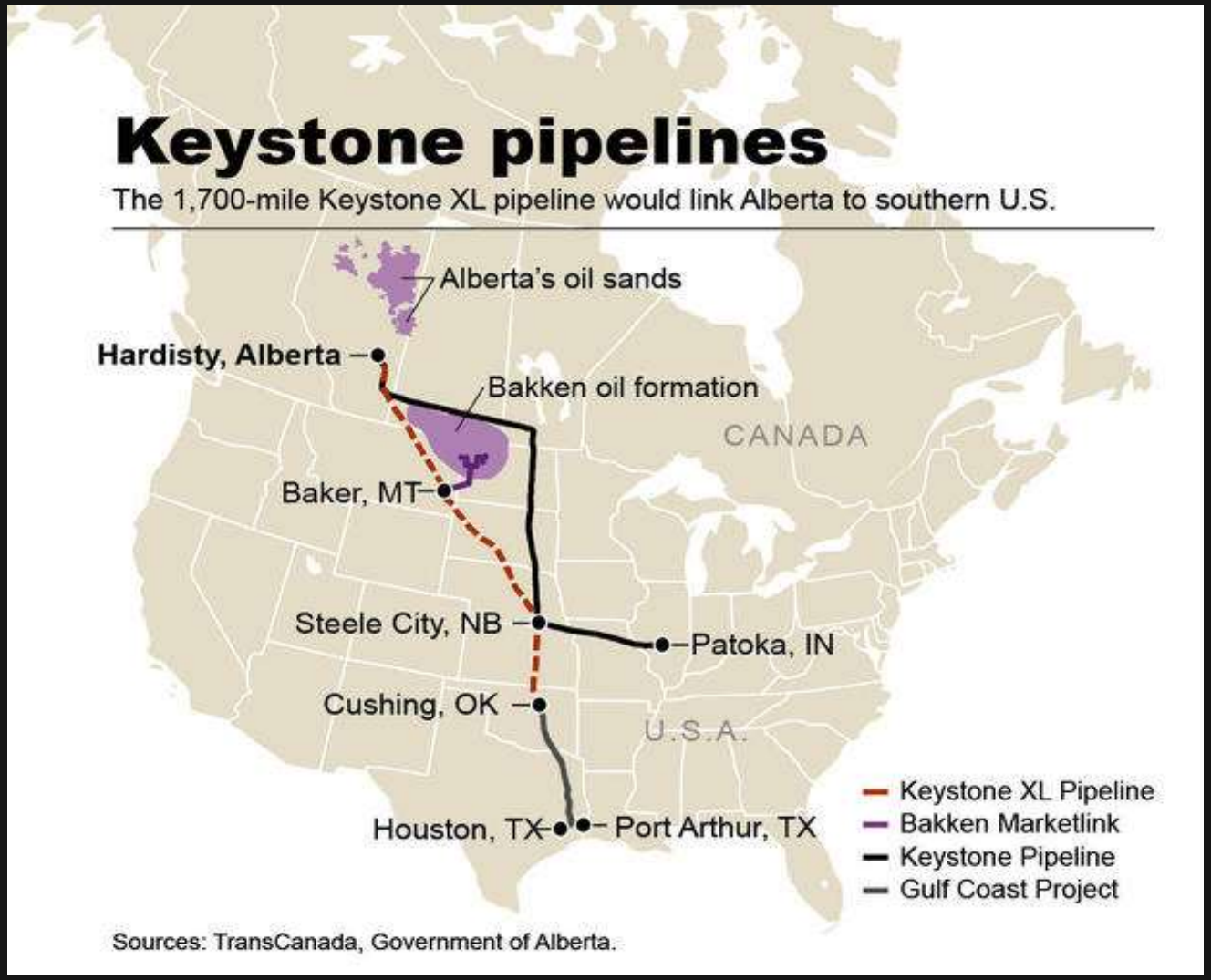
- Tanker crash → 1989 Exon Valdeez Alaskan oil spill

- 1991 Persian Gulf oil spill (one of the largest in world history)

2010 Oil Spill in the Gulf

- Deep well rig explosion led to leak → flowed for 3 months
- Largest in history
  - Released 205.8 million gallons of crude oil
  - 80-square-mile (210 km^2) "kill zone" surrounding the blown BP well where "it looks like everything is dead" on the seafloor

In the news today



Dakota Pipeline

Pipelines

- Pros
- Jobs
- Pipelines = cheaper and safer than rails

- Cons
- Temporary jobs
- Construction → short term disturbances to towns and ecosystems
- Long term environmental risks
- Diverts funding from renewable energy projects

NEPA requires EIS

- NEPA = National Environmental Policy Act (1970)

- Created the EPA
- Requires all federal construction projects to submit **environmental impact statements**

Pipeline oil spill cleanup

How to prevent / clean up spills

- Build better pipelines
- Oil Pollution Act (1990) requires use of double hull tanker ships

Comprehensive Environmental Response Compensation and liability Act of 1980 (CERCLA) = Superfund Law

- Requires polluters to pay for cleanup
- Creates a superfund to help clean up hazardous waste sites on the National Priorities List

Bioremediation = use bacteria to clean up oil spills

Problems associated with burning petroleum

- CO_2 emissions → global warming
- Nitrogen oxide emissions → acid rain and photochemical smog

NATURAL GAS

- NATURAL GAS = NONRENEWABLE gas made mostly of methane
  - found deep underground near crude oil reserves
  - gasses are liquefied and removed as liquefied petroleum gas (LPG).
- Fracking = technique to extract natural gas

Issues with Hydrolic Fracturing (aka: Fracking)

- From Fracking video

Fracking

NATURAL GAS

- Russia and Iran = half of the world's reserves of conventional gas
- US has large reserves
- Global reserves should last 62-125 years.

- Natural gas = cleaner than coal & gasoline
- No nitrates, sulfates, or particulates but → greenhouse gases carbon dioxide (when burned) and methane (from leaks).

NATURAL GAS

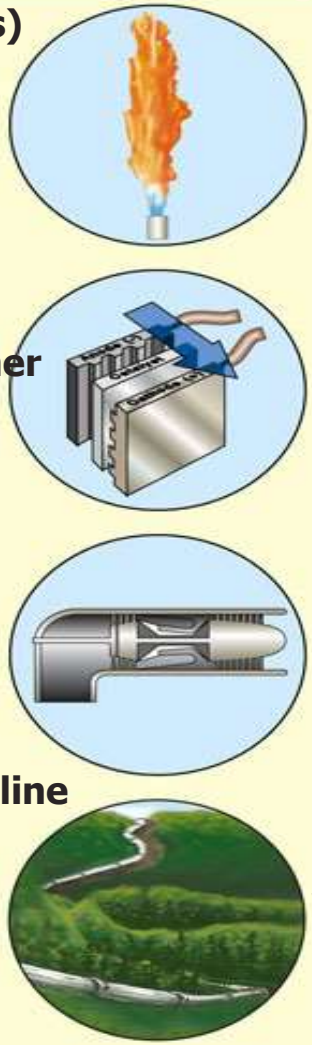
- Used primarily for heating
- Compressed natural gas can be used in vehicles

- Note:
- Renewable natural gas (RNG) is produced from anaerobic digestion of organic material

Trade-Offs

Conventional Natural Gas

Advantages	Disadvantages
Ample supplies (125 years)	Nonrenewable resource
High net energy yield	Releases CO_2 when burned
Low cost (with huge subsidies)	Methane (a greenhouse gas) can leak from pipelines
Less air pollution than other fossil fuels	Difficult to transfer from one country to another
Lower CO_2 emissions than other fossil fuels	Shipped across ocean as highly explosive LNG
Moderate environmental impact	Sometimes burned off and wasted at wells because of low price
Easily transported by pipeline	Requires pipelines
Low land use	
Good fuel for fuel cells and gas turbines	



Diesel

- Diesel comes from crude oil
- Diesel = more efficient than gasoline
  - (more miles per gallon) BUT more polluting
- Biodiesel can be made from oil
- Produces more particulate matter, NOx, and sulfur than regular gasoline
  - (more air pollutants per gallon)

Conversion from Diesel to CNG

- CNG vehicles are quieter and cut particulate emissions by 95%, CO by 75%, and NOx by 15%
- Domestic natural gas supply plus potential for renewable natural gas production → decreased fuel costs.
- Many technologies exist to convert current diesel vehicles to hybrid (Diesel / CNG) or to a complete CNG system

http://www.geo.cornell.edu/eas/energy/the_challenges/peak_oil.html