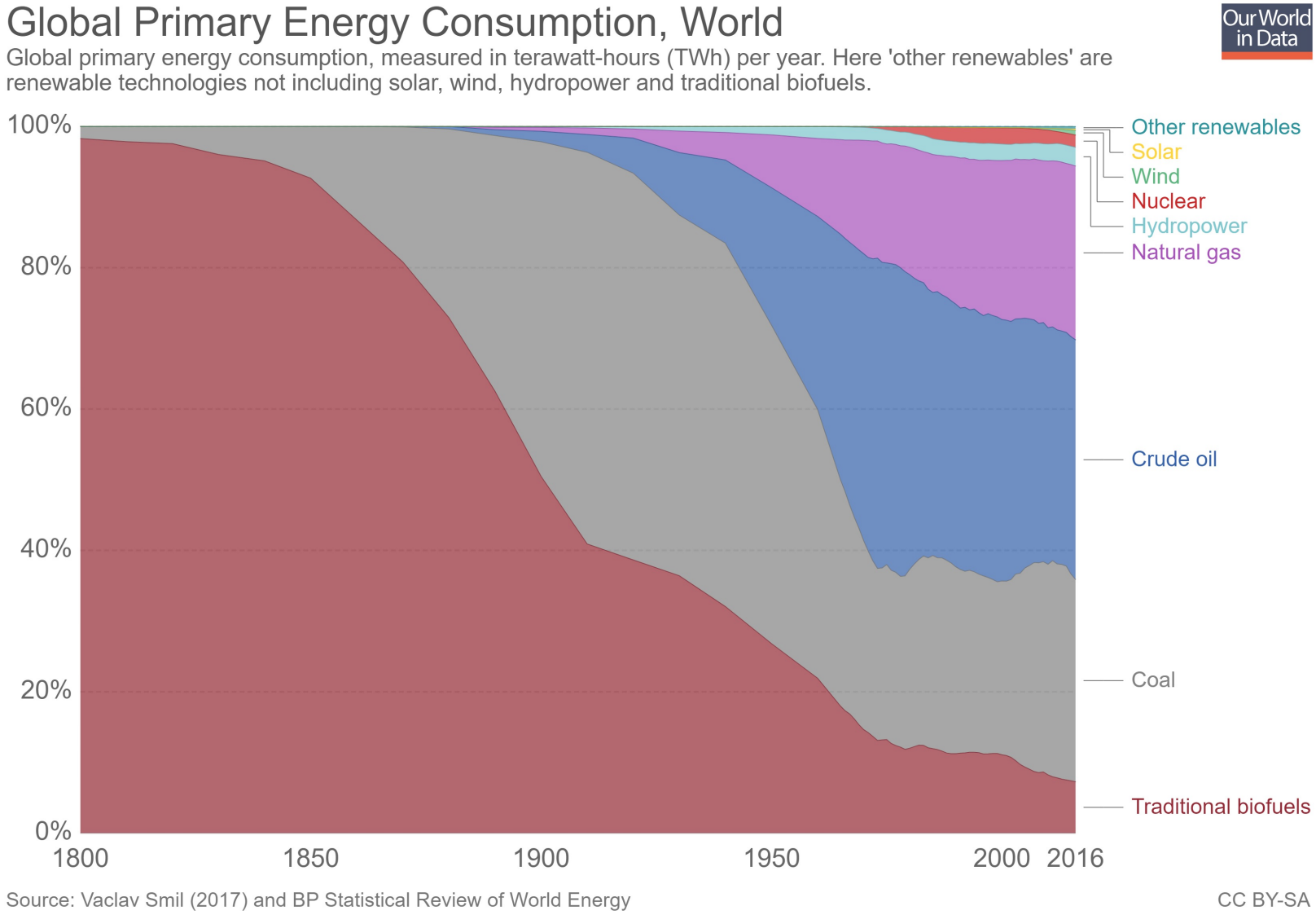

Fossil Fuels
+
Air Pollution
+
Climate Change

Outline

- Fossil Fuels
  - Coal
  - Petroleum
  - ‘Tight’ Oil & Natural Gas
- Air pollution
- Climate change

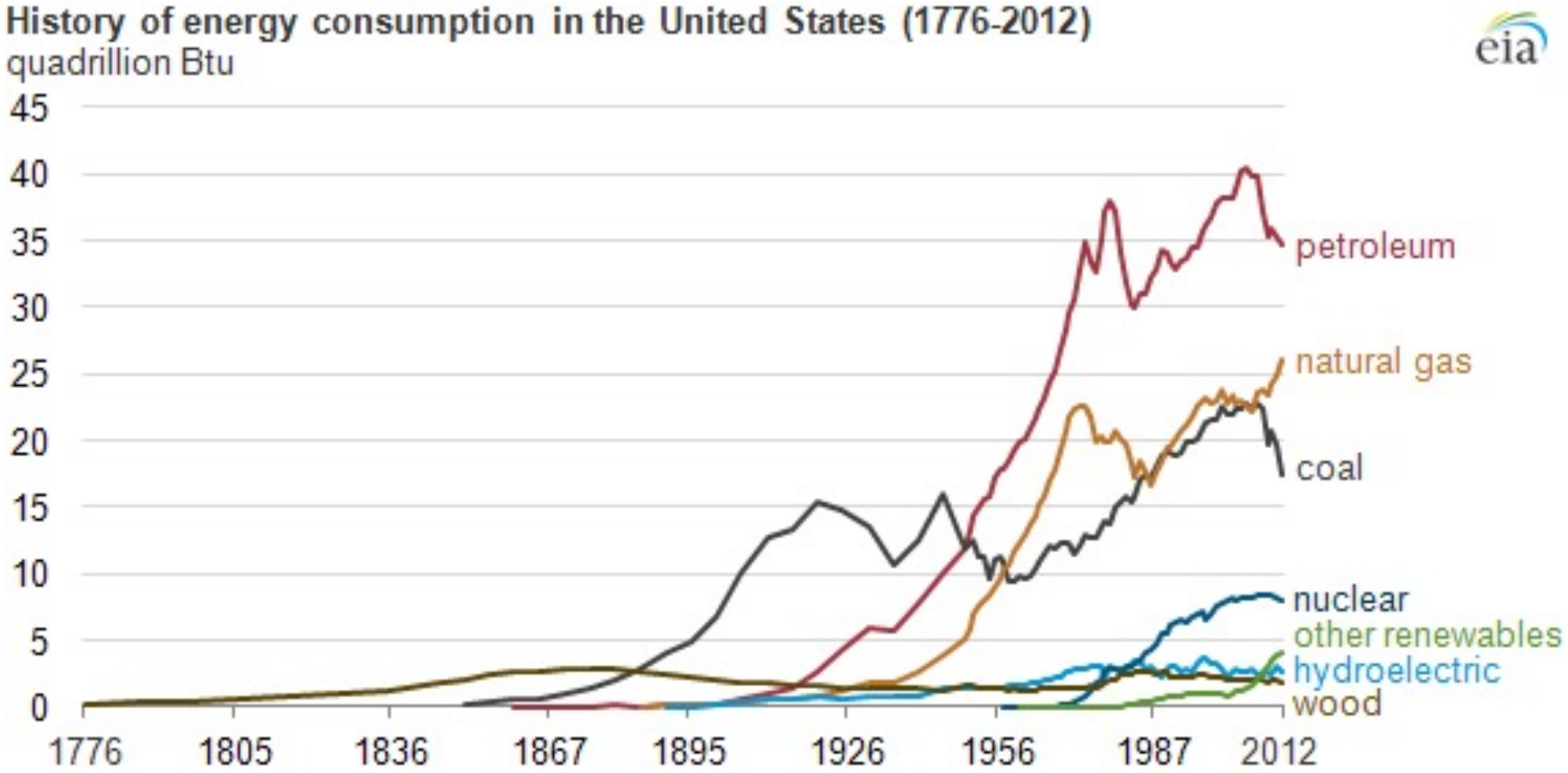
Fossil Fuels

What are fossil fuels?
How did they form?
How quickly are we using them?
How much is left?
Are there alternatives?



A shift from using traditional biofuels (burning wood and other organic matter) to using coal, oil, natural gas, which now provide 90% of energy consumed worldwide

Source: https://ourworldindata.org/energy-production-and-changing-energy-sources



Source: eia.gov

Total energy consumption in the US 1950-2012:
The biggest rise from natural gas and oil

Renewable v. non-renewable

- **Renewable resources:** replenished rapidly, at a rate equal to or greater than the rate at which we use them. *Example*: a well-managed forest, where trees are not cut faster than they grow back.
- **Non-renewable resources:** replenished more slowly if at all, such that we are using *up* the resources as we use them. *Example*: deposits of gold, which would not be regenerated except over geologic time scales, of 10s-100s of millions of years. As we extract these resources they are gone forever (from our perspective).

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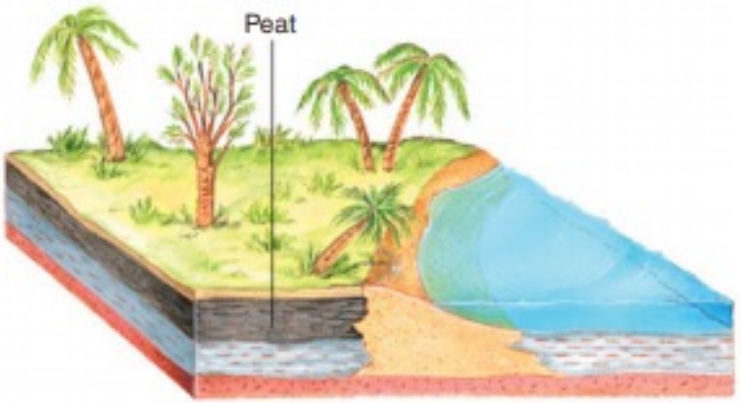
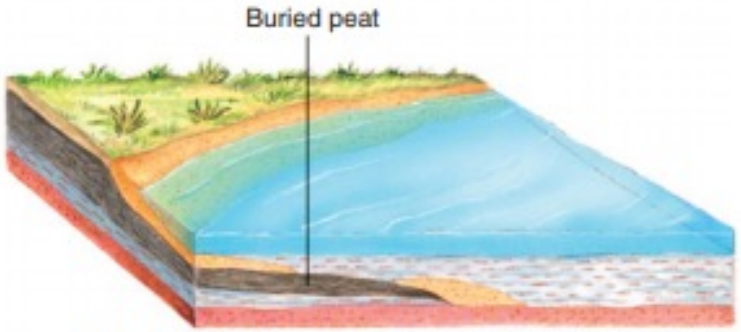
  - **Coal**
  - Petroleum
  - ‘Tight’ Oil & Natural Gas
- Air pollution
- Environmental justice
- Climate change

Coal

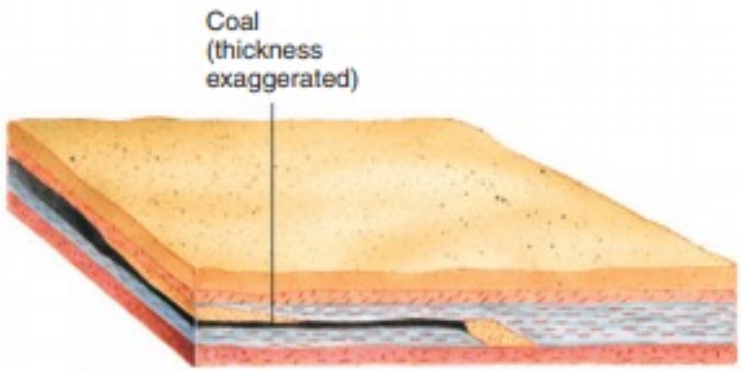
- Forms from terrestrial (swamp) deposits
- Slow transformation with burial peat - lignite – coal
- Different types of coal depending on energy and sulfur content: lignite subbituminous, bituminous, anthracite



Coal swamps form.



Rise in sea level buries swamps in sediment.



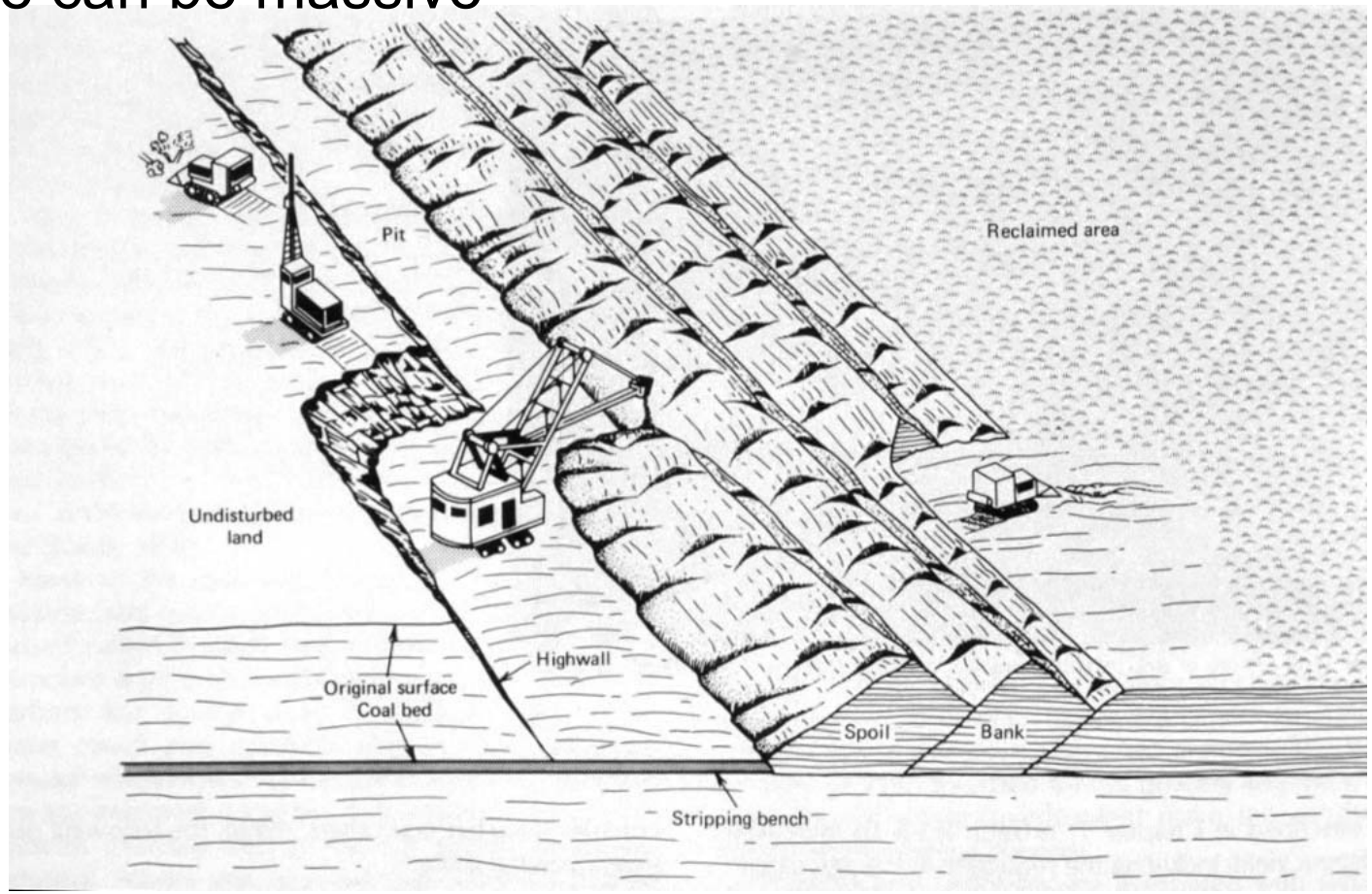
Compression of peat forms coal.

Coal - Extraction

Underground mine following a coal seam (Utah)
note train tracks right up to mine, heavy bulk product to ship

Strip mining

- Remove ‘overburden’ (rock & soil overlying coal seam)
- Remove the coal
- Regrade landscape using the removed overburden material
- Scale can be massive



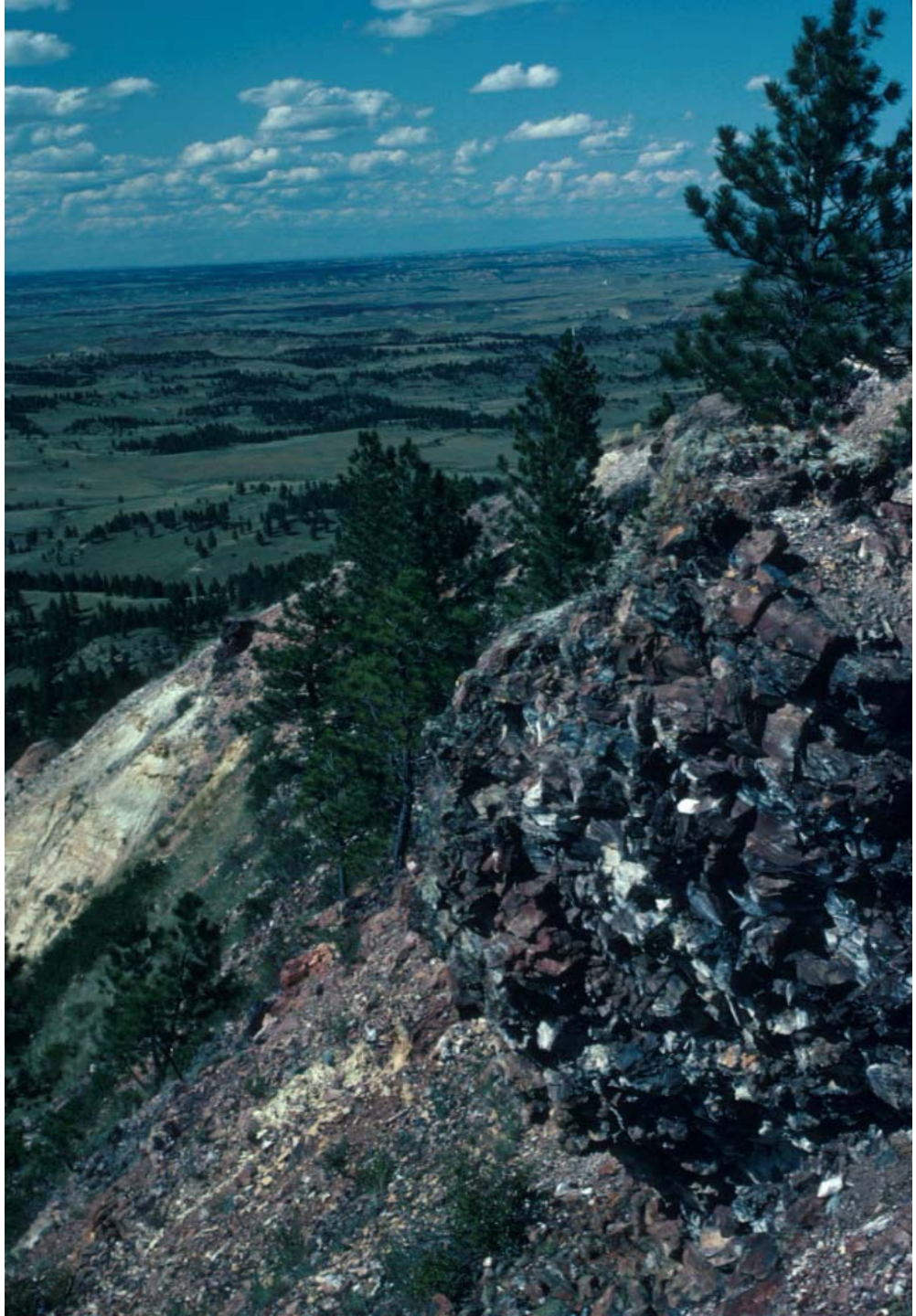
Large strip mine in Germany

And the ‘reclaimed’ landscape post-mining

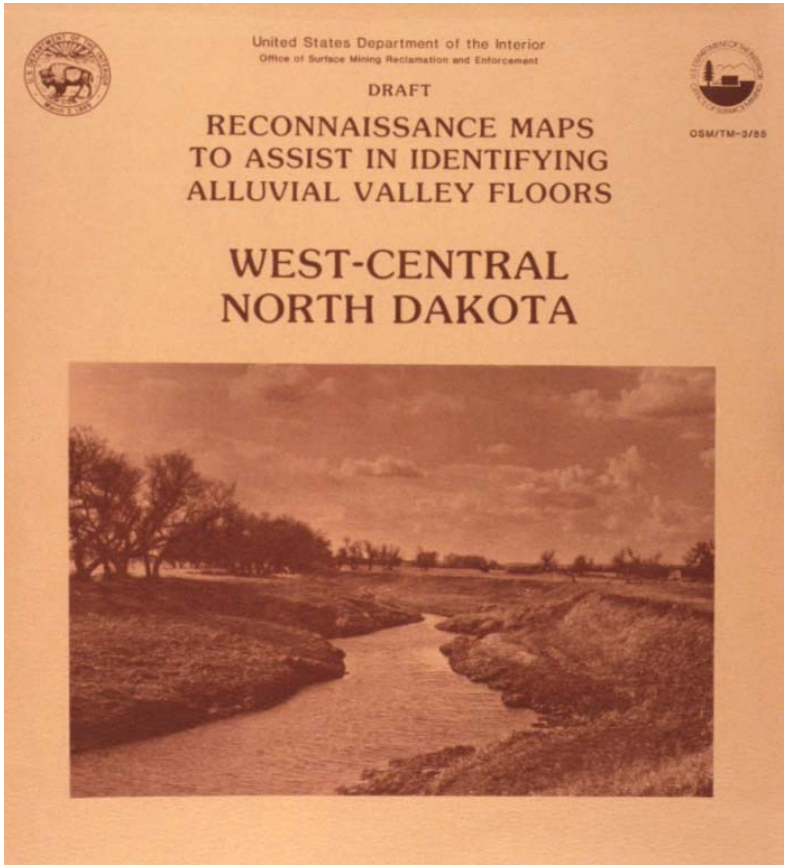
Western strip mines are at a huge scale

Example: Powder River Basin, eastern Wyoming

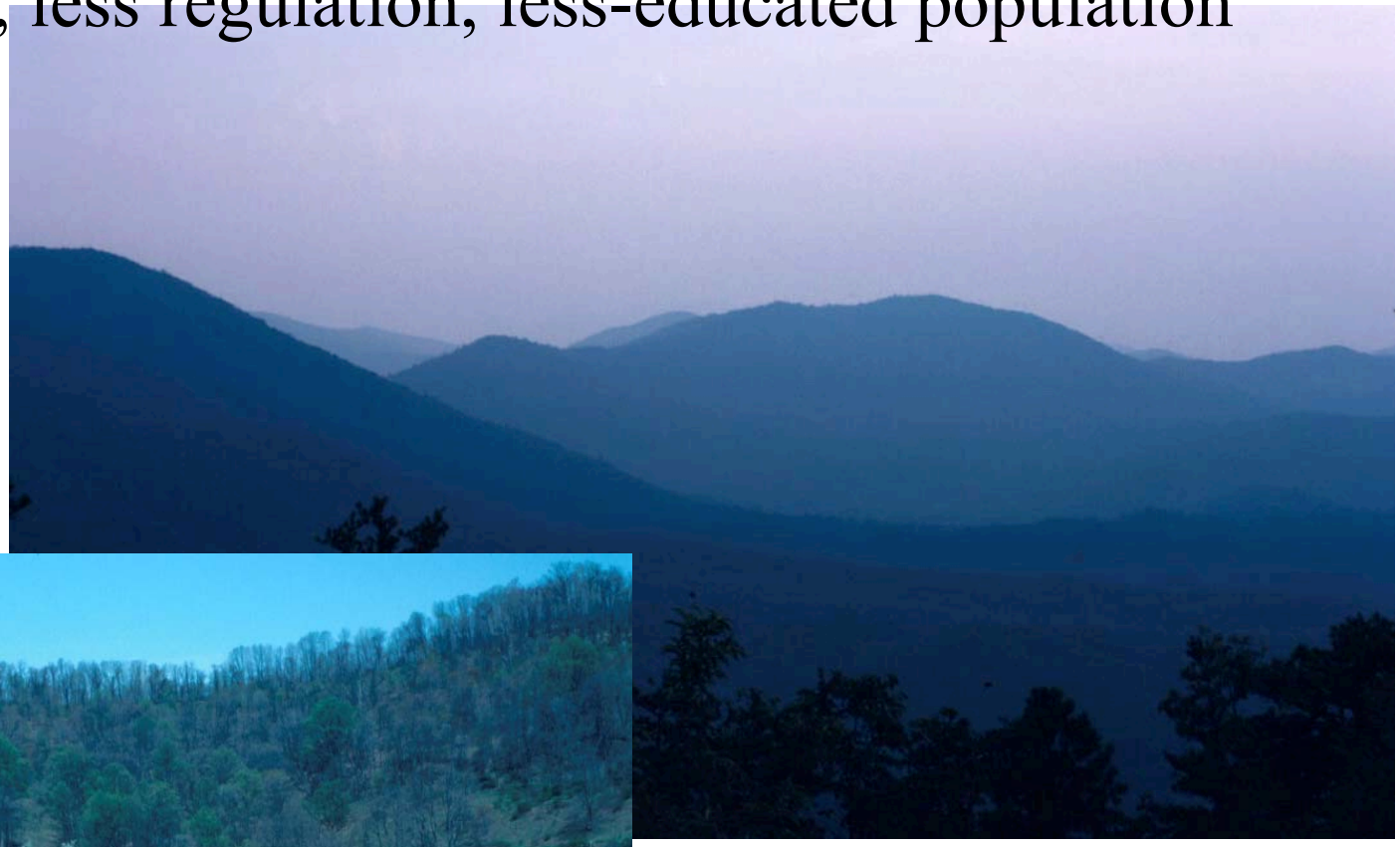
The 'snake' in the photo is a train of continuous coal cars



The Powder River Basin of eastern Wyoming, Montana, and western North Dakota



Contrast with the isolated valleys of the Appalacian Plateau: Smaller mines, less regulation, less-educated population



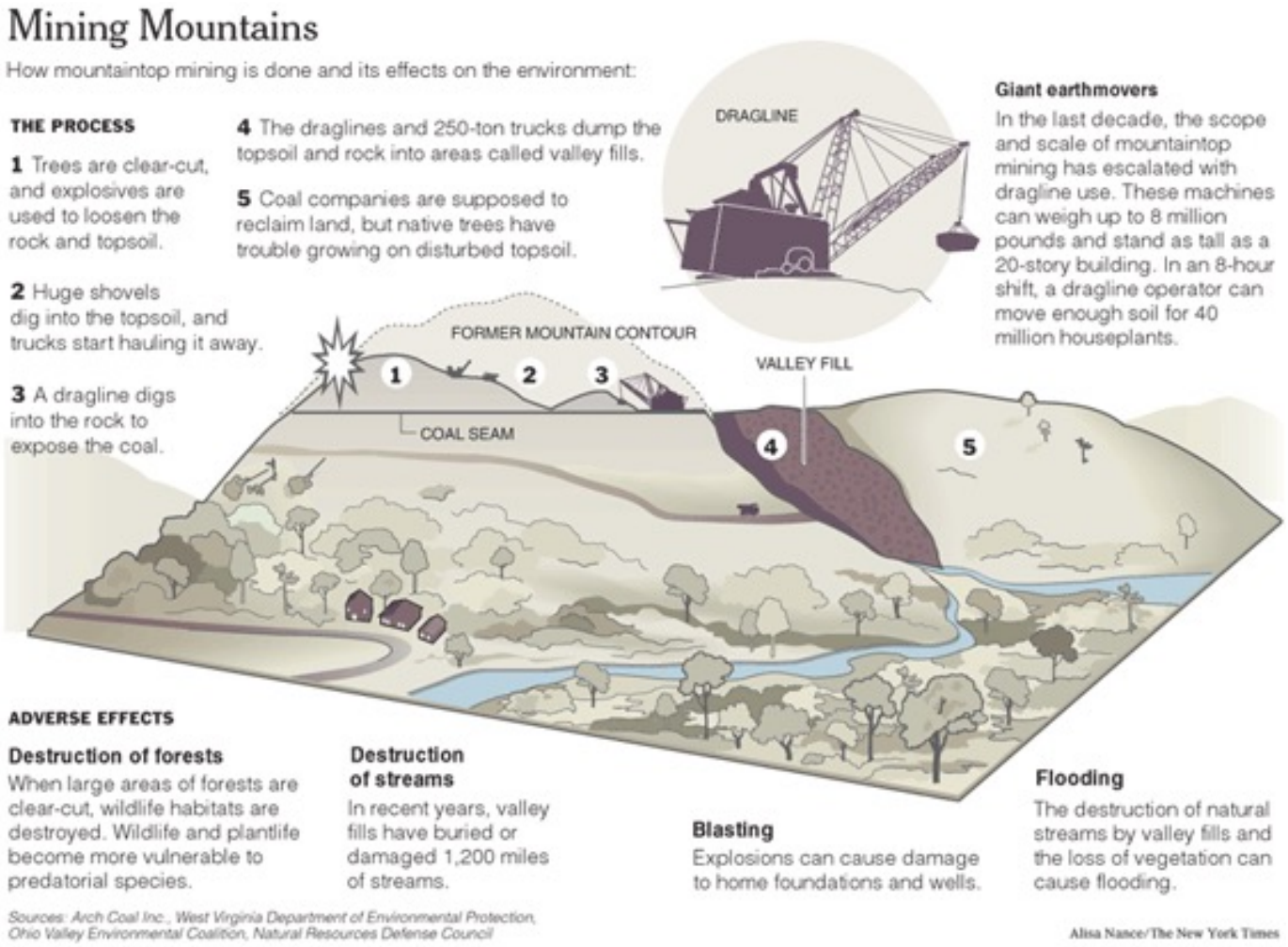
Wells have dried up because mines have drained aquifers

Acid-mine drainage “yellow boy”

in West Virginia

and in Korea

“Mountaintop Removal” (a type of strip mining)



1. Trees are clear-cut and explosives are used to loosen the rock and topsoil.
2. Huge shovels dig into the topsoil and trucks haul it away.
3. A dragline digs into the rock to expose the coal.
4. The dragline and 250-ton trucks dump the topsoil and rock into “valley fills” (ie completely filling in stream valleys).
5. Coal companies are supposed to reclaim land, but native trees have trouble growing on disturbed topsoil

Mountaintop Removal Issues

- Acid mine drainage, coal waste sludge (toxic)
- Sedimentation in rivers and behind dams increases flood risk
- Coal dust, public health hazards
- Permanently altering landscape!

Mountaintop removal in the Appalachians

A coal mine along the Yangtze River (before being flooded by 3 Gorges Dam)

Coal Combustion Products

- *Ideal combustion of coal:*

$C_5H_4O + 6O_2 \rightarrow 5\mathbf{CO_2} + 2H_20$ + energy vs.

Burning 1 ton coal gives off almost 3 tons CO2

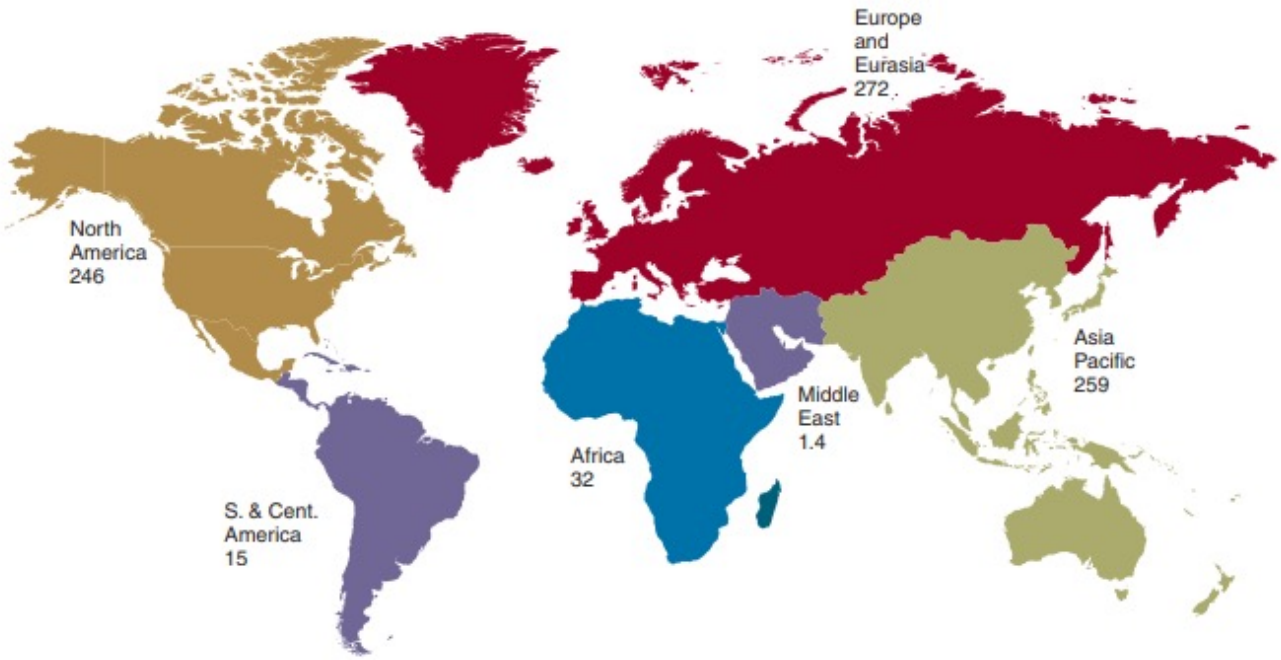
- *Real combustion of coal:*

Fuel(C,H,O,N,S,Hg, etc.) + air(O_2, N_2) → (CO_2, H_2O, CO, NO_X, SO_X, VOCs, particulates) + Hg + ash + … + energy

Coal is never 'pure' and its impurities produce noxious pollutants (in addition to CO2 emissions)

World Coal Reserves

US has about 30% of world coal, China even more – thus its high consumption and tremendous air pollution

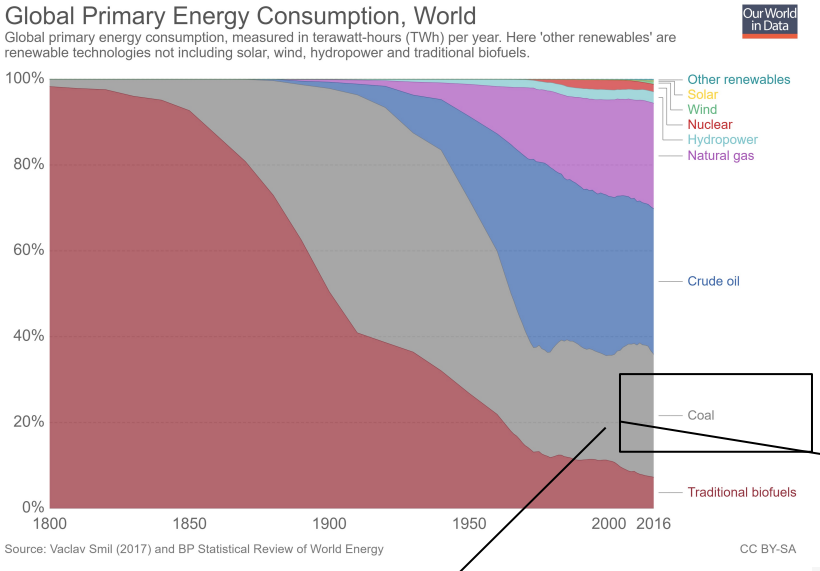


World Coal Reserves
Source: Botkin 2010

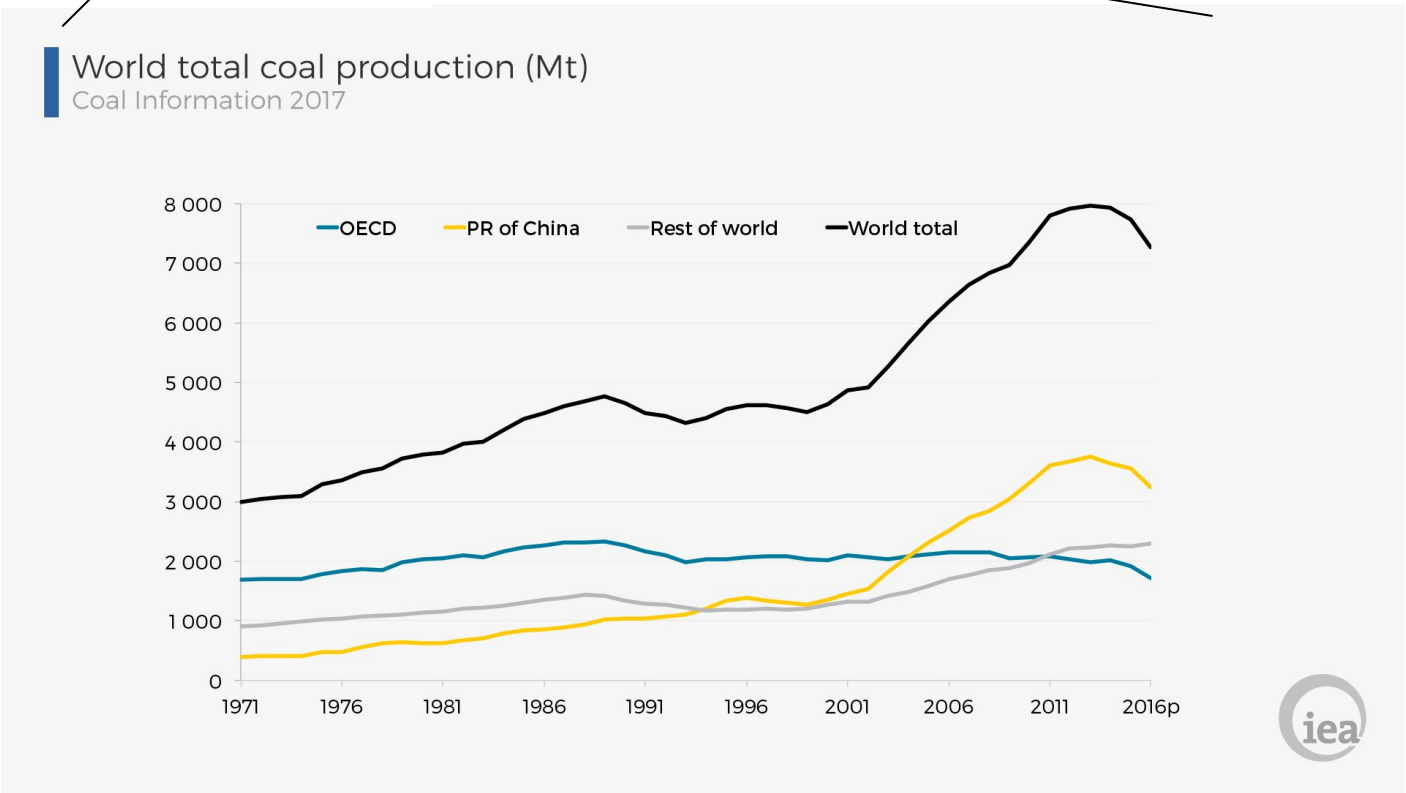
Estimated 825 billion metric tons of coal reserves remain …

At current consumption rate, coal could last **120 years**

World Coal Production

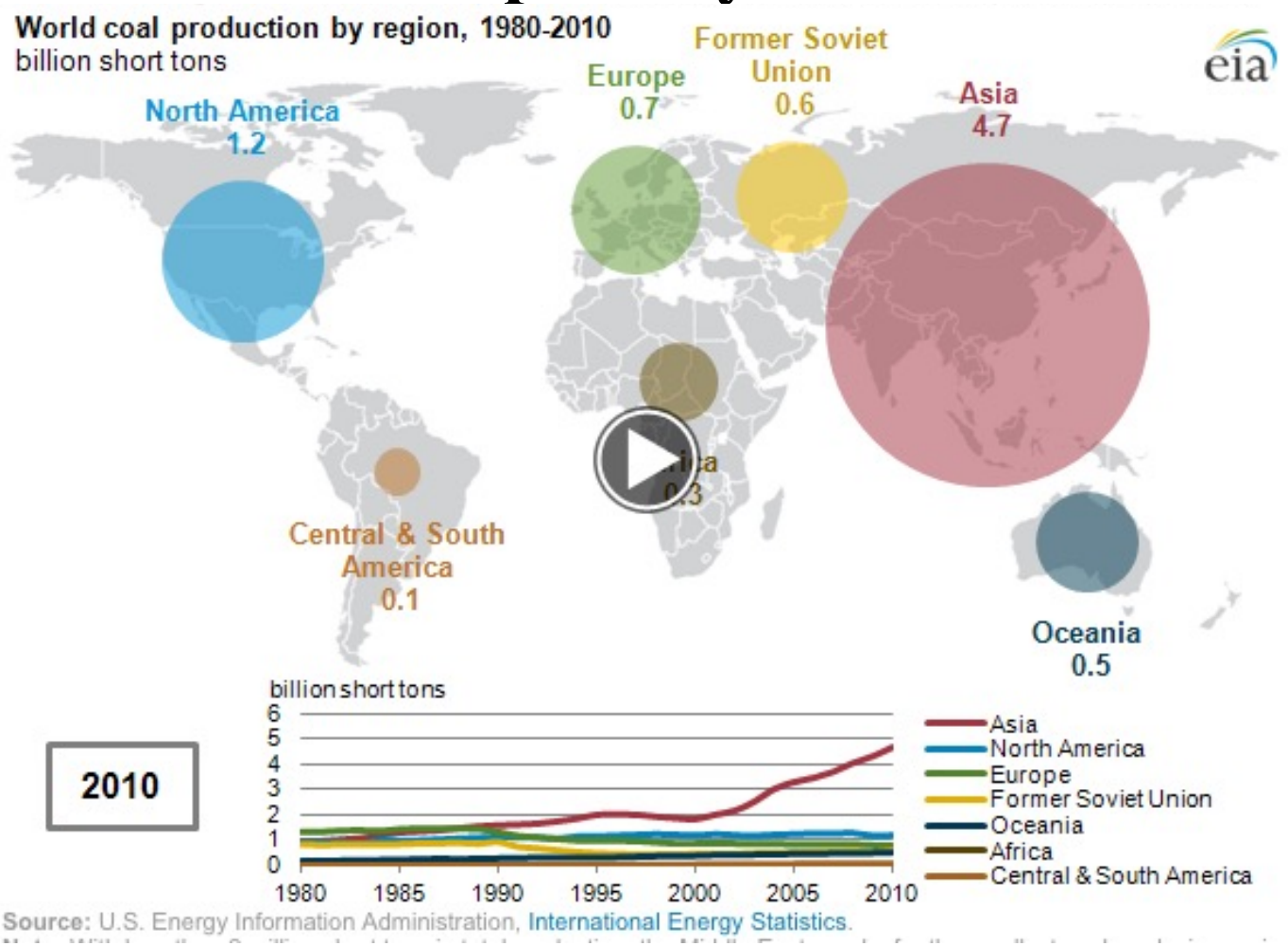


Increase since 1970's, decrease since 2012



https://www.iea.org/newsroom/energysnapshots/world-total-coal-production-1971-2016.html

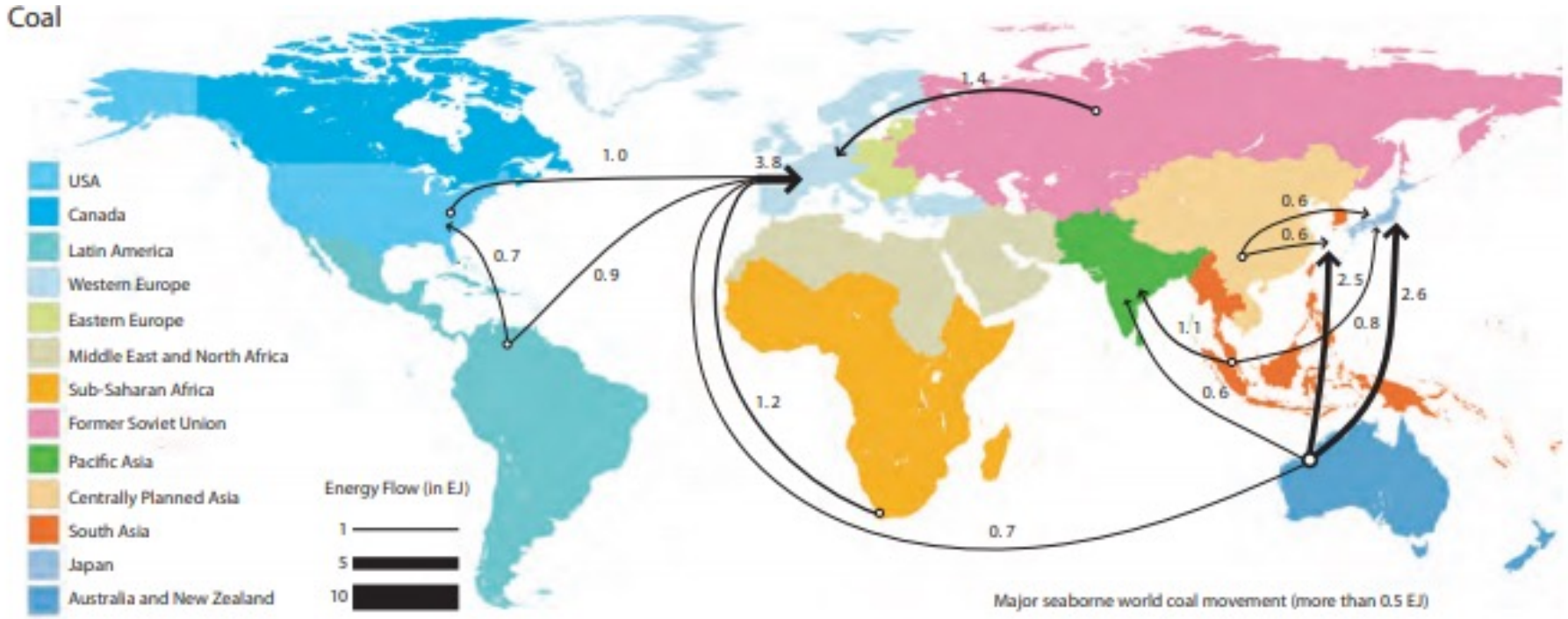
Share of Global Coal Consumption by Continent



Decrease in all continents since 2000 except Asia

http://www.eia.gov/todayinenergy/detail.cfm?id=4210

World energy trade of coal



Source: Global Energy Assessment - Toward a Sustainable Future (2012)

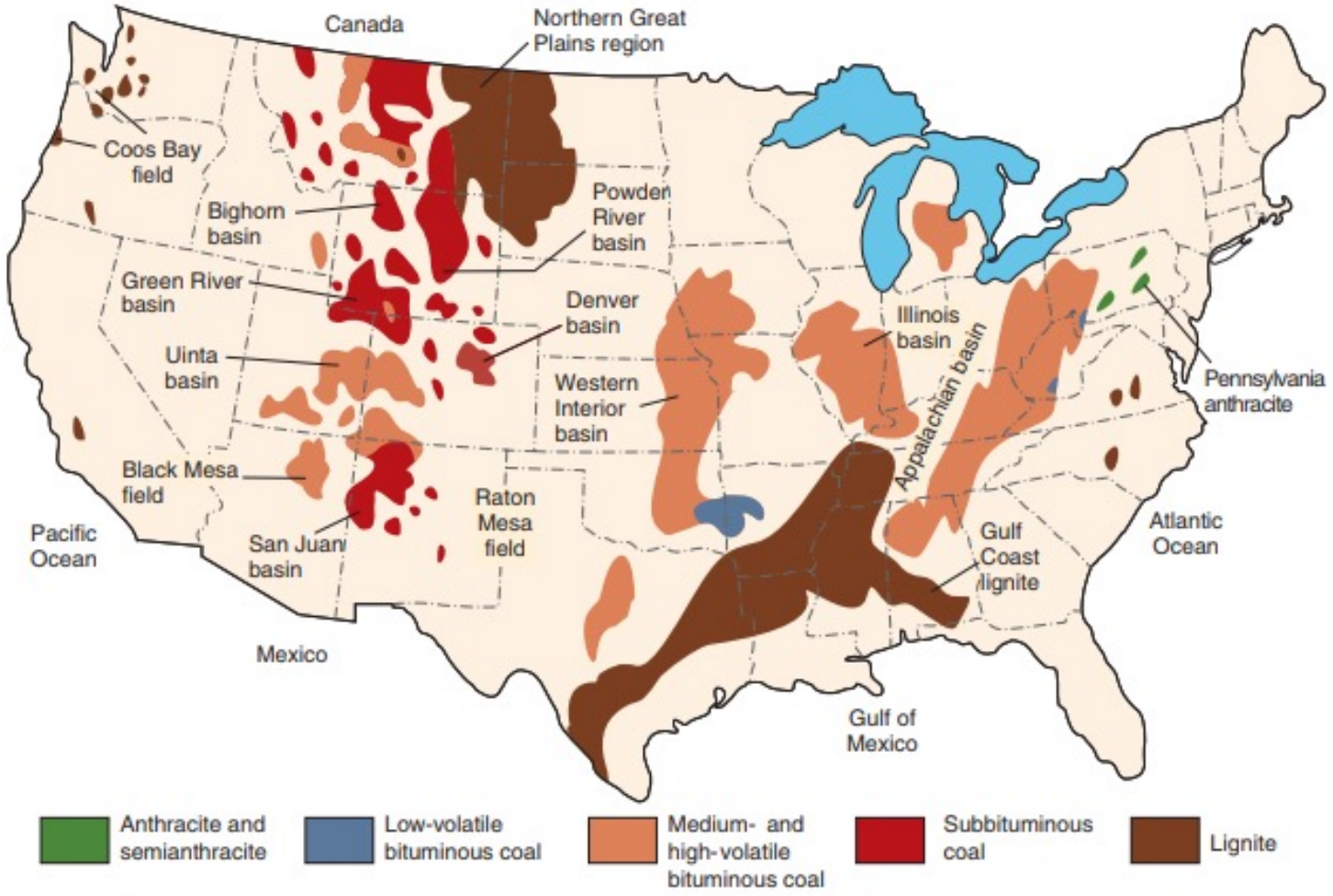


FIGURE 15.12 Coal areas of the contiguous United States. This is a highly generalized map, and numerous relatively small occurrences of coal are not shown. (*Source*: S. Garbini and S.P. Schweinfurth, *U.S. Geological Survey Circular 979, 1986.*)

US Coal – important for early industrial history

Different coal mining practices western US vs Appalachia

Coal Impacts Quick Facts

Extraction	Transportation	Use	Abundance
• Easily mined- different methods include mountain top removal, strip mining, underground mining • Mining poses environmental and human health risk (mountain top removal, strip mining, acid mine drainage, land subsidence, coal fires, respiratory diseases)	Transportation of coal from mining areas to where it is needed typically use coal-slurry pipe lines, freight trains, results in high CO2 emissions	• High SO2 emissions from coal burning power plants • Impurities in coal – incombustible organic matter leave inert residue (ash) after combustion, increase PM; nitrogen and Sulphur impurities contribute to acid rain • Public health impacts	Plentiful – the world's most abundant fossil fuel, sufficient for ~120 years at current rate

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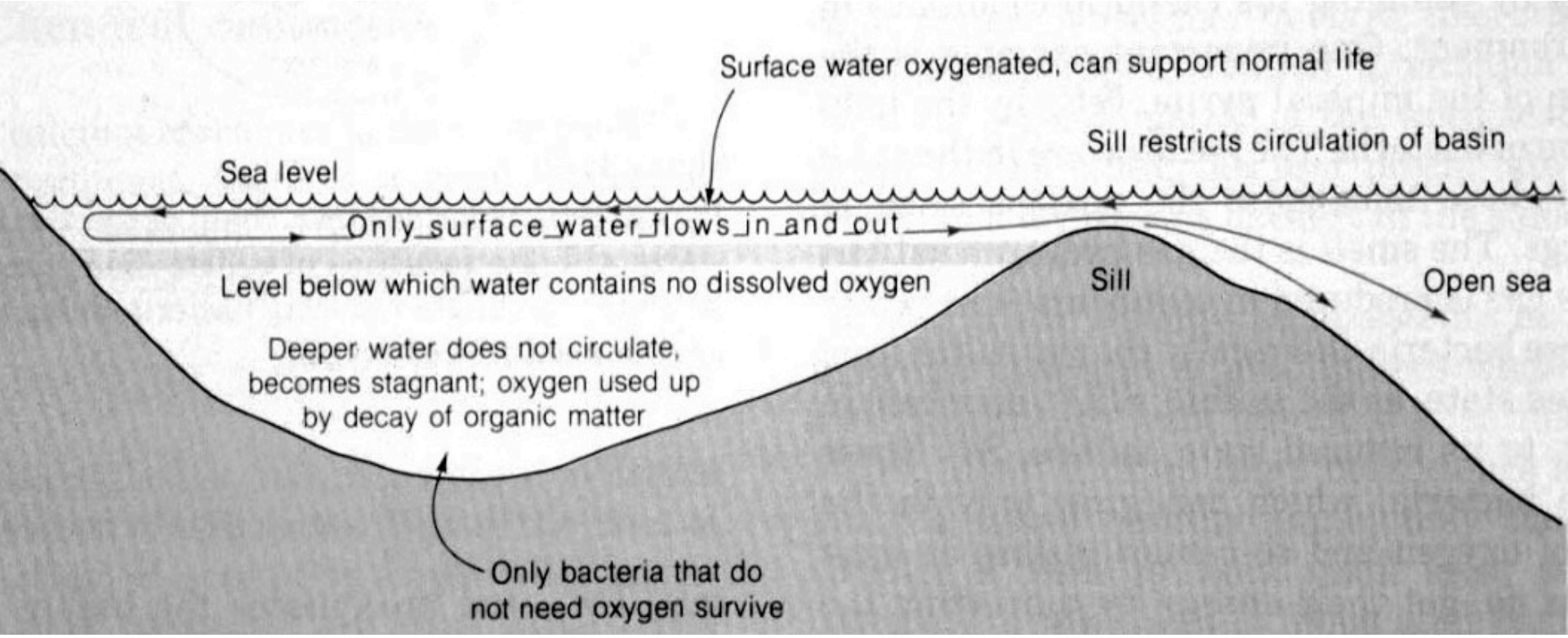
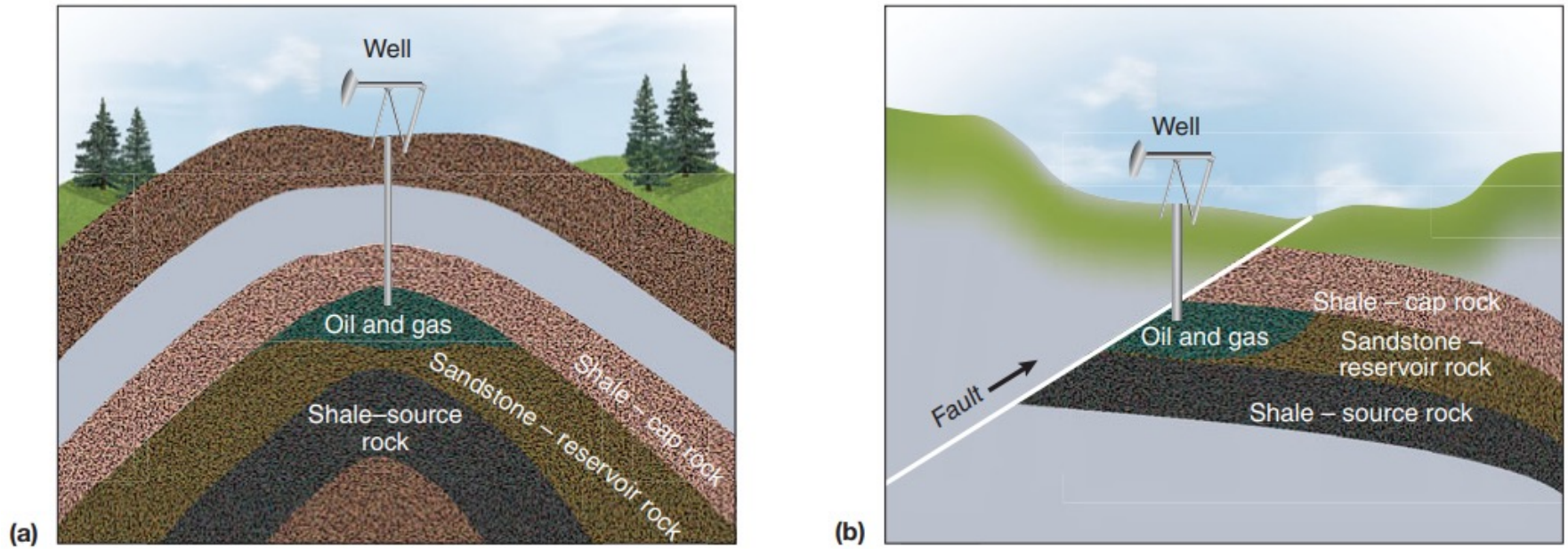
Petroleum - Formation



Origins of petroleum

Marine organisms preserved in an anoxic environment

e.g., closed ocean basins (as currently off southern Calif)



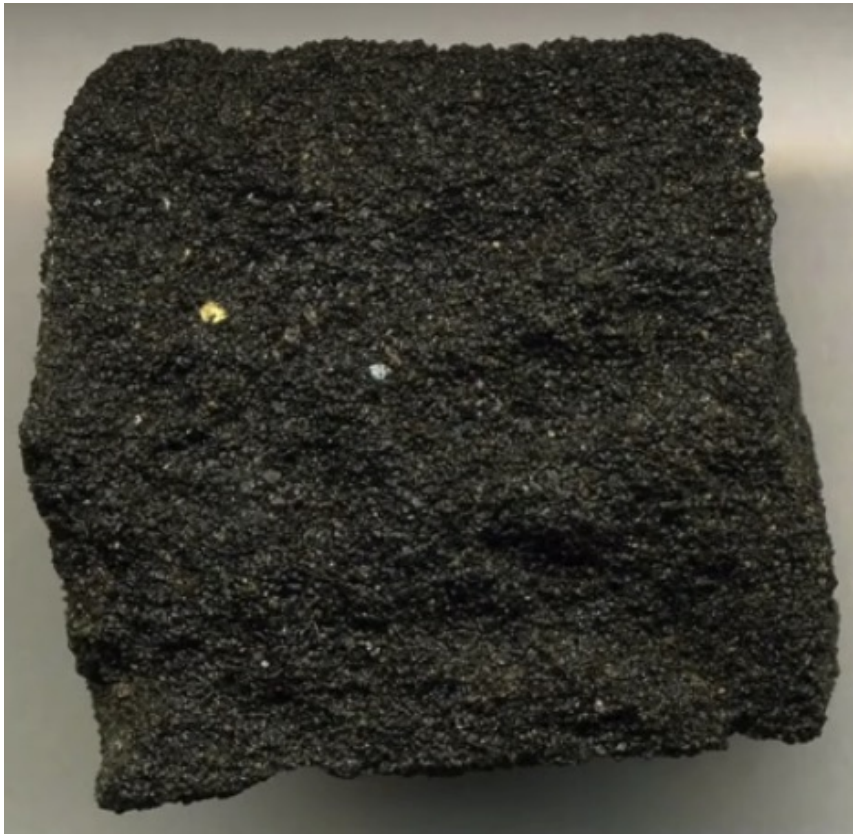
IGURE 15.5 **Two types of oil and gas traps: (a)** anticline and **(b)** fault.

- Oil first develops in a *source rock* – usually a fine-grained organic-rich marine sediment at a depth of >2-3.8km.
- High heat + pressure cause chemical transformation of organics into oil and gas.
- Migrates (over millions of years) upwards into a *reservoir rock*, with higher permeability, so the oil can flow to a pumped well.
- Geologists look for *traps* within reservoir rocks – traps created by less permeable *cap rock*

Shale – ‘tight’ oil

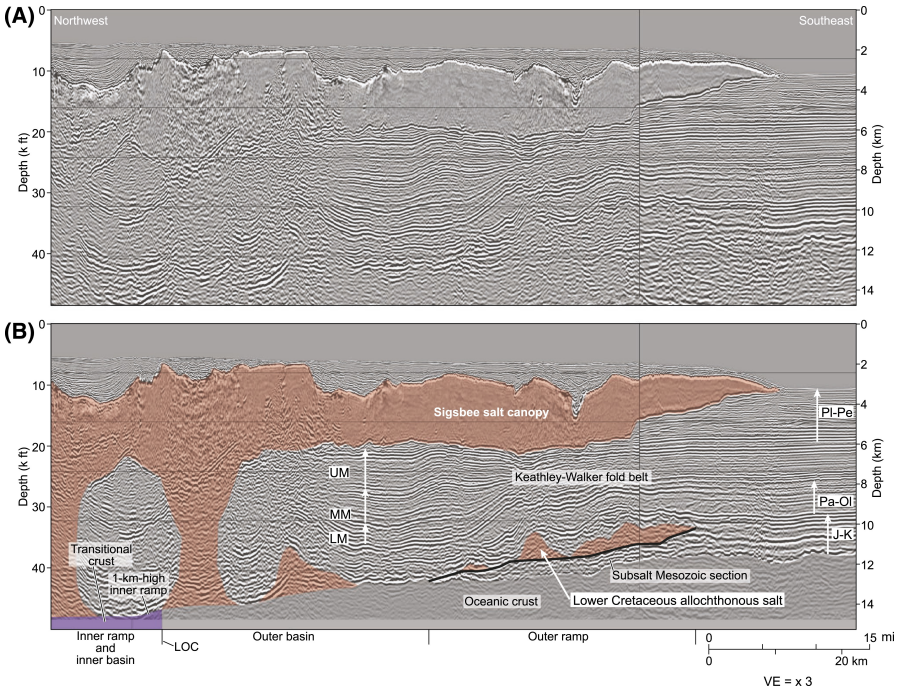
Source rock – fine grained, organic rich, subjected to high heat and pressure

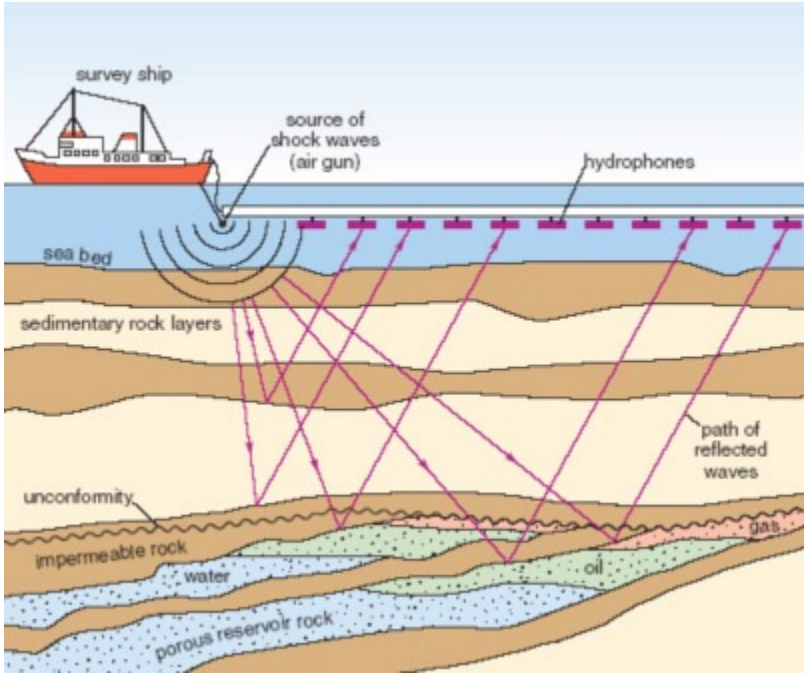
Sands



Reservoir rock – coarser, more permeable

Exposure of **tar** in Monterey Shale, Southern Calif

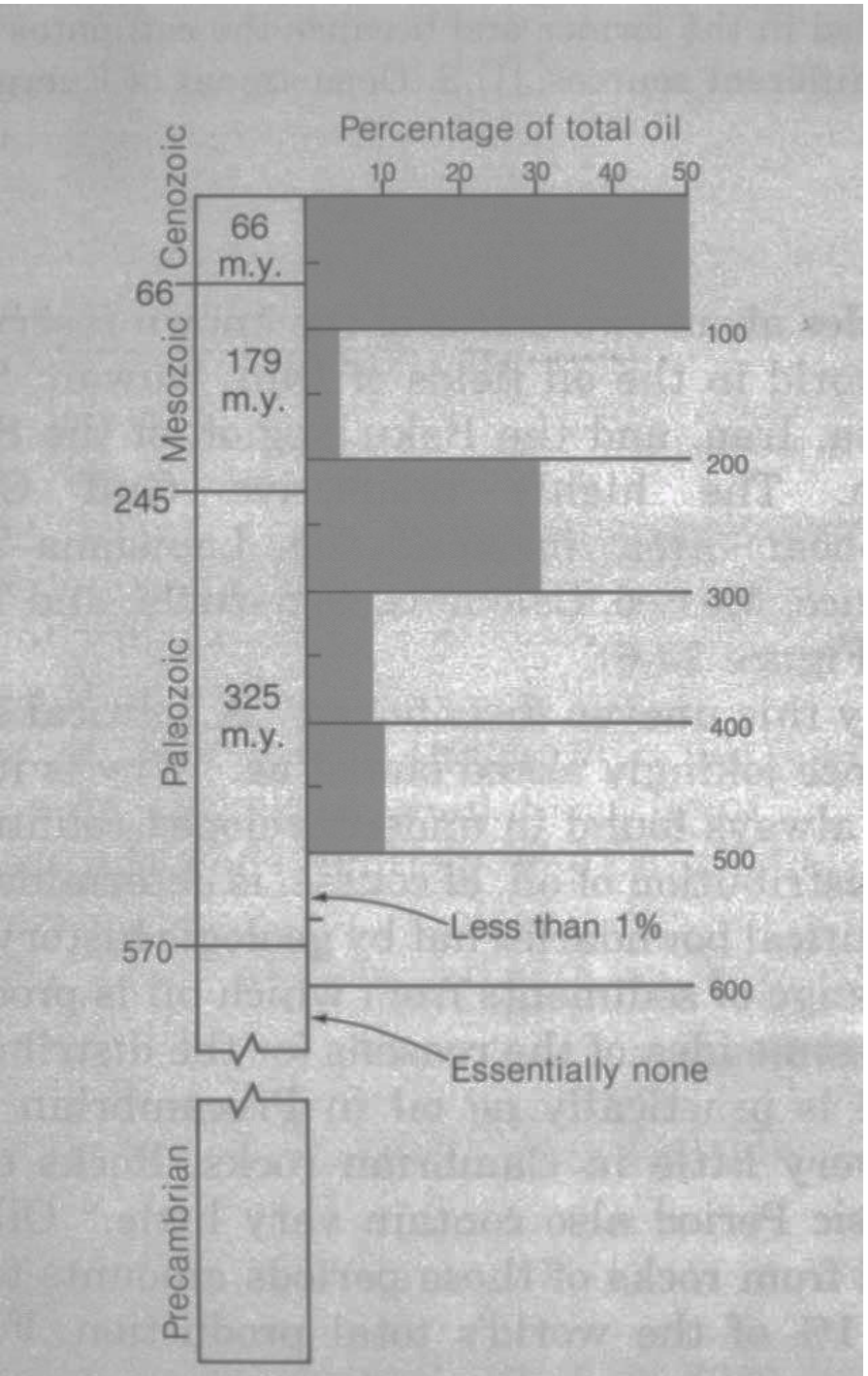




Seismic profile (Gulf of Mexico)

How seismic exploration works

Geologists look for traps within reservoir rocks with exploration wells and seismic profiling



'Preservation potential' of oil is low: if buried too little, it's just methane, too much, it's tar.

Remarkable *not* how little oil there is, but how much survived over geologic time.

On our human time scale, oil is a *non-renewable* resource.

Over 200 year period, we will use up nearly all the oil that accumulated over the previous 500 million years!

Now, let's take a tour of a producing oil well (southern California)

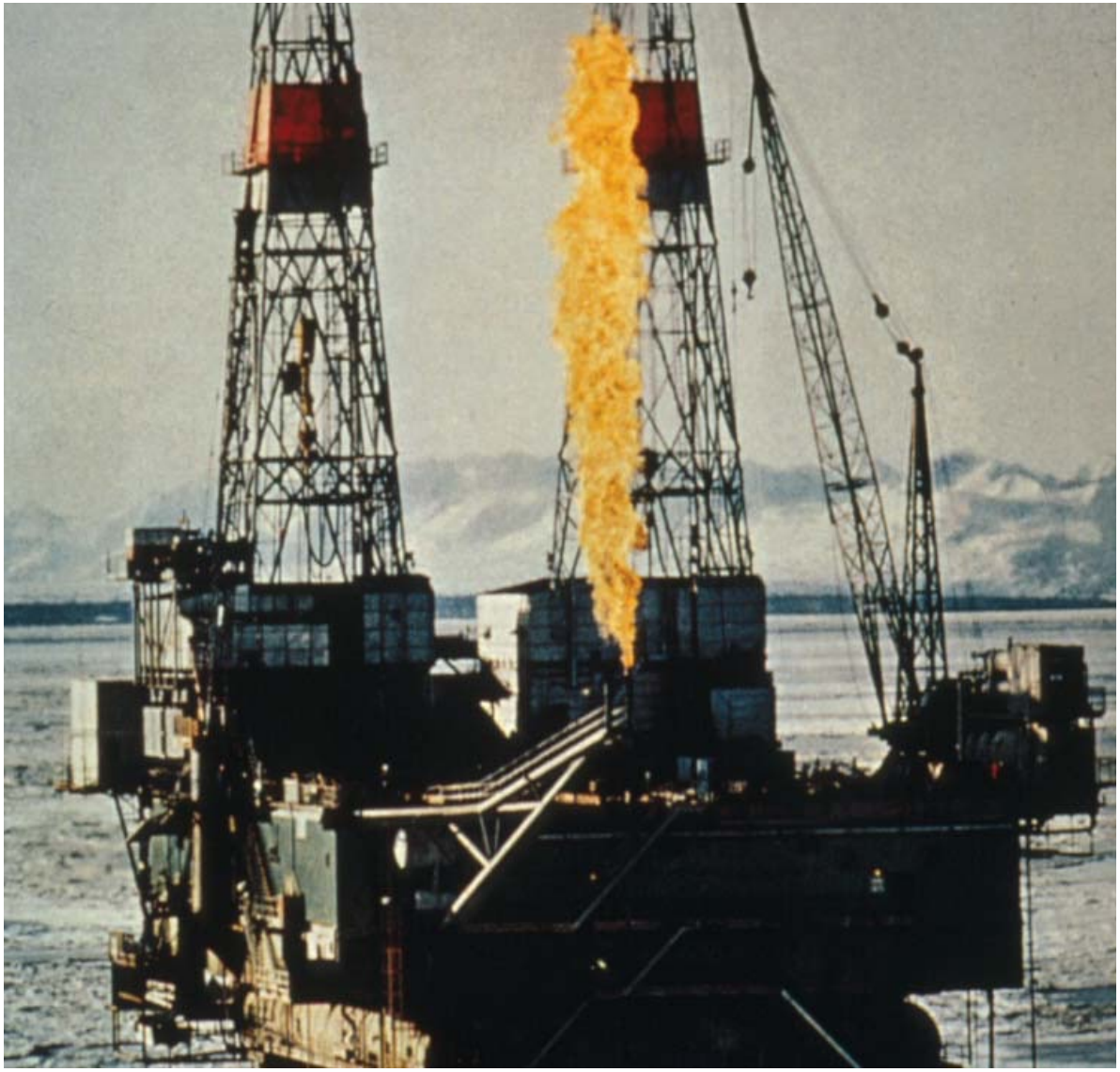

ATLANTI

Aerial view, West Texas

Oil fields make a huge impact on the landscape, visible from the air

Aerial view, Kern County, Calif

Aerial view, Kern County, Calif



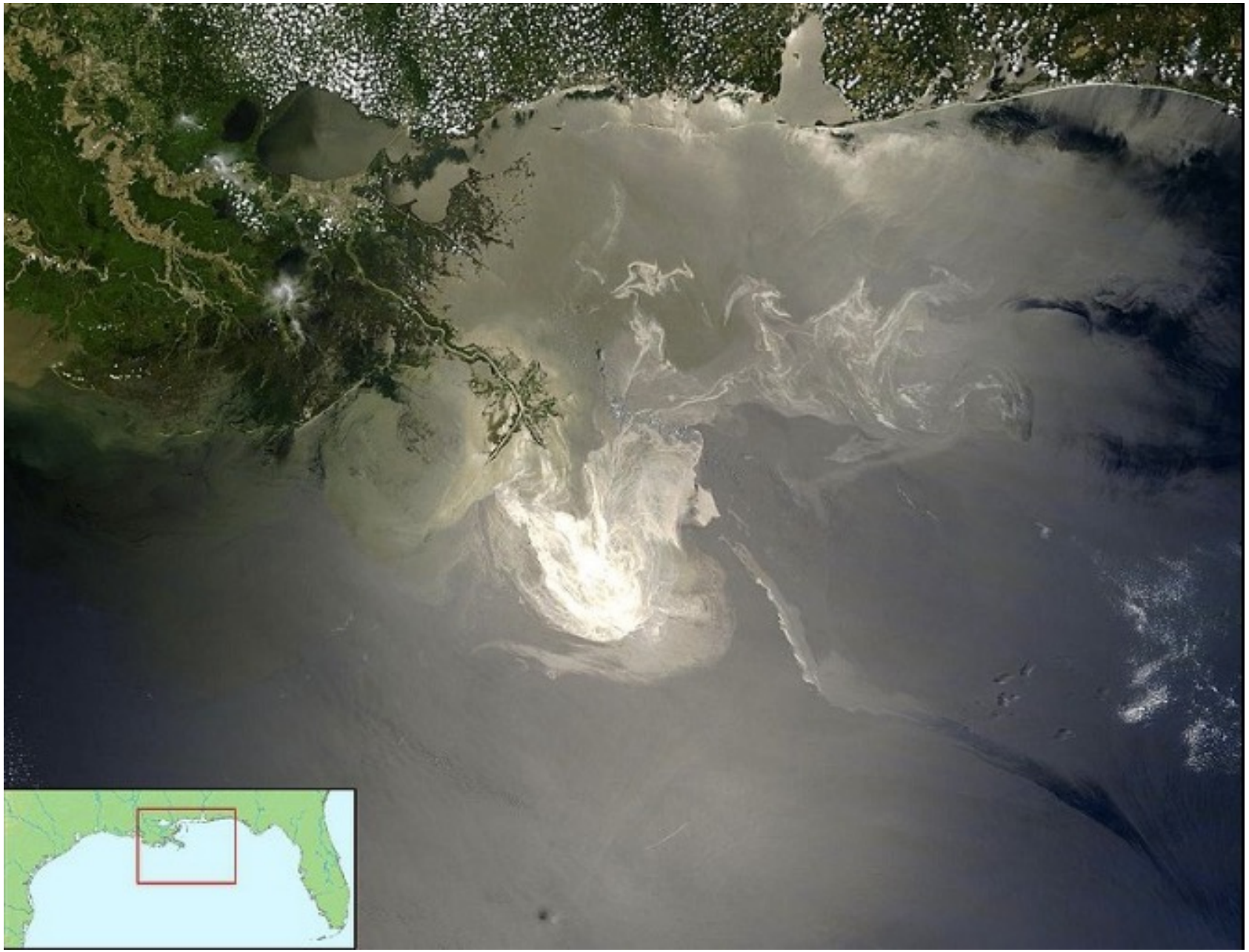
Offshore oil drilling and production is especially risky

Off-shore Drilling and Wells

Highly vulnerable infrastructure (dominant production type in Gulf of Mexico, North Sea, etc)

Deepwater Horizon

- mobile, floating drilling rig
- blowout 20 April 2010
- sank 22 April
- leaked 4.9 million barrels oil



Spill affected 68,000 mi2 of Gulf, 491 mi of coastline

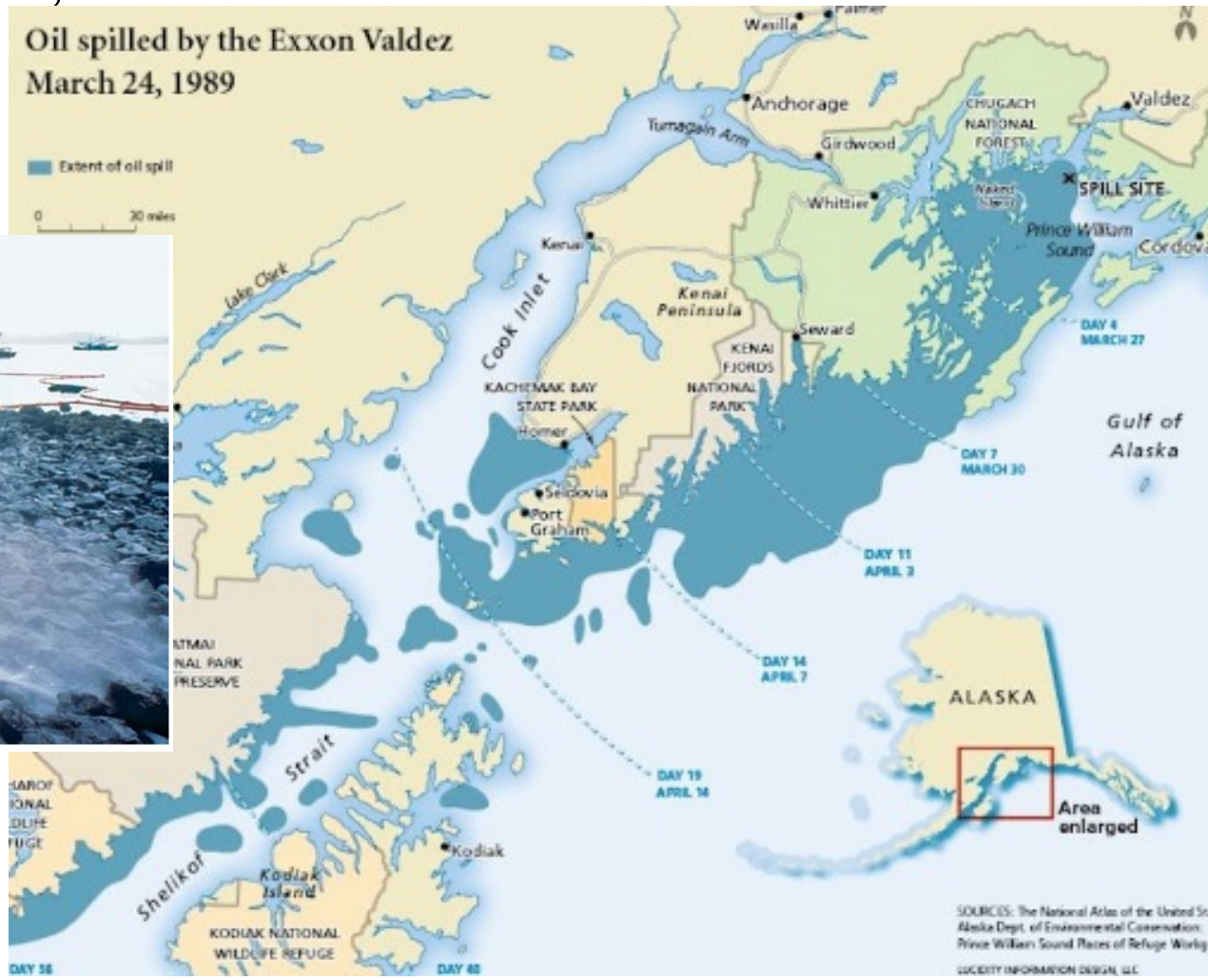
Effects of transportation (oil tankers, pipelines)

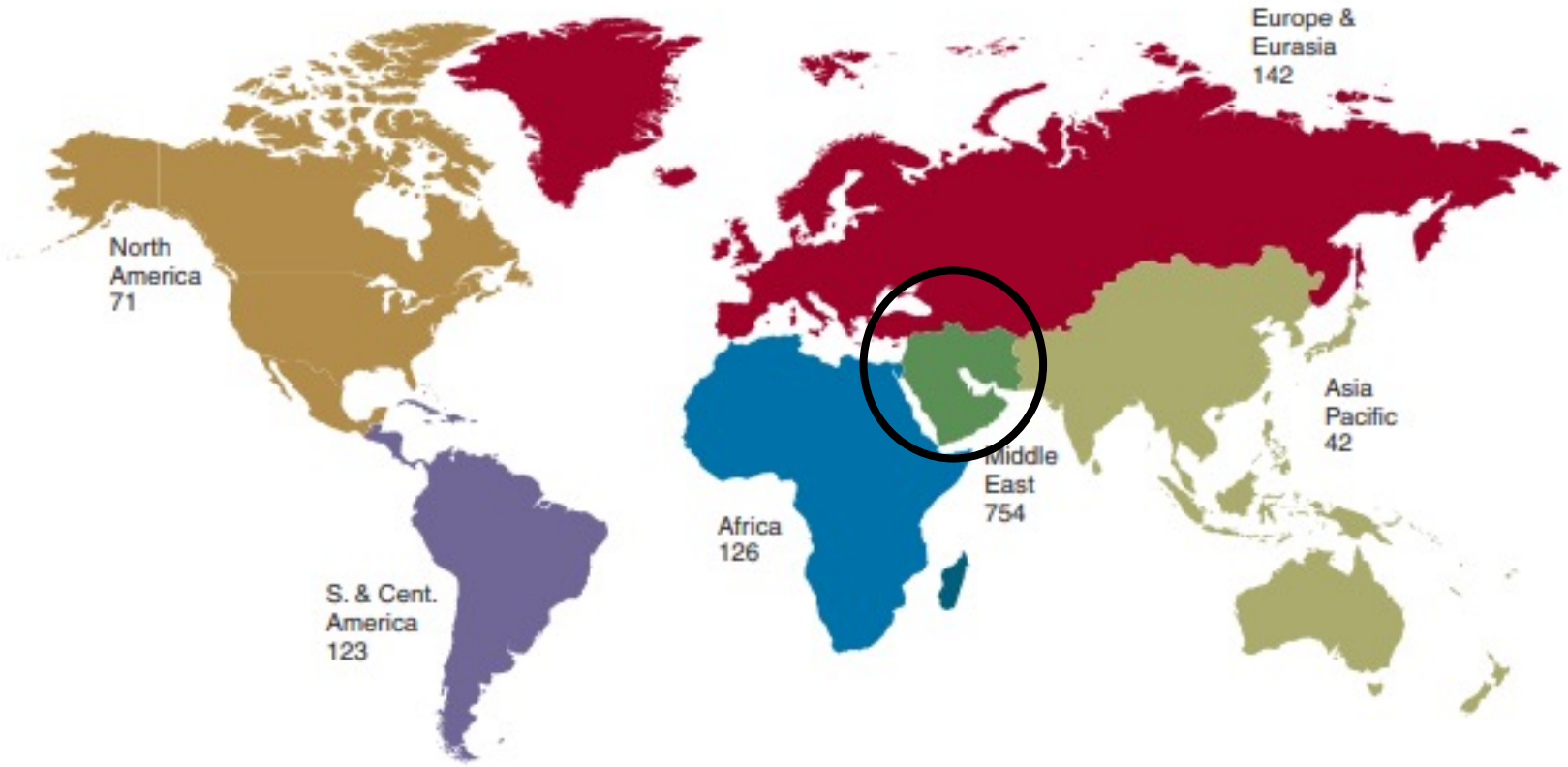
Oil tanker spills

Exxon Valdez ran aground 1989

How much spilled? Disputed: est 260,00 to 750,000 barrels

Affected 11,000 mi2, 1300 mi coastline

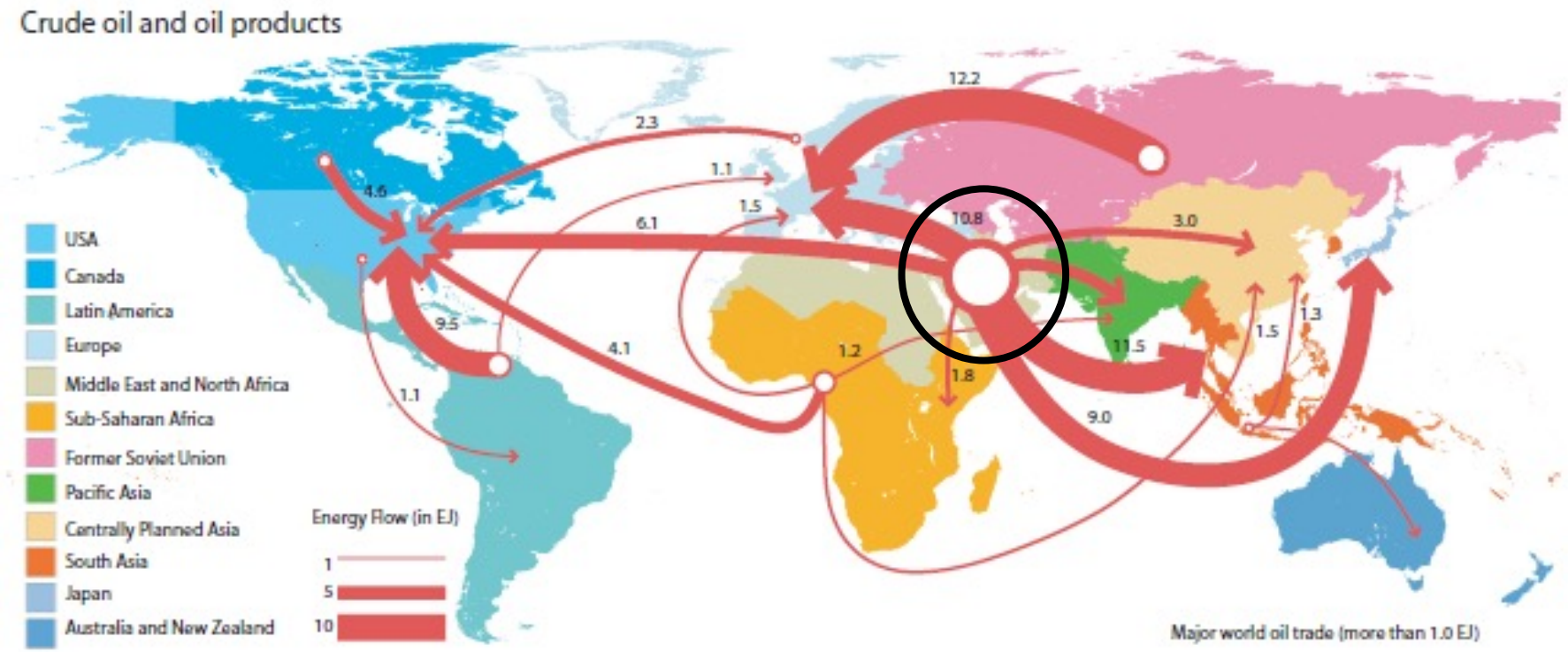




Proven world oil reserves (billions of barrels) in 2010
Source: Botkin 2010

The Middle East dominates, with 60% of total reserves.

Major World Oil Trade: Crude Oil and Oil Products

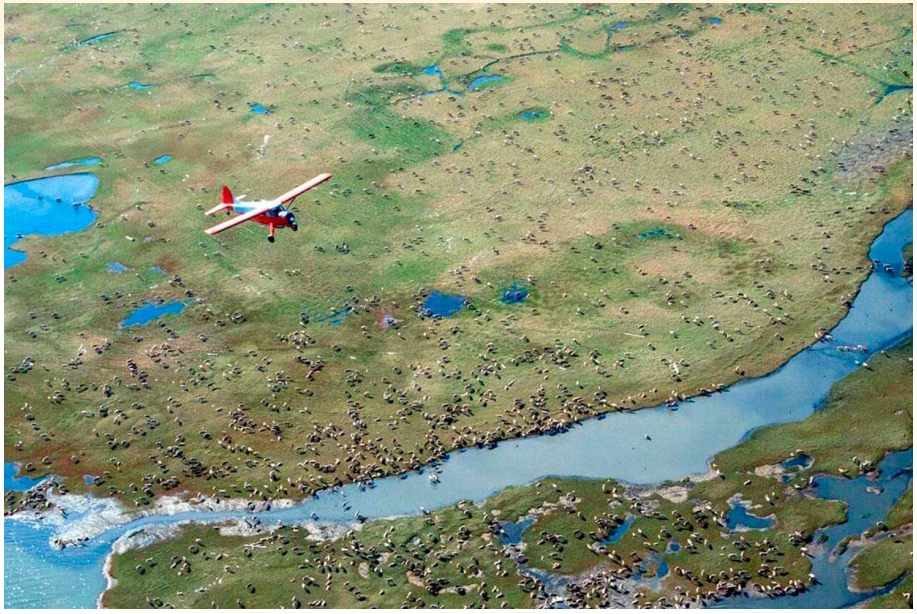


Source: 2012 GEA Global Energy Assessment report

The Arctic National Wildlife Refuge: To Drill or Not to Drill

FIGURE 15.8 The Arctic National Wildlife Refuge, on Alaska's North Slope, is valued for its scenery, wildlife, and oil.

- One of the few remaining pristine wilderness areas in the world
- Contains about 3 billion barrels of recoverable oil
- Would result in release of 4.3 billion metric tons of CO_2 over the lifetime of the project (including emissions from burning the oil)
- Has been under debate for decades
- Trump administration moved to open up to energy exploration
- Biden halted drilling in June 2021 pending review of impacts and legal basis of the leases



A porcupine caribou herd in the ANWR

Petroleum Quick Facts

Extraction	Transportation	Use	Abundance
• Use of land to construct pads for wells, pipelines, and storage tanks and to build a network of roads and other production facilities • Pollution of surface water and groundwater from leaks and brine brought to surface with the oil • Land subsidence from drilling • Loss and disruption of ecosystems such as wetlands • Refinery operation risks, leaks, polluting soil and groundwater below the site	• Easier to transport than coal due to liquid form; transportation via pipelines or tankers across land or water • Earthquakes, marine spills that kill sea birds, aquatic species, and spoil beaches	• Energy dense • Cleaner than coal but still has impurities	• Proven reserves = 1.3 trillion barrels • 90 years of petroleum sources remain at current rate of consumption • Today, for every three barrels of oil we consume, we are finding only one barrel

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  - **Natural Gas & ‘Tight’ Oil**
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Natural Gas

- Naturally occurring gas (e.g., methane, CH4)
- Commonly found in the same rock formations as oil, produced with oil
- We can capture this natural gas and use as energy
- Rather than buy the technology to collect and market the natural gas, operators commonly burn the excess gas at the well site ('flaring')

See night-time light image for western North Dakota!

Natural Gas Quick Facts

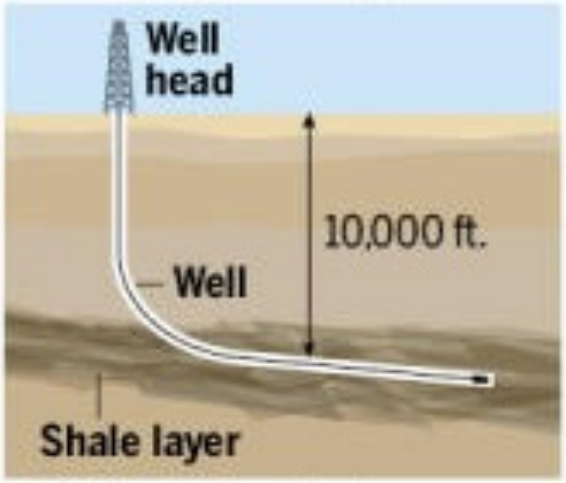
Extraction	Transportation	Use	Abundance
• Many of the same issues as petroleum • Uses huge amounts of water per well, potential strain on ground and surface water supplies	Transportation of natural gas in pipelines can result in leakage of methane - much more potent GHG than CO2	• Natural gas is a 'clean' fuel; burning it produces fewer pollutants than does burning oil or coal (but methane losses must be kept low) • Natural gas produces about 40% less CO2 than coal for the same energy. • Public health benefits from reduced emissions	• 185 trillion cubic meters recoverable natural gas remaining • 90 years of natural gas sources remain at current rate of consumption

‘Tight’ Oil

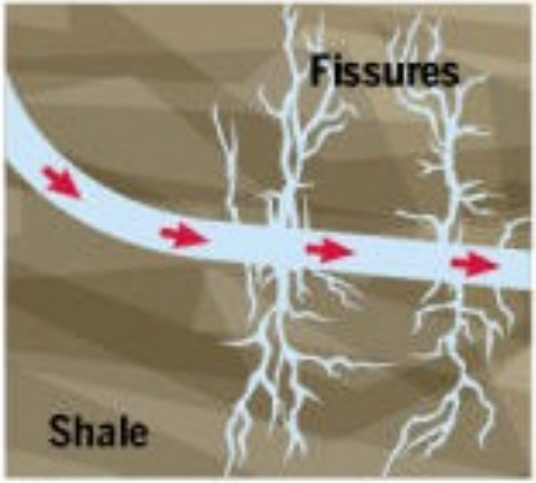
- Emissions intensive source of oil found in low permeability rocks (often shale)
- Because oil is trapped in smaller pore spaces, extraction requires hydraulic fracturing (fracking)
- Produces more pollution to extract than conventional sources of oil

Fracking

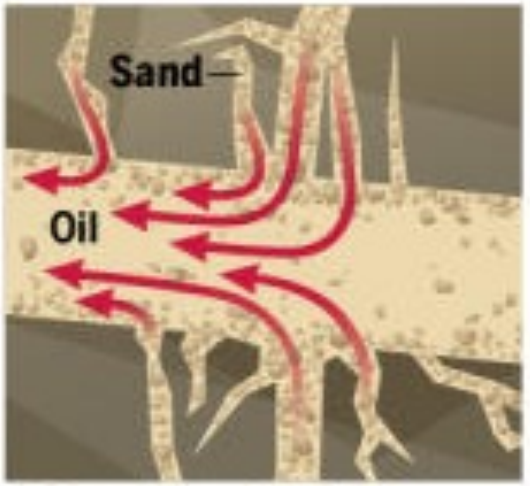
How fracking works



1. Wells are bored using directional drilling, a method that allows drilling in vertical and horizontal directions to depths of over 10,000 feet.



2. Large amounts of water, sand and chemicals are injected into the well at high pressure, causing fissures in the shale.

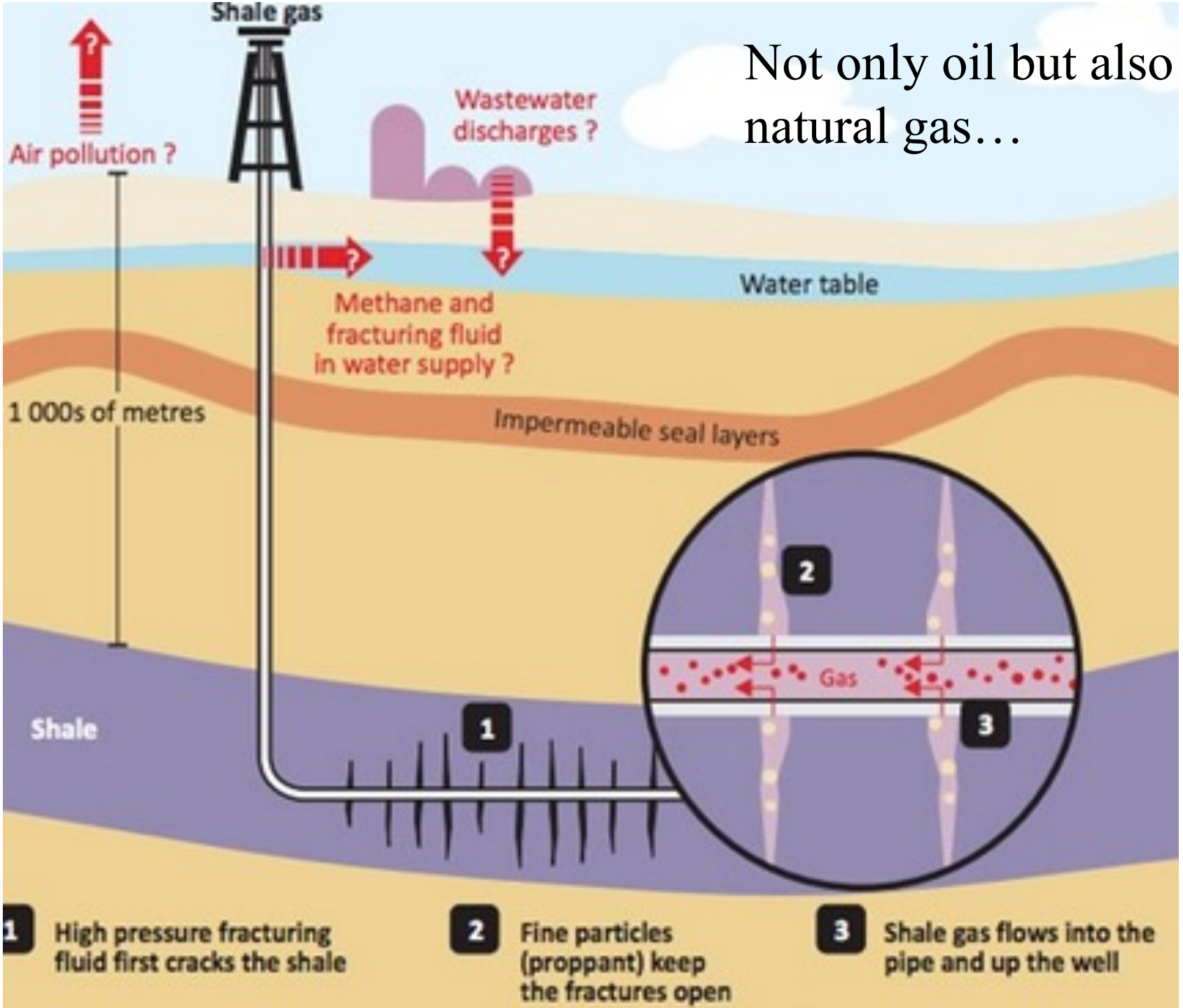


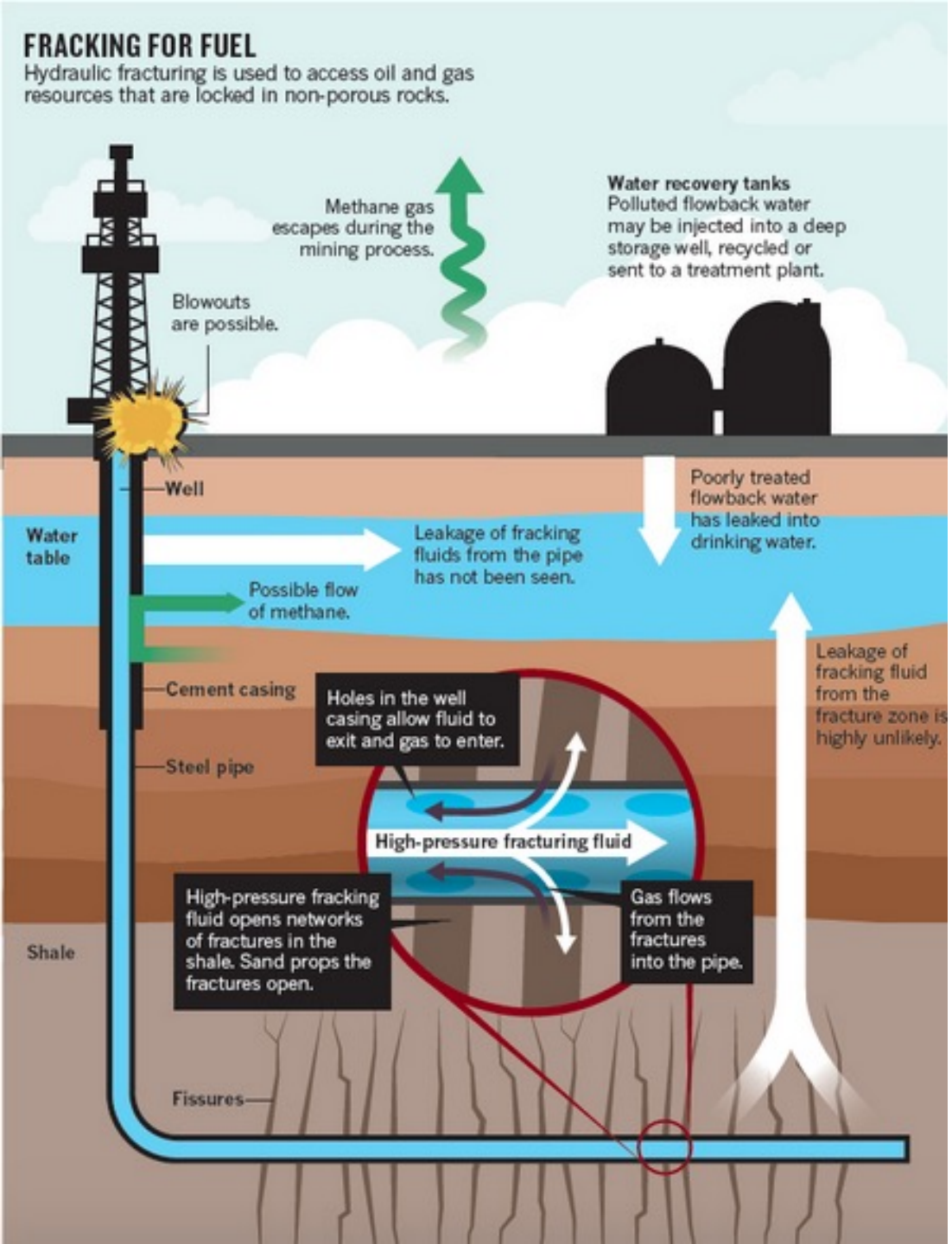
3. Sand flows into the fissures, keeping them open so that the oil from the shale can flow up and out of the well.

Sources: USC, Los AngelesTimes

McCLATCHY-TRIBUNE

Not only oil but also natural gas…



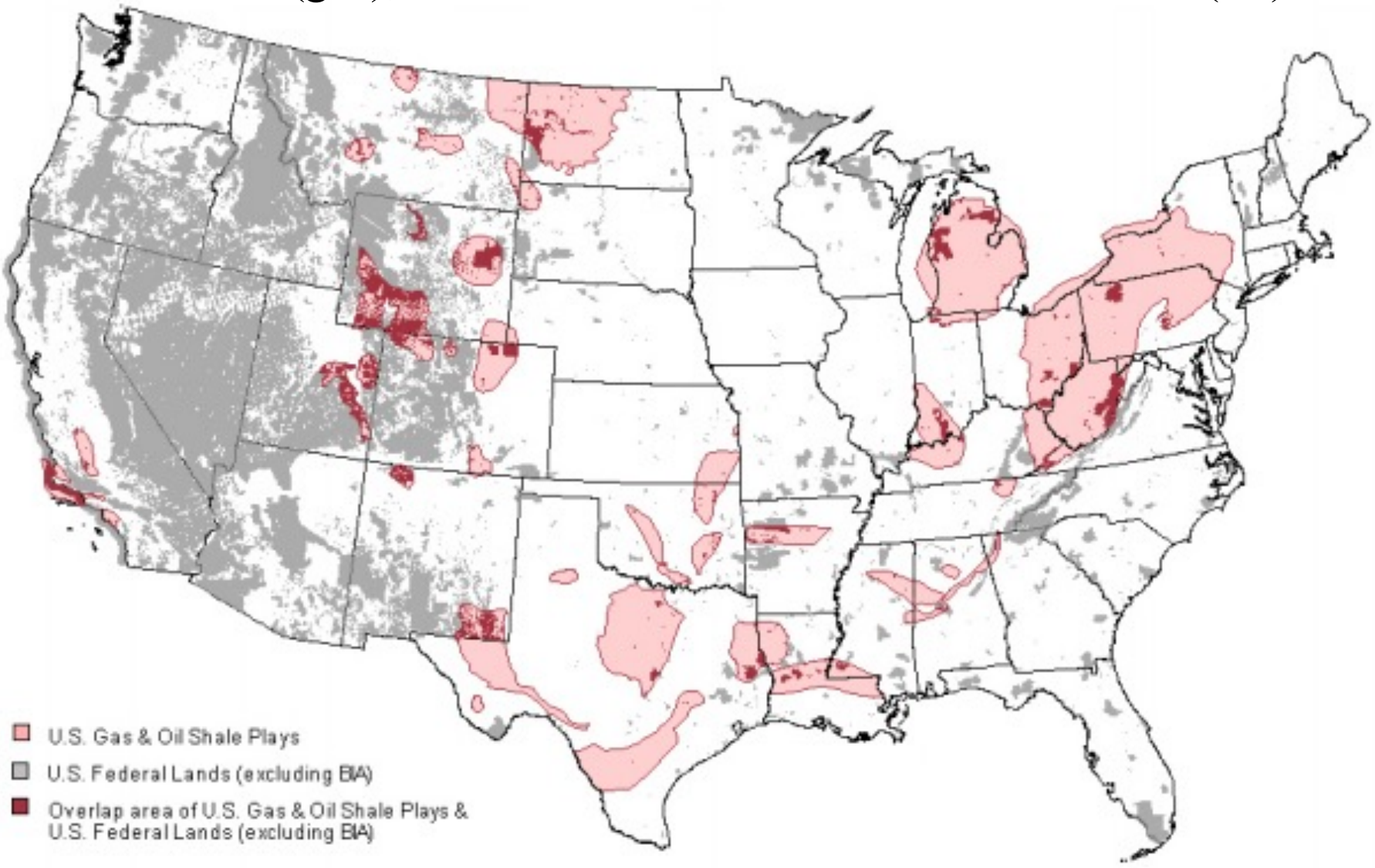


Many potential impacts:

- Direct leakage of fracking fluids and oil into aquifers
- Allow leakage of brines into aquifers
- Blowouts

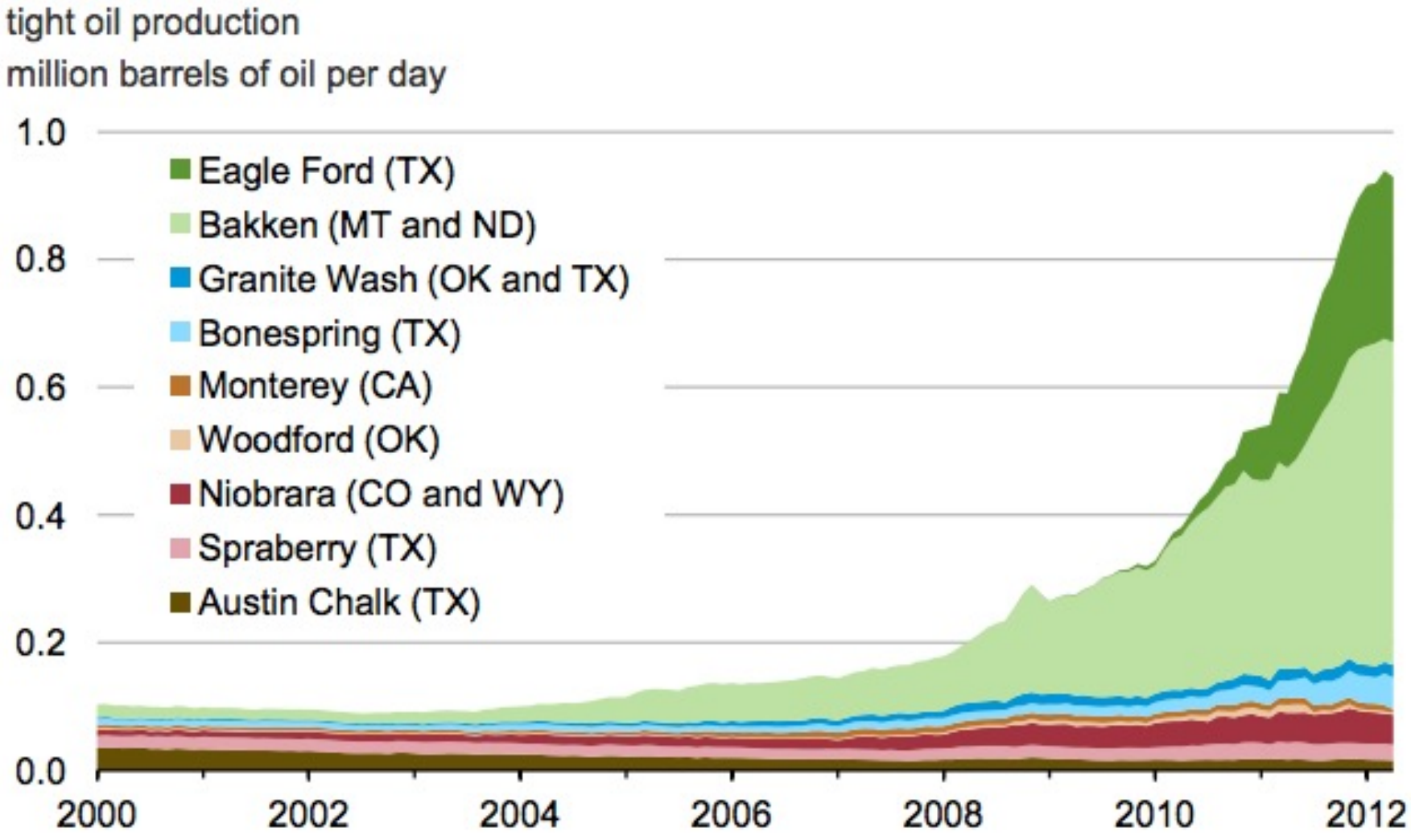
Ironically, the drop in oil prices resulting from increased US production may slow adoption of alternative energy strategies because they are becoming less economical.

Where is fracking going on? Hotspots: the Allegheny plateau of the Northeast US (gas), and the Brakken Shale in North Dakota (oil)

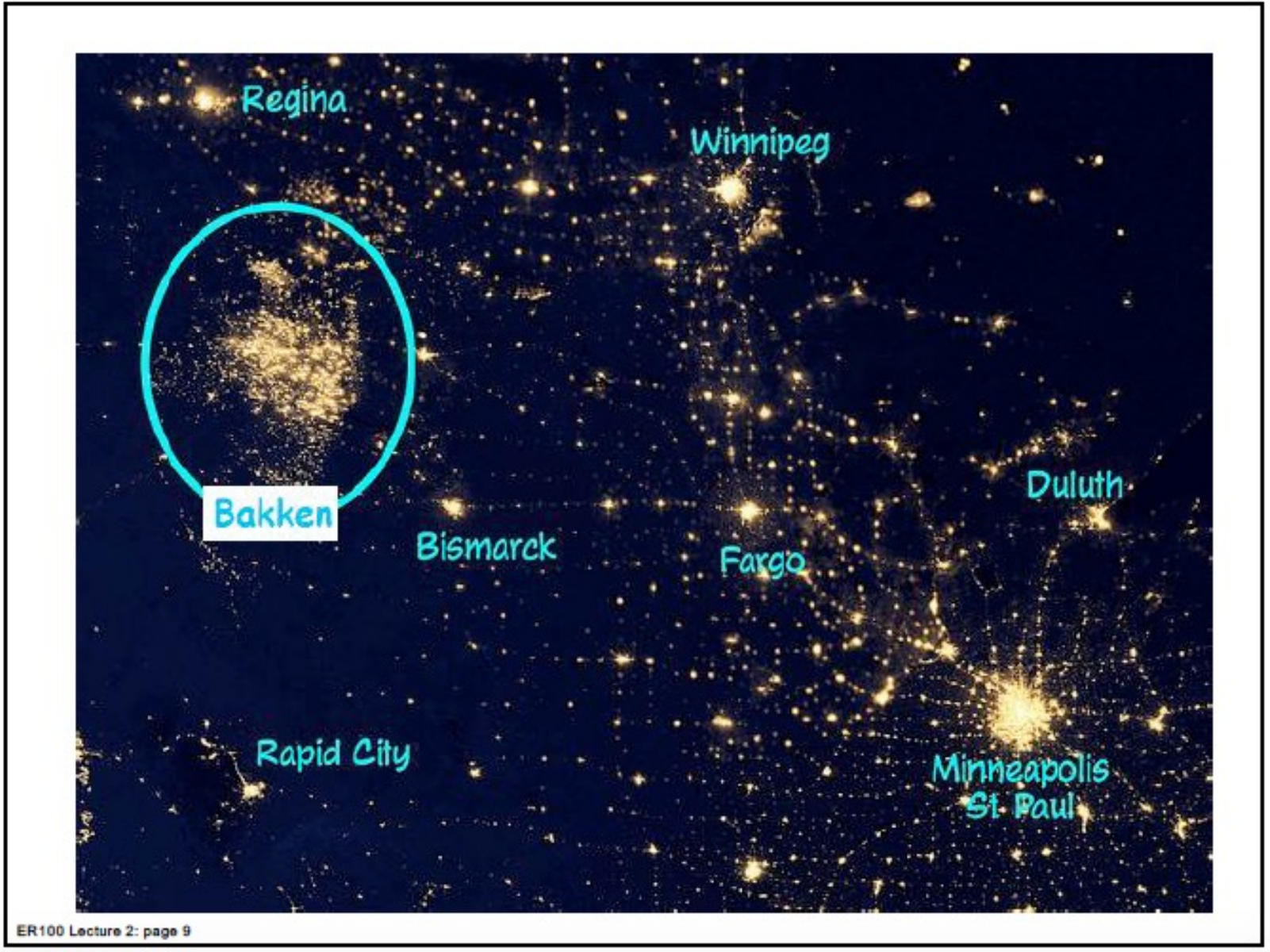


Source: U.S. Energy Information Administration

The biggest production of ***oil*** from fracking shales is in the Brakken Shale of western North Dakota



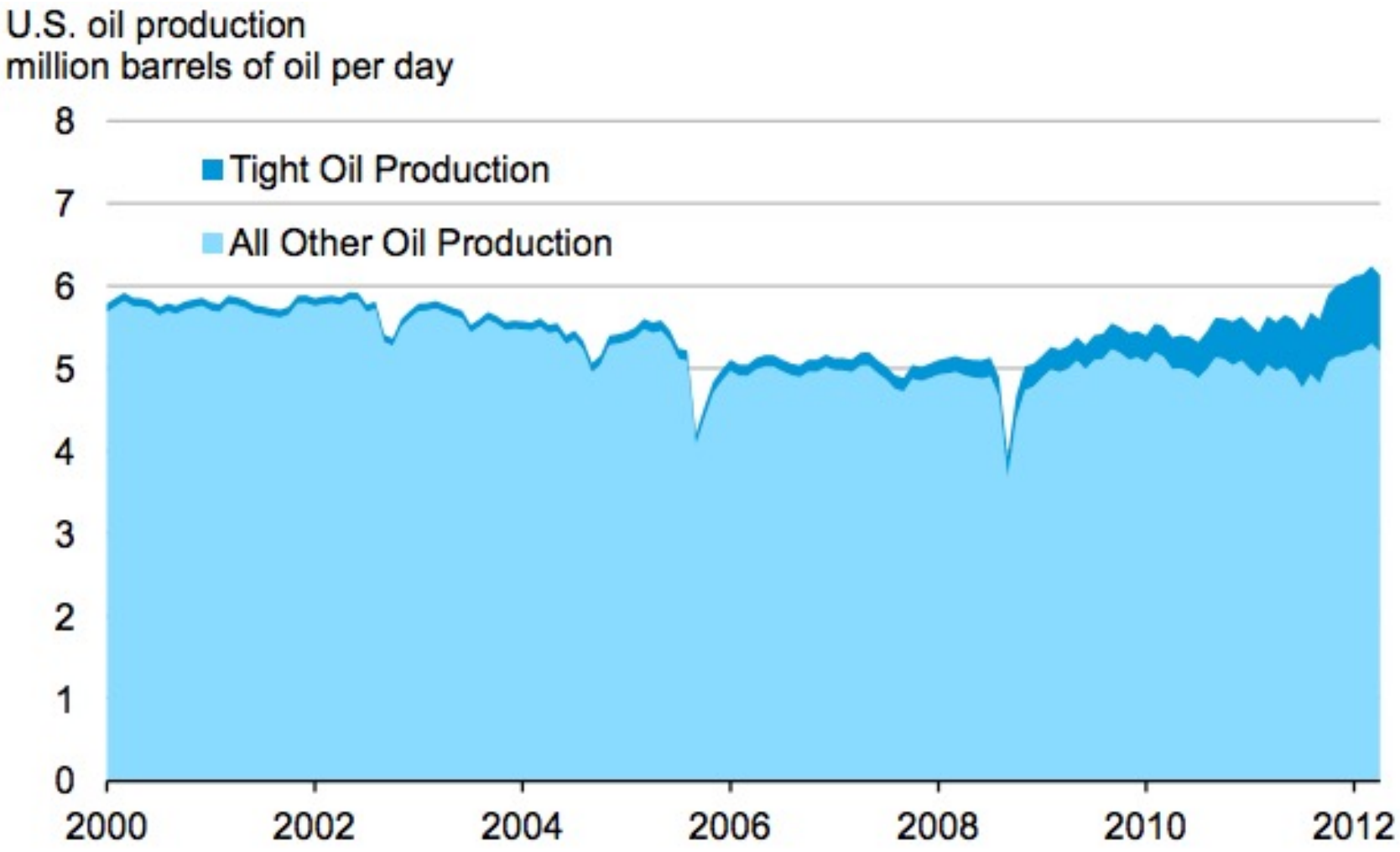
Source: U.S. Energy Information Administration, HPDI, Railroad Commission of Texas, and North Dakota Department of Mineral Resources, through April 2012



Night-time lights from Minneapolis northwest to North Dakota Bakken shale region. Lights in Bakken are natural gas flares.

Image courtesy of D Kammen, ERG 100

Creating an oil boom in the region, with boom towns, social problems…



Source: U.S. Energy Information Administration, HPDI, Railroad Commission of Texas, and North Dakota Department of Mineral Resources

US oil production increased from 5.6 million barrels per day in 2010 to 9.37 million in 2017.

US oil *imports* fell from 10 million barrels per day to 3.7.
But only 55% of that drop was due to shale-oil production, the rest was due to increased fuel efficiency standards in cars & trucks!
With declining oil prices in recent years, many wells shut down.
How quickly can they restart to profit from current high oil prices?

"Peak Oil"

This was formerly the concern:

After global oil production reaches its maximum rate, production will gradually decline…

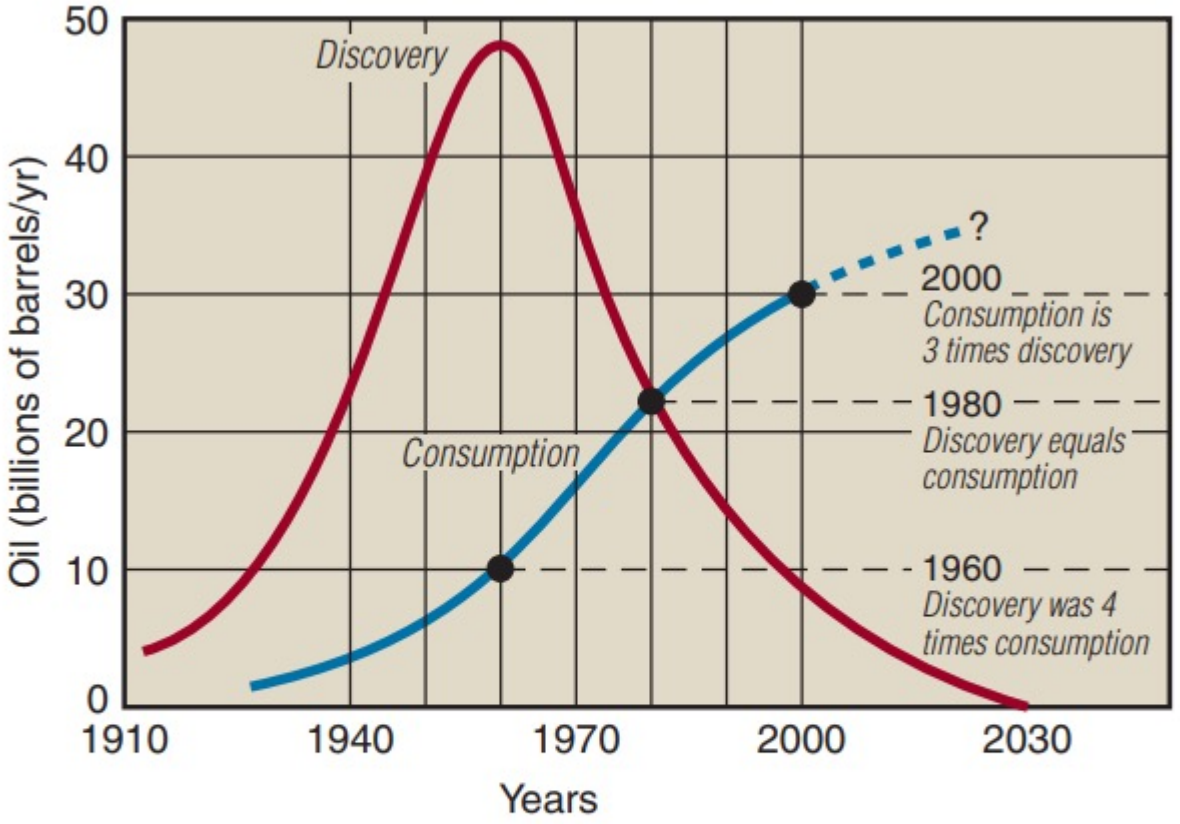


FIGURE 15.1 Discovery of oil peaked around 1960, and consumption exceeded discovery by 1980. *Source:* Modified after K. Alekett, "Oil: A Bumpy Road Ahead," *World Watch 19*, no. 1(2006):10–12.)

…and we will run out of oil.

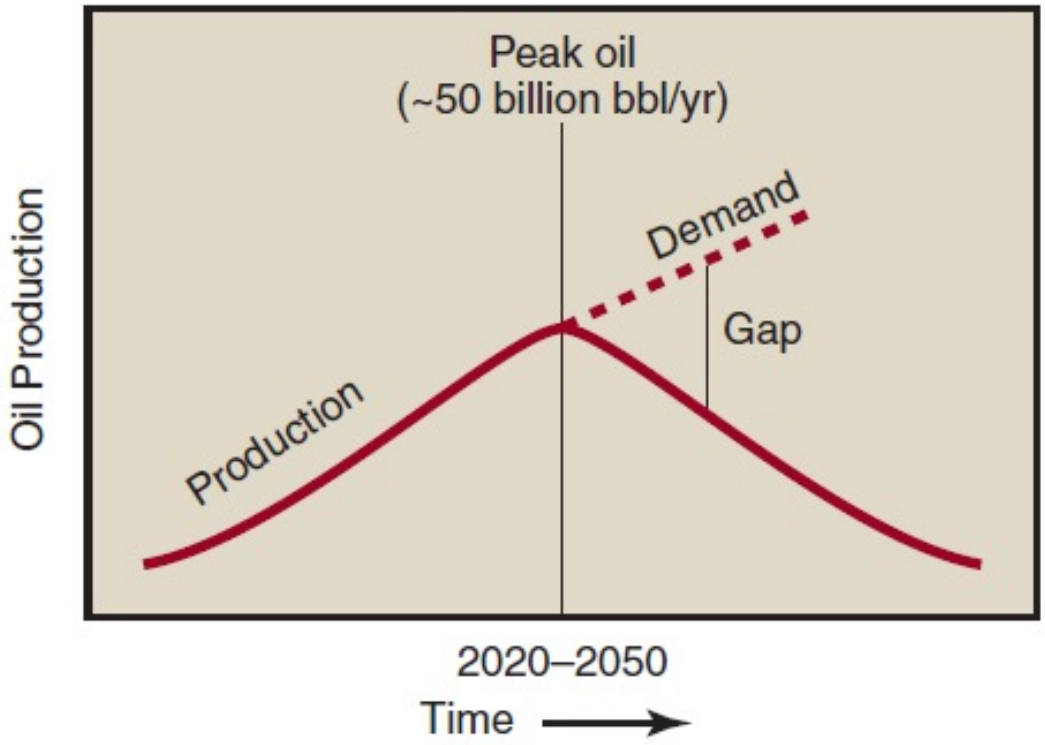
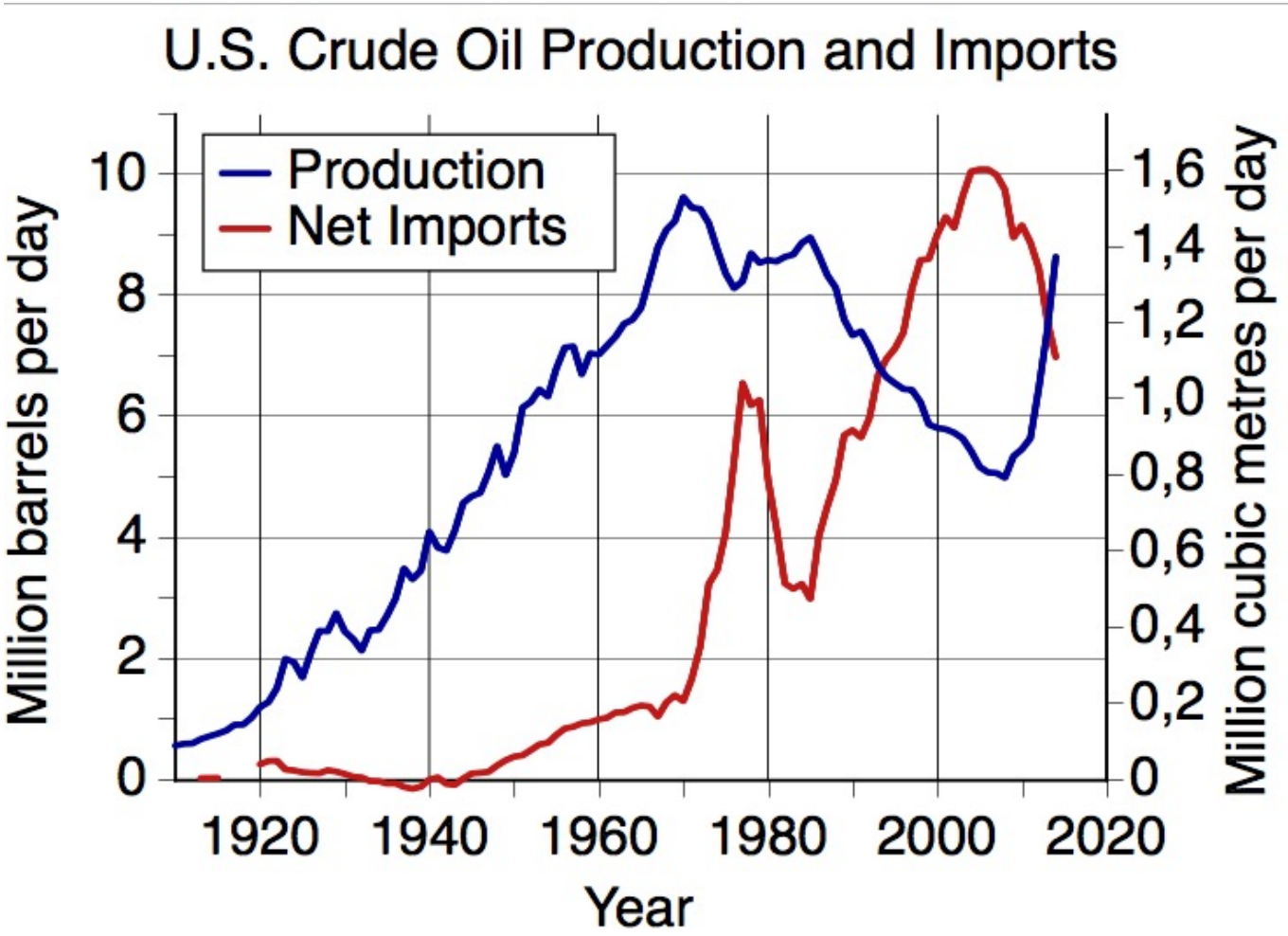


FIGURE 15.2 Idealized diagram of world oil production and peak between 2020 and 2050. When production cannot meet demand, a gap (shortage) develops.

But with new technologies, oil supplies are increasing.
Real issue: if we burn up all our oil and coal, we 'fry' the planet

Until recently, US oil imports continued to rise and production to fall. But then demand dropped (due to economic slowdown starting in 2008) and production unexpectedly increased due to new technology.



Now with demand falling, and oil prices fluctuating, big oil companies are pivoting to plastics (made from petrochemicals).

Pressure on African countries to accept plastic waste.

The New York Times

National Edi
Northern California: E
low clouds. Hazy from
where. Hot inland. High
to lower 100s Cent
Weather map appears o

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MONDAY, AUGUST 31, 2020

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KHADIJA M. FARAH FOR THE NEW YORK TIMES

Much of the billions of pieces of plastic waste exported from the United States to be recycled ends up in rivers and oceans instead.

Big Oil Pivots to Plastics and Eyes Africa as Its Dumping Ground

*This article is by **Hiroko Tabuchi**, **Michael Corkery** and **Carlos Mureithi**.*

Confronting a climate crisis that threatens the fossil fuel industry, oil companies are racing to make more plastic. But they face two problems: Many markets are already awash with plastic, and few countries are willing to be dumping grounds for the world's plastic waste.

The industry thinks it has found a solution to both problems in Africa.

According to documents reviewed by The New York Times, an industry group representing

wrestled with the proliferation of plastic. It passed a stringent law against plastic bags in 2017, and last year was one of many nations around the world that signed on to a global agreement to stop importing plastic waste — a pact strongly opposed by the chemical industry.

The chemistry council's plastics proposals would "inevitably mean more plastic and chemicals in the environment," said Griffins Ochieng, executive director for the Centre for Environmental Justice and Development, a nonprofit group based in Nairobi that works on the problem of plastic waste in Kenya. "It's shocking."

*This article is by **Thomas Kaplan** and **S**
macher.*

PORTLAND, Ore.
shooting in Portland,
the weekend led Presid
to unleash a torrent of
attacks on Sunday, capp
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becoming a major them
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On Saturday, a mar
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folded for three c
months. No suspect has
licly identified and th
identity has not been re

The shooting came i
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people dead and one in

The pro-Trump rally i
drew hundreds of truck
with Trump flags and
porters into the city.
Trump supporters and
protesters clashed on t
with fistfights occur
Trump supporters shoo
ball guns from the beds
trucks as protesters thr
at them.

Mr. Trump on Sunday
posted or reposted a
tweets about the clashe

Outline

- Fossil Fuels
  - Coal
  - Petroleum
  - ‘Tight’ Oil & Natural Gas
- **Air pollution**
- Climate change

Air Pollution

Any substance (chemicals, particulate matter, etc.) that people introduce into the atmosphere that have damaging effects on living things and the environment.

http://www.ecoinstitution.com/green-news/

Sources

Stationary

- **Point** - large, stationary sources of air pollution, such as factories & power plants. Includes leaks from pressurized equipment
- **Area** – smaller sources of air pollution, such as drycleaners, gas stations & auto body paint shops (individually emitting <25 tons/year pollutants)

Mobile

- includes on-road vehicles (such as cars, trucks and buses) and off-road equipment (such as ships, airplanes, agricultural and construction equipment)

Air Pollutants

Air Quality	Greenhouse Gases
Particulate Matter Gaseous Pollutants • Sulfur Oxides • Nitrogen Oxides • Carbon Monoxide • Ozone • Volatile organic compounds (VOC)	Carbon Dioxide Chlorofluorocarbons (CFCs) Nitrous oxide Carbon Monoxide

Criteria Pollutants

Air pollutants for which there are US national air quality standards defining allowable concentrations of these substances in the air.

Table 21.2 U.S. EMISSIONS OF CRITERIA POLLUTANTS FROM 1970–2007

	MILLIONS OF TONS PER YEAR							
	1970	1980	1985	1990	1995	2000	2005	2007
Carbon Monoxide (CO)	200	178	170	144	120	102	89	81
Lead	ND	0.074	0.023	0.005	0.004	0.002	0.003	0.002
Nitrogen Oxides (NO_x)	~27	27	26	25	25	22	19	17
Volatile Organic Compounds (VOC)	~30	30	27	23	22	17	15	15
Particulate Matter (PM)								
PM_{10}	ND	6	4	3	3	2	2	2
$PM_{2.5}$		ND	ND	2	2	2	1	1
Sulfur Dioxide (SO_2)	32	26	23	23	19	16	15	13
Totals	ND	267	250	220	191	161	141	129

NOx and SO2

- Nitrogen Dioxide (NO_2)
  - Sources: Industrial processes combusting coal and petroleum, thunderstorms
- Sulfur Dioxide (SO_2):
  - Sources: volcanoes, industrial processes- combustion of coal and petroleum
  - Reflect light when released in the atmosphere, which keeps sunlight out and causes Earth to cool

Acid Rain

SO_2 and NO_2 $\rightarrow$ H_2SO_4 (Acid Rain)

- Most rainfall is naturally slightly acidic (~ph5.6)
- Sulfur dioxide & nitrogen oxides are transformed by reaction with oxygen & water vapor to sulfuric & nitric acids.
- Rain pH ~ 5-5.5

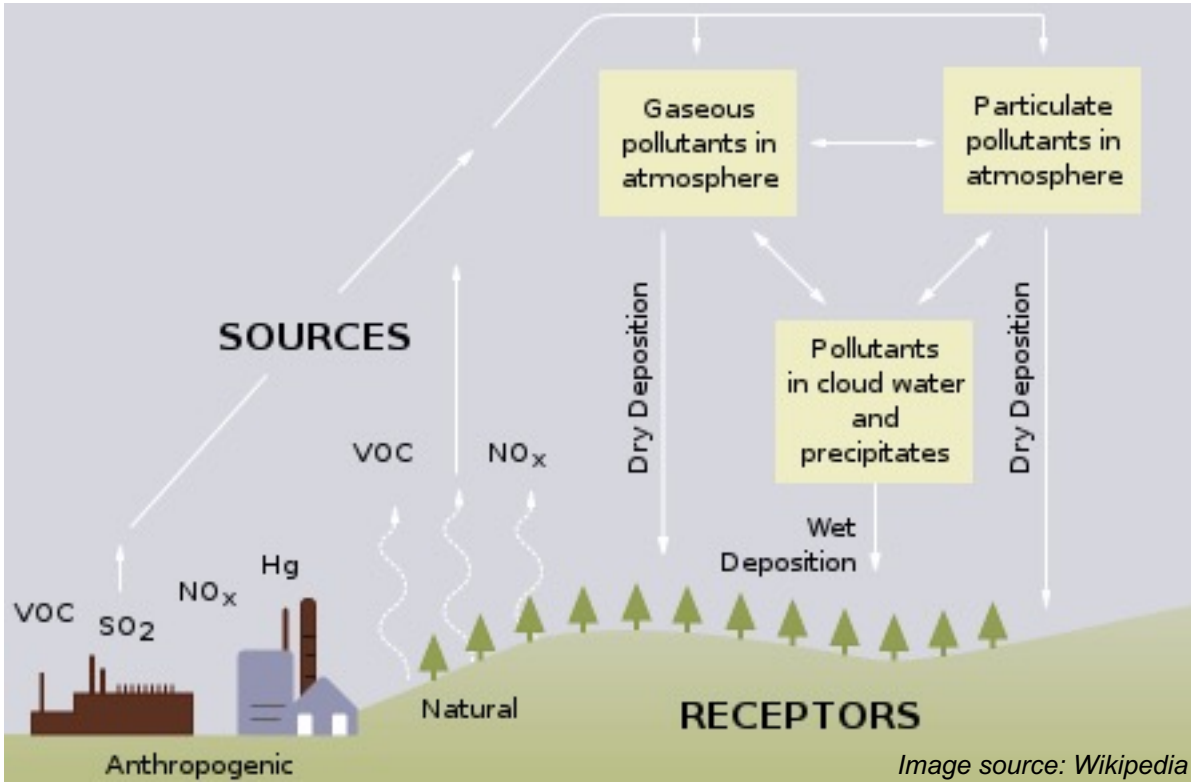


Image source: Wikipedia

With acid rain, the air pollution emitted in one area affects the environment in regions hundreds of miles downwind of industrial centers

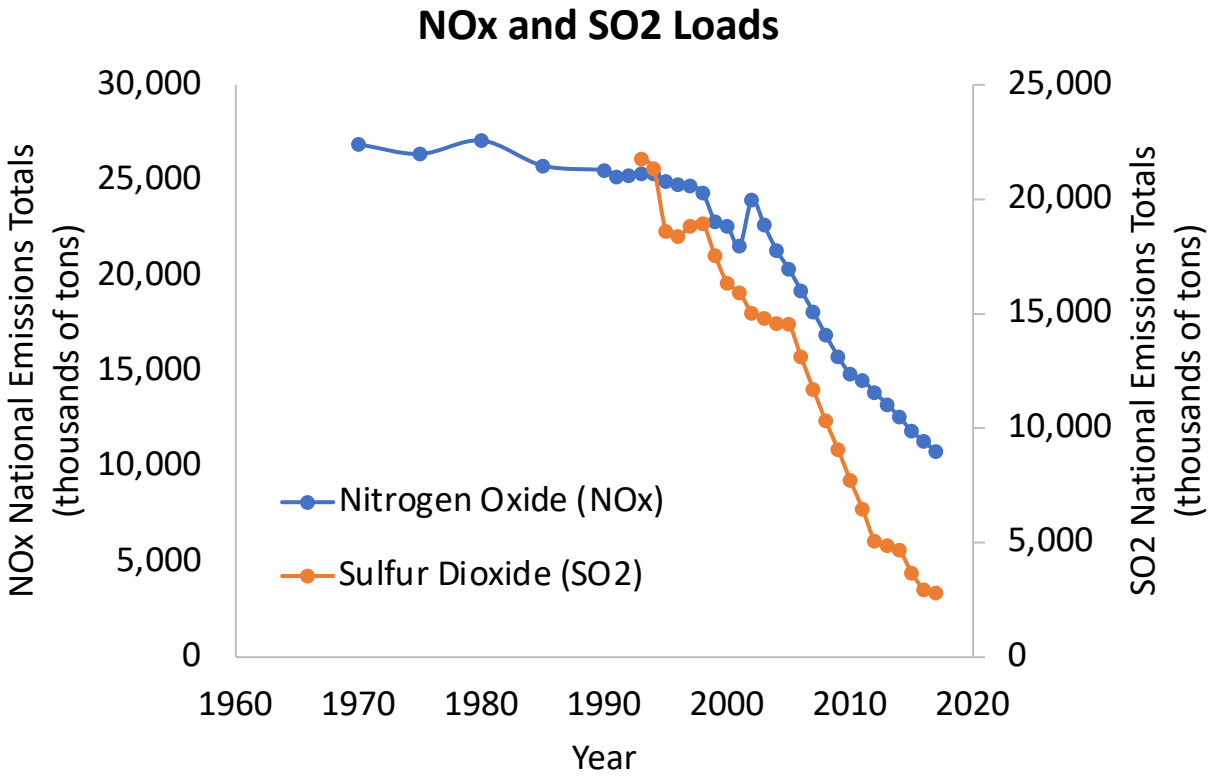
Effects of Acid Rain

More severe in areas underlain by acidic rocks, such as granite. (eg, upstate NYork, New England, Scandinavia severely affected.) Areas underlain by carbonate rocks such as limestone have a natural buffering capacity and are less vulnerable.

Little echo pond in Franklin NY is one of the most acid lakes – pH of 4.2

1. Damages aquatic species: fish, amphibians and crayfish by disrupt life processes – crayfish produce fewer eggs
2. Dissolves chemical elements necessary for life on lakes – algae do not grow
3. Leaches metals out of rocks – lead, mercury, calcium

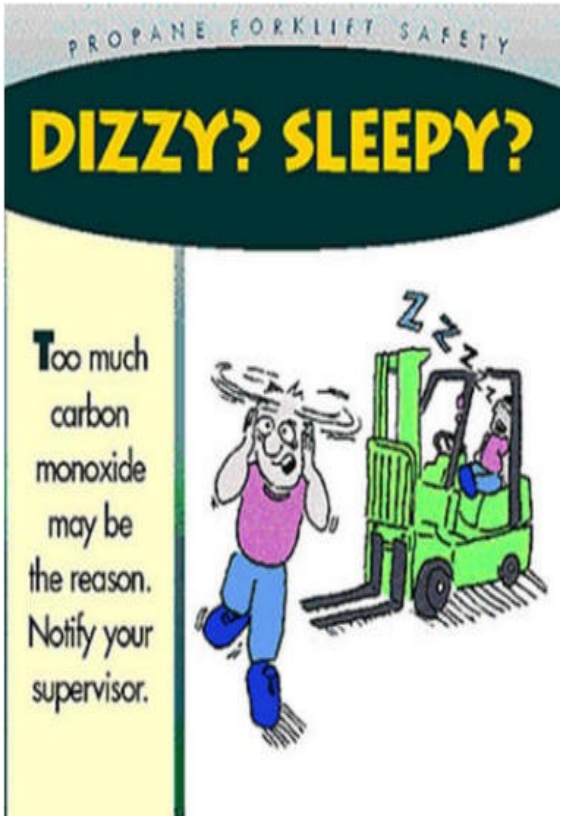
…but good news: major reductions in NOx and SO2 since revisions to Clean Air Act in 1990 that required emission reductions from power sectors, including coal industry (cap and trade program)



Data source: EPA (includes natural sources of Nox and SO2)

Carbon Monoxide (CO)

- Colorless, odorless
- Vehicular exhaust (produced by incomplete combustion of fuel such as natural gas, coal, or wood)
- Landfills



Particulate Matter

- Particles < 10 um in diameter
- Volcanoes, burning fossil fuels
- Visible as smoke, soot, dust, or not easily visible

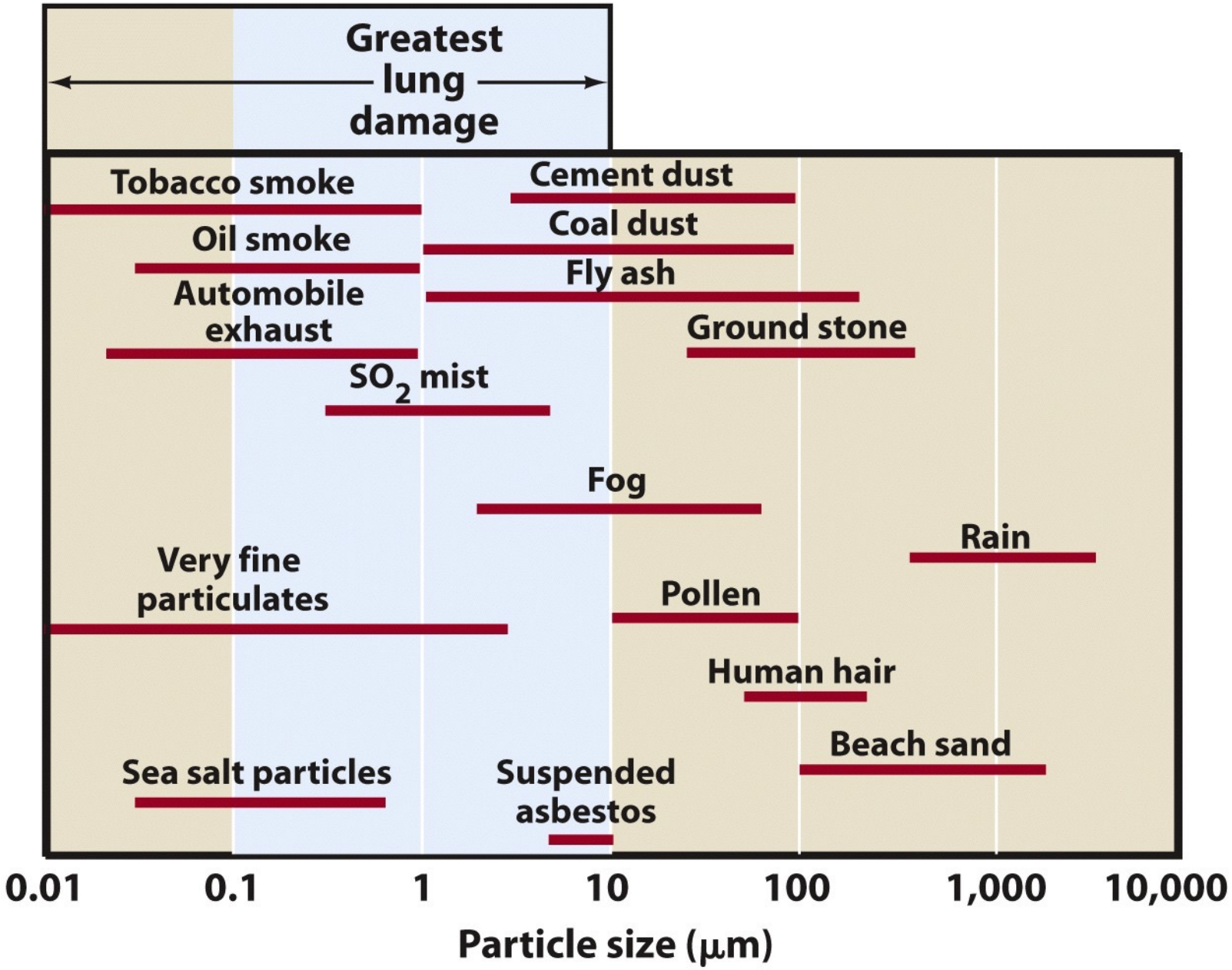
http://www.nrdc.org/air/

- Very fine particle pollutants- <2.5um in diameter (for scale: a human hair is 60-150um)
- Inhaled into lungs/absorbed in blood stream

Why we care about particulate matter:

Linked to lung cancer, asthma, & bronchitis

Other human health effects



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PM10

- PM_{10} is made up of particles less than 10μm in diameter
  - Present everywhere but high concentrations and/or specific types dangerous
  - Much particulate matter easily visible as smoke, soot or dust
  - Includes airborne asbestos and heavy metals

PM2.5

- Very fine pollutants—greatest concern
  - $PM_{2.5}$ –less than 2.5 μm in diameter
  - Easily inhaled into the lungs, then absorbed into the bloodstream
  - Ultrafine particles <0.18 μm released by automobiles
- Common term: Total Suspended Particulates (TSPs)
  - Tend to be highest in large cities in developing countries

Types of Pollution

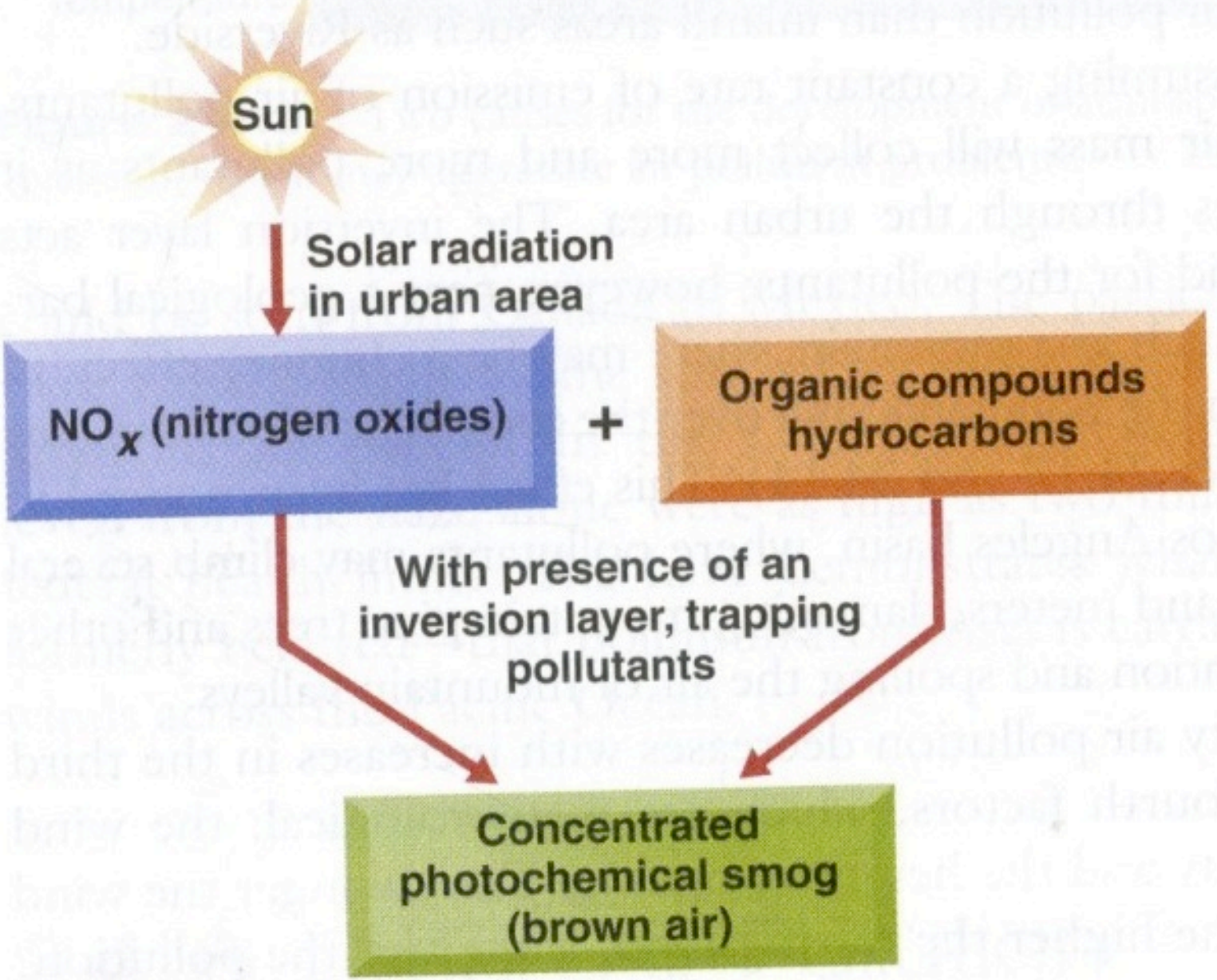
Primary Pollutants – emitted directly into the air

PM, CO, CO2, SO2, NO2, VOCs…

Secondary Pollutants – produced through reactions between primary pollutants and other atmospheric compounds (commonly with energy from the sun)

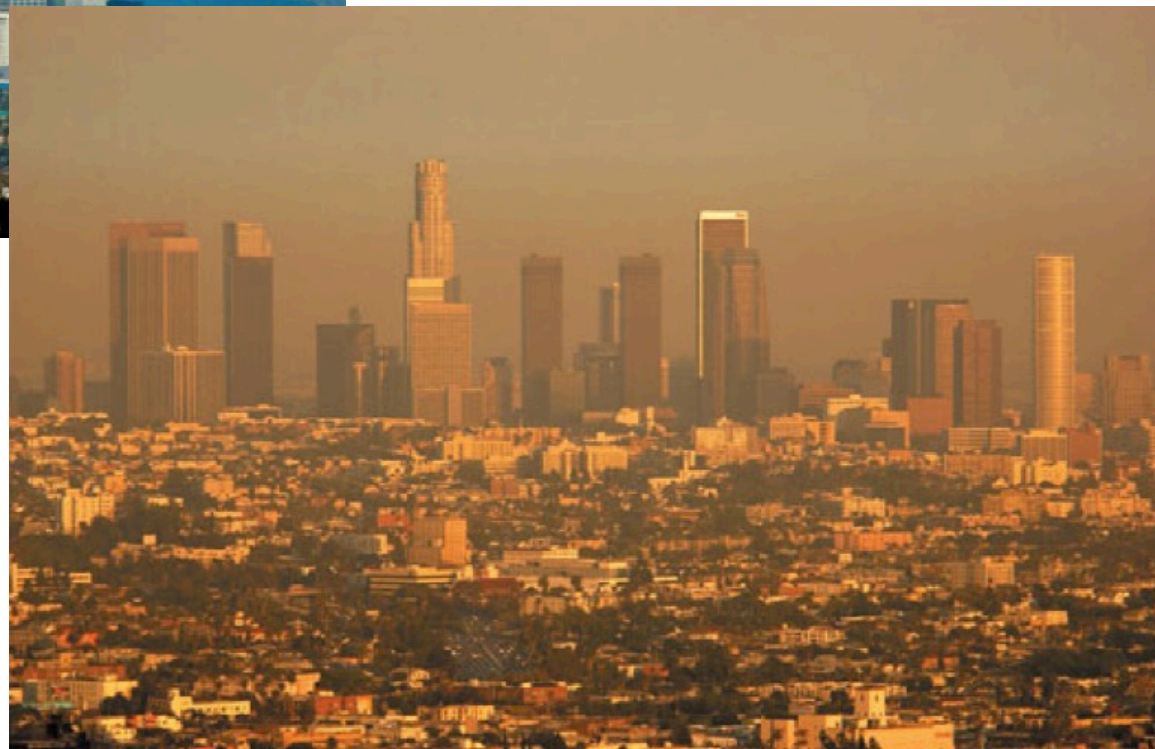
Smog

- Smog: term first used in 1905 as mixture of smoke and fog that produced unhealthy air
- Two major types
  - *Photochemical smog*: produced by combination of nitrogen oxides and hydrocarbons in the presence of sunlight
    - Directly related to automobile use
    - LA-type smog or brown air
  - *Sulfurous smog*: produced by combustion of coal or oil
    - London-type smog, gray air, or industrial smog

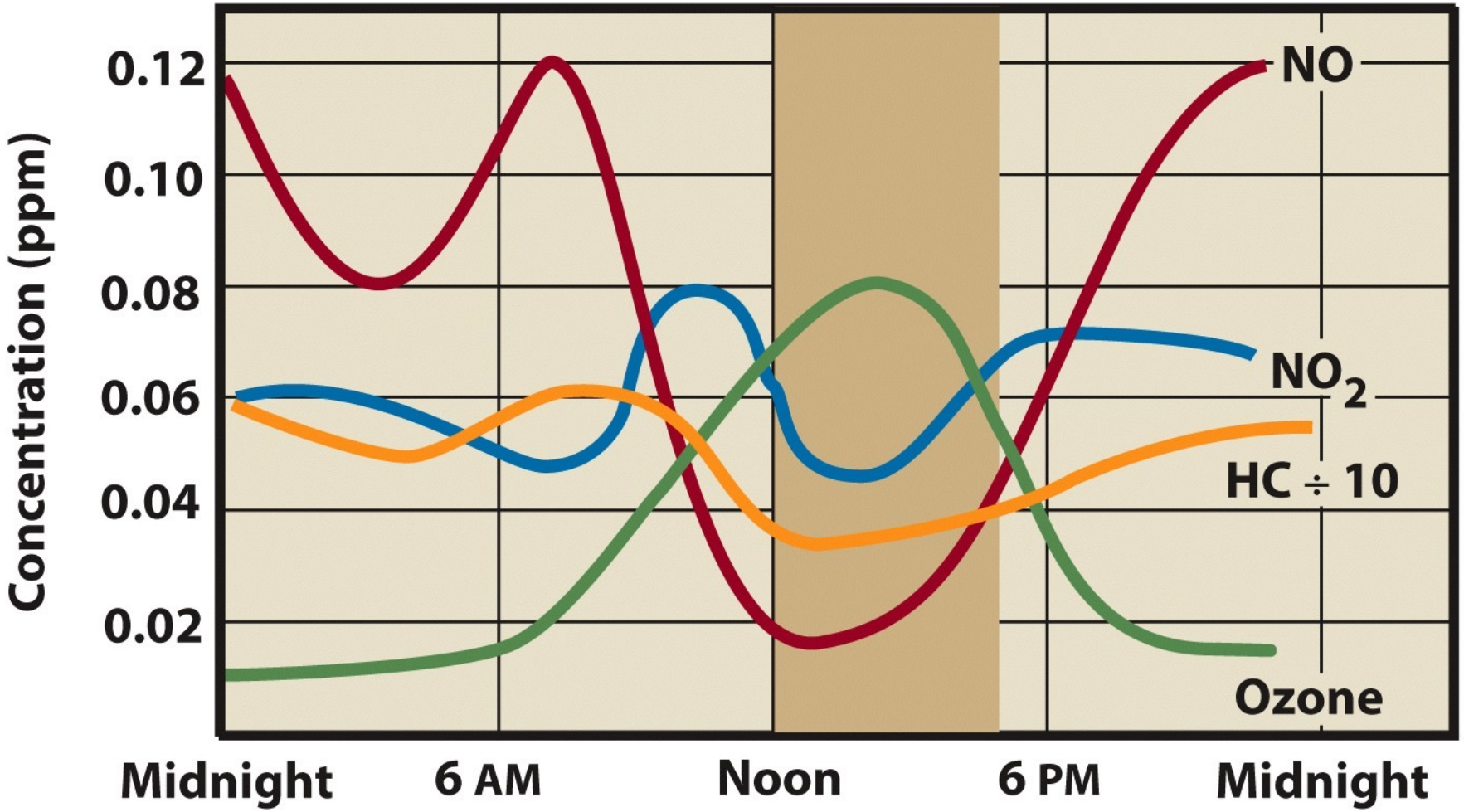


How photochemical smog is produced.

Photochemical smog is worse in summer with more UV radiation



Concentration of Air Pollutants Throughout the Day



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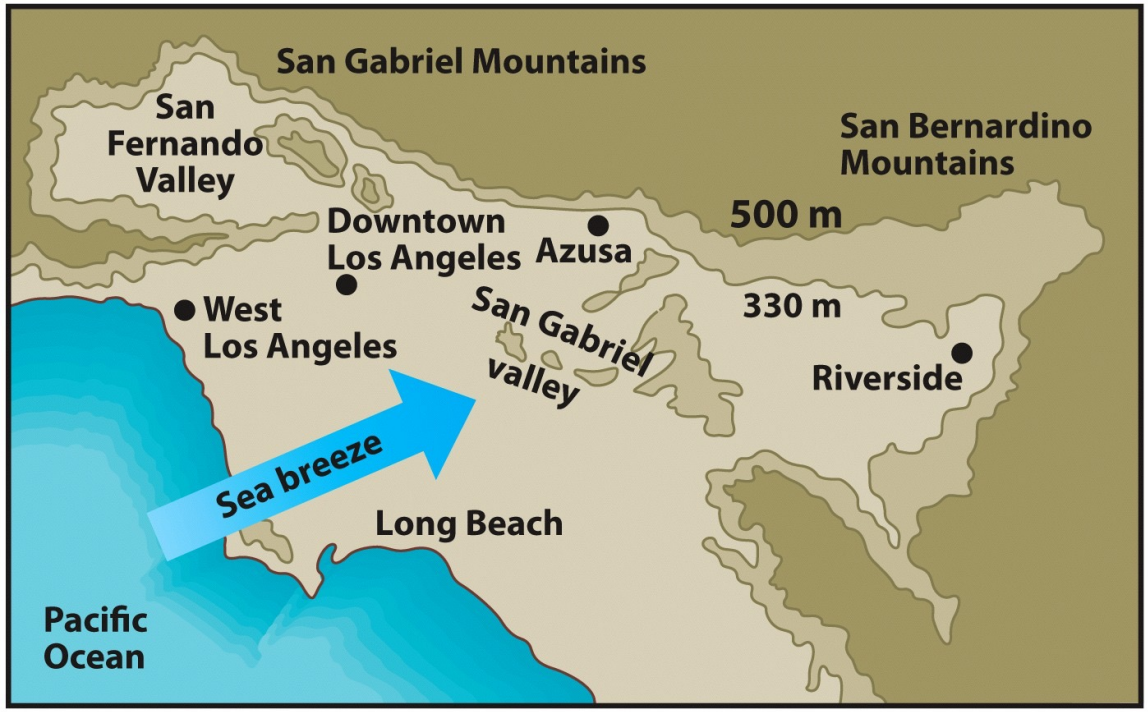
Cities situated in a valley or topographic bowl are more susceptible to smog problems

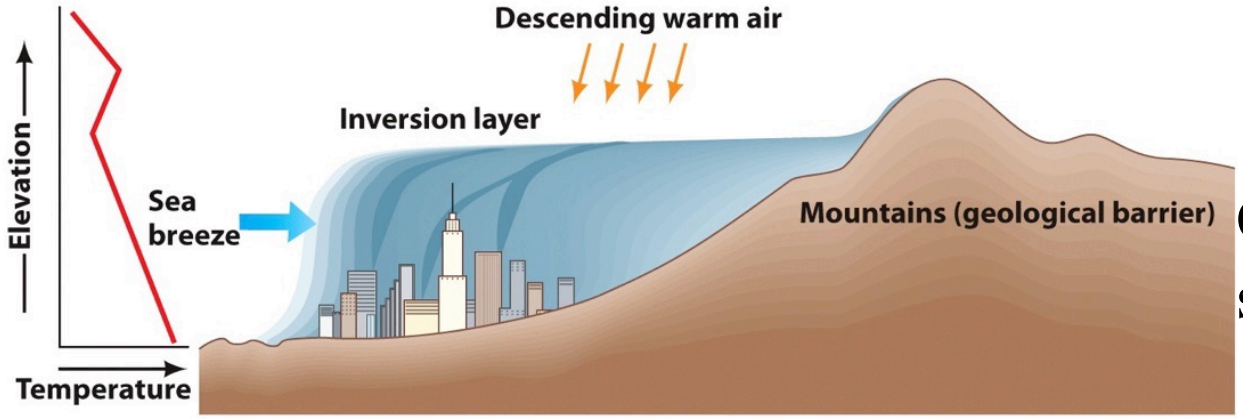
- Surrounding mountains and inversions prevent pollutants from being transported by wind
- *Examples:*
- Missoula, Montana, and Los Angeles CA



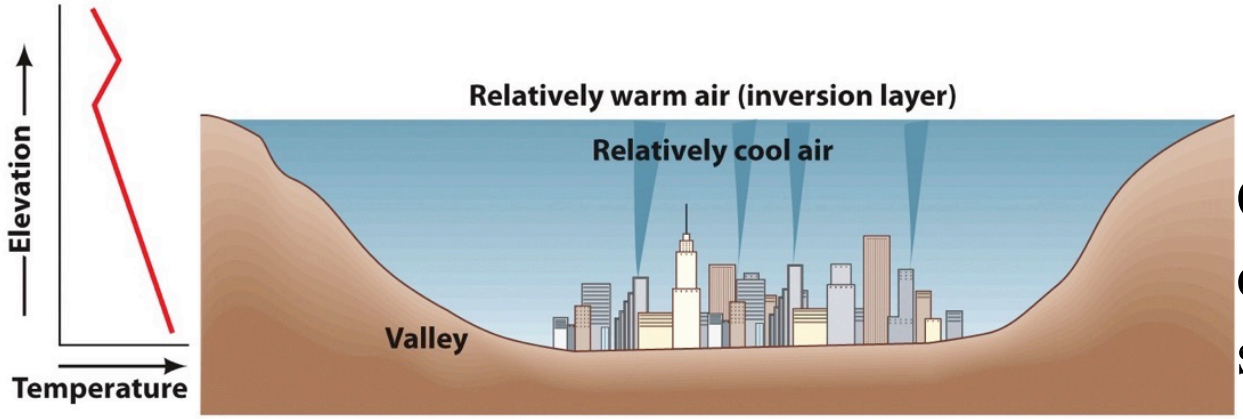
(*Source: Modified from S.J. Williamson, Fundamentals of Air Pollution* [Reading, MA: Addison-Wesley, 1973].)

Atmospheric Inversion

Atmospheric inversion occurs when warmer air is found above cooler air, and can lead to a pollution event



Occurs primarily in summer and fall



Occurs when cloud cover associated with stagnant air

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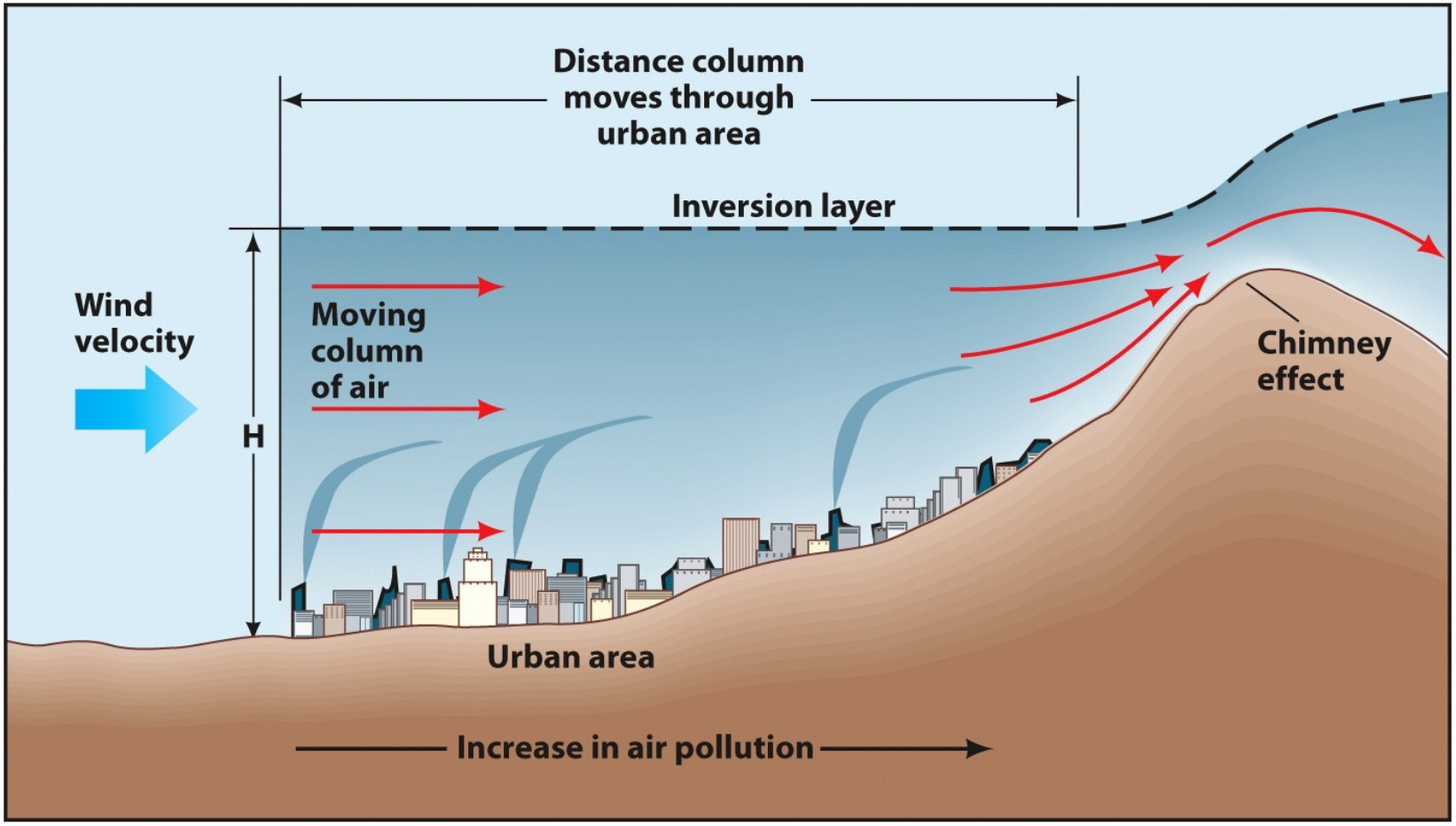

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Air pollution potential increases downwind as pollutants accumulate in air flowing over the city.

Effects of Pollutants

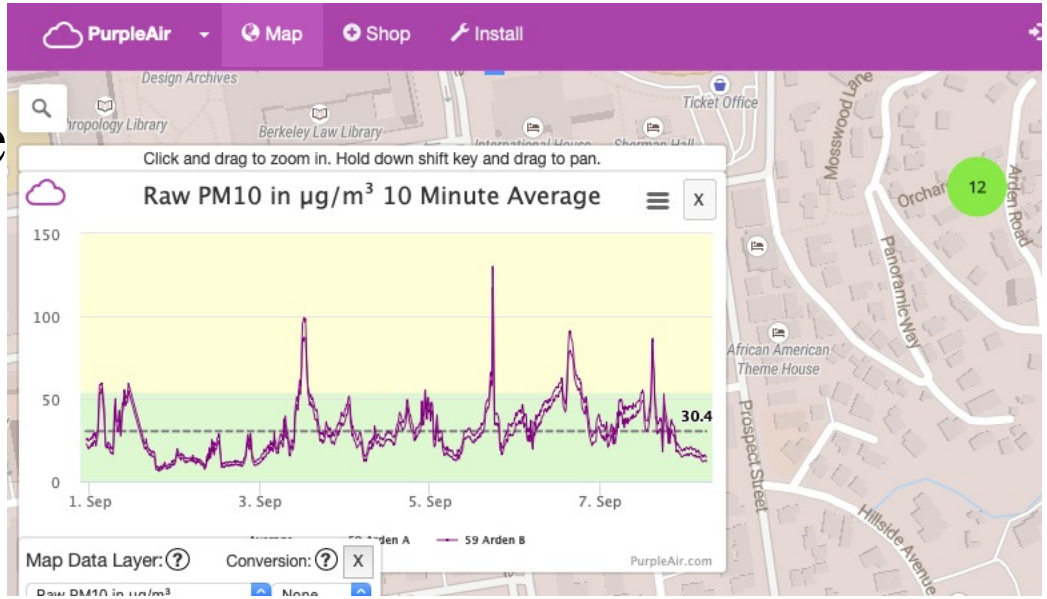
- Visual quality reduced
- Vegetation affected
- Animals
- Human Health: chronic asthma
- Photochemical smog
  - Damage to green plants and aggravation of chronic disease
  - Usually low-level over long period of time, but major disasters have occurred (e.g, Great Smog of 1952 killed >8,000 in London)

Getting Information on Air Pollution

Sources of information (covered in lab section):

Measuring PM10 concentration with Dustrak

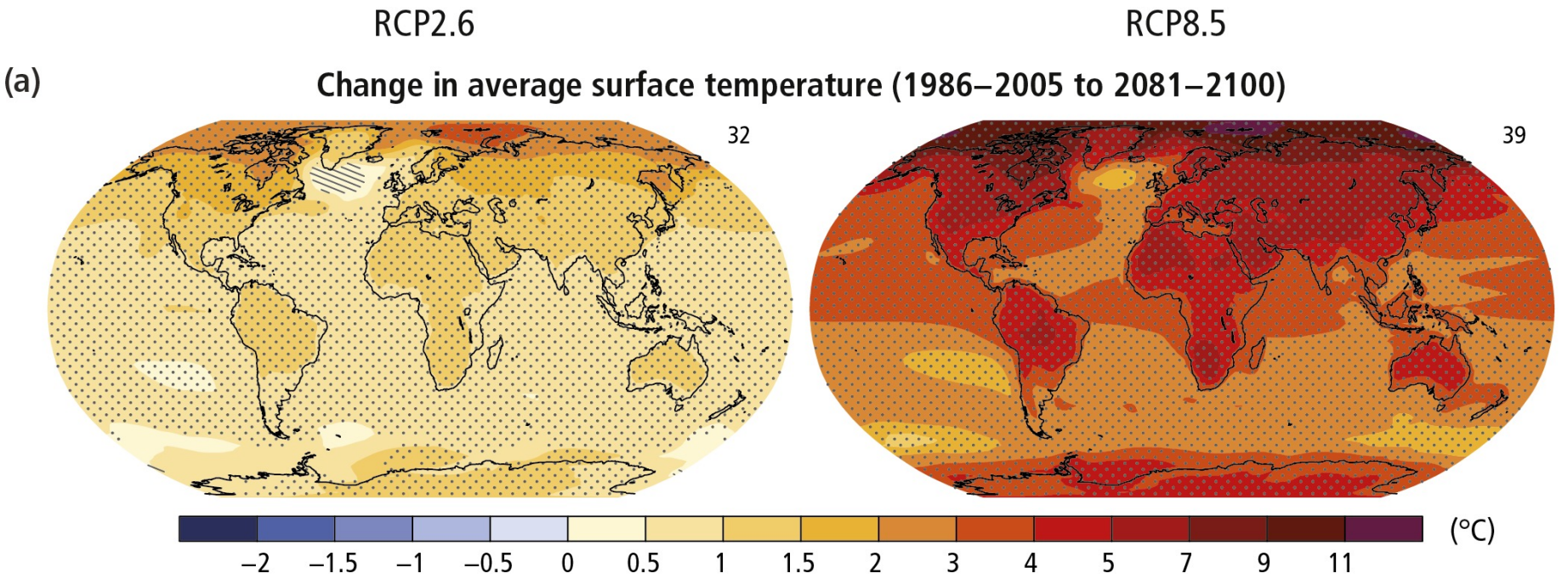
Purple Air website

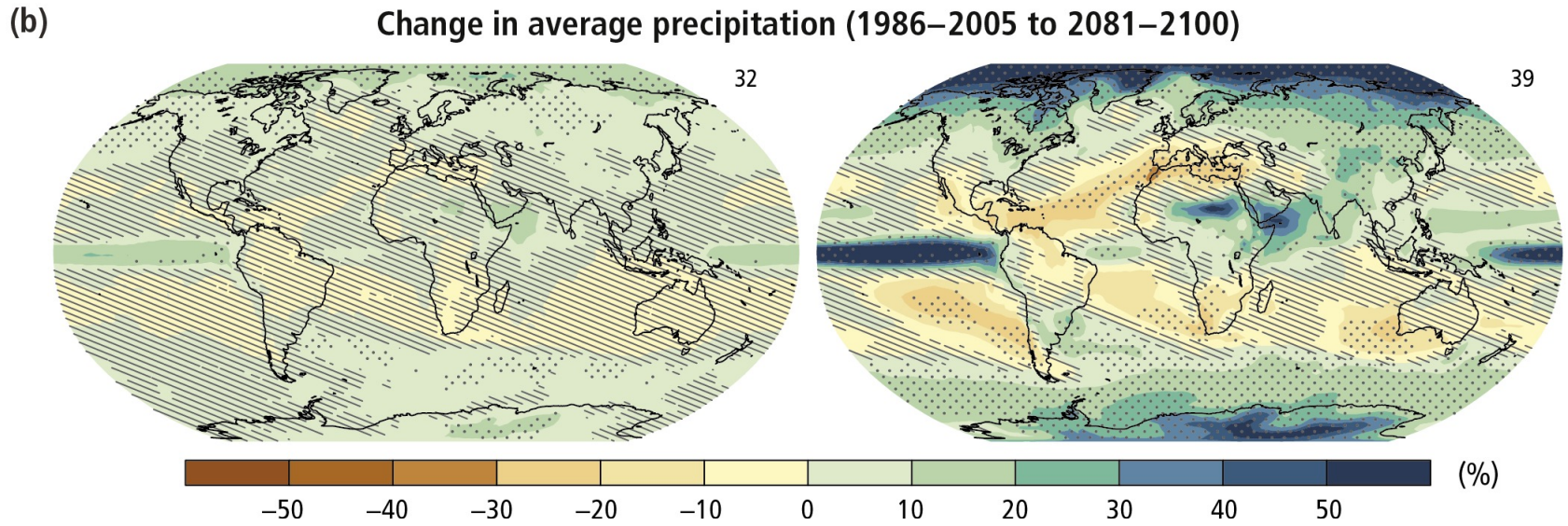


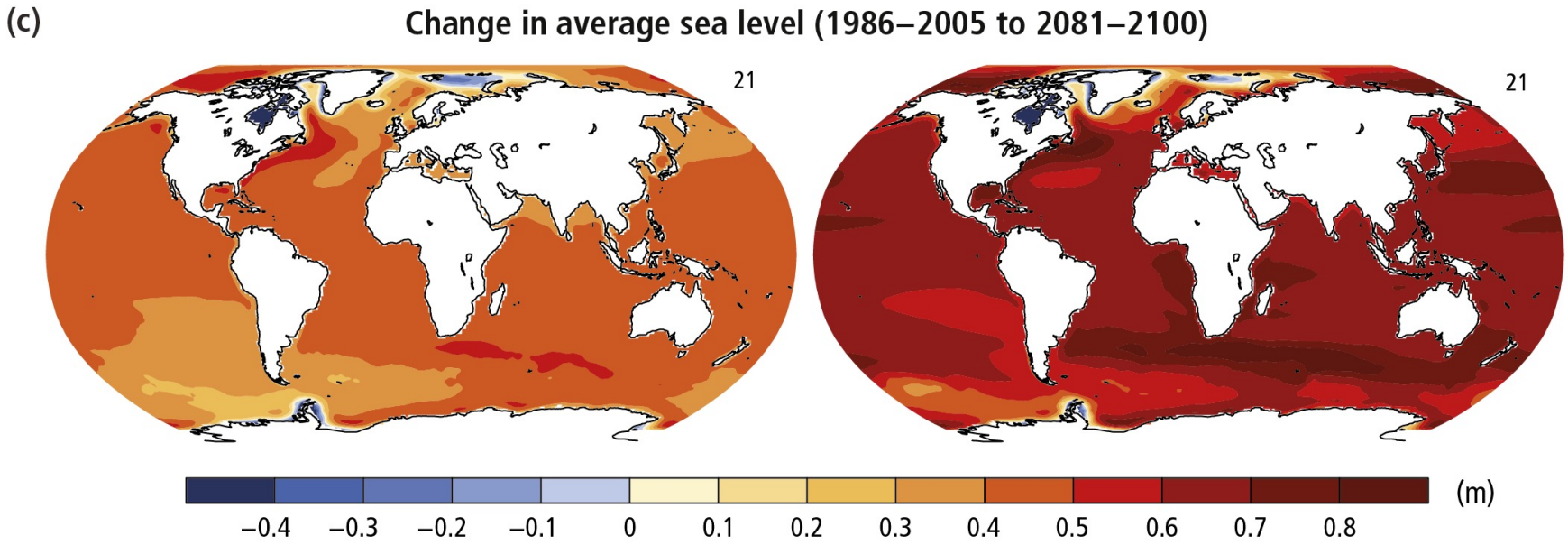
AQI (Air Quality Index) on AirNow

Climate Change: Review of Impacts

Direct effects:
Changes in temperature, precipitation, and (due to melting icecaps) rising sea level.
Models used to predict future conditions

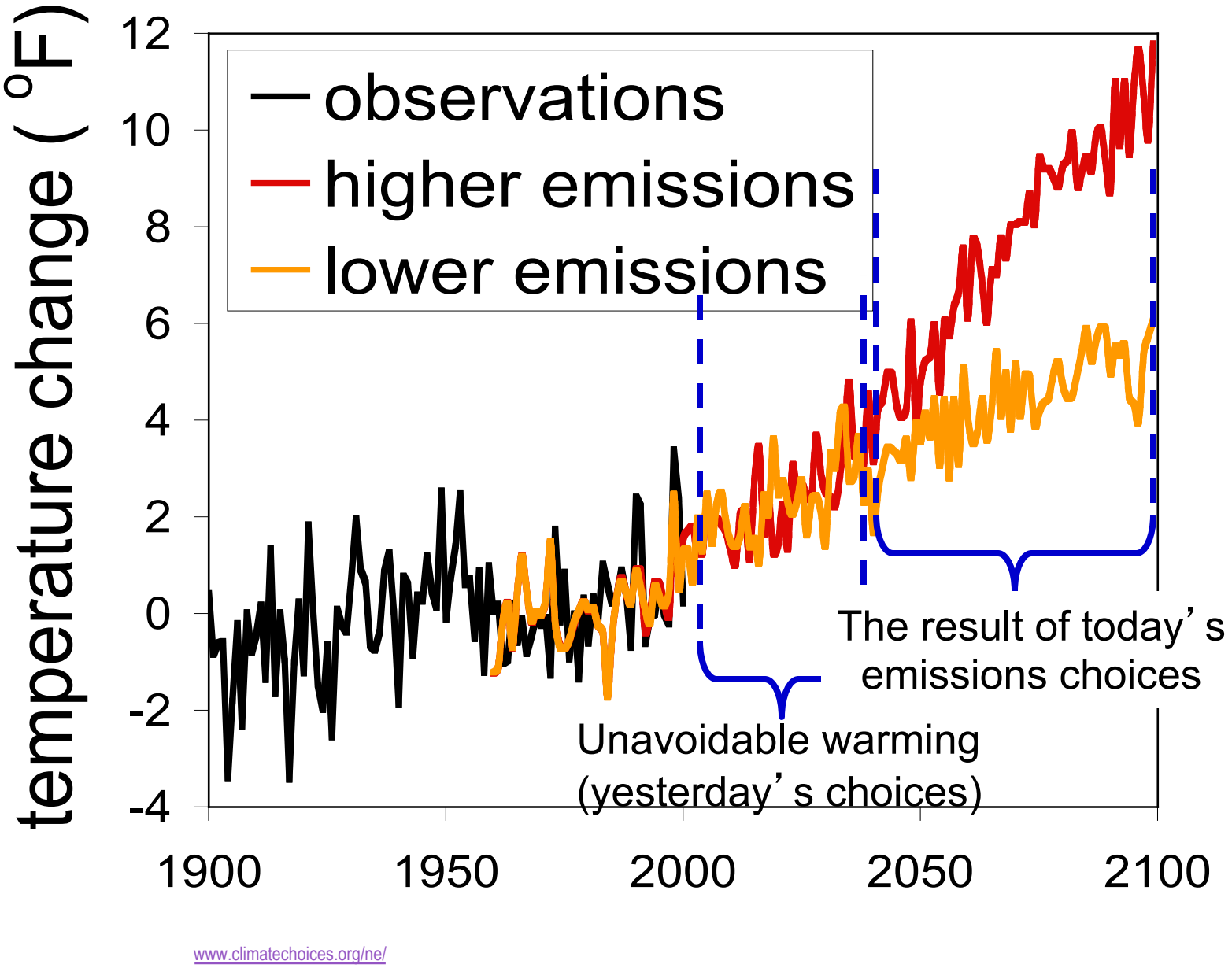






From 1993 to 2019 global average sea level increased 3.4 inches, from melting & heat expansion. (Melting is increasing)

https://oceanservice.noaa.gov/facts/sealevel.html



www.climatechoices.org/ne/

Observed and model-based changes in annual average temperature for the Northeast US (in °F) relative to 1961-1990 average temperature.

Climate change impacts presented in the film *Inconvenient Truth*

Summary – 1 of 2

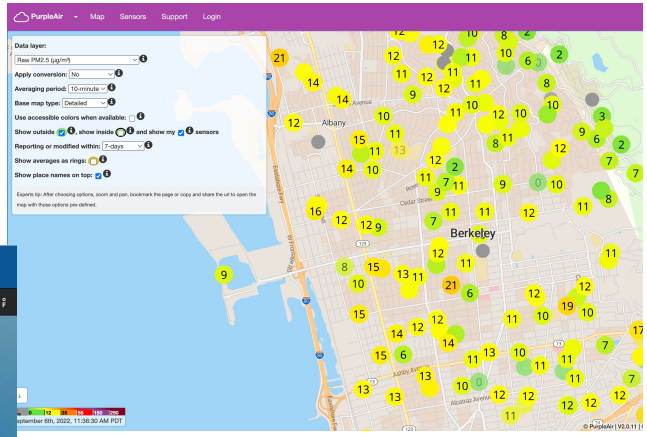
- Coal reserves remain abundant
  - low-quality, highly polluting coal
  - creates air pollution, global warming problems.
- Oil is a remarkable resource
  - high energy content, tremendous flexibility in use
  - We're using oil accumulated over millions of years
- Natural gas and 'tight' oil accessed by fracking
  - US oil now imports less oil,
  - Not running out of oil as quickly as expected.
- We cannot use up all available coal and oil without disastrous consequences for climate change

Summary – 2 of 2

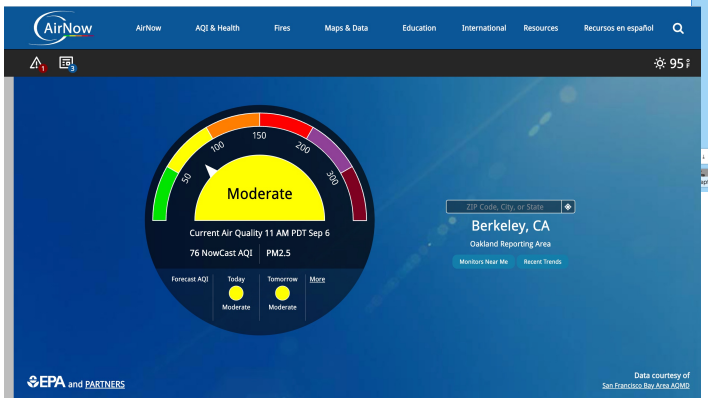
- Air pollution sources: stationary (point, area) and mobile; criteria air pollutants regulated under Clean Air Act - CO, NO2, VOC, PM, SO2
  - Nox, So2 produce acid rain, severe impacts on lakes
  - PM 2.5 causes greatest lung damage, easily inhalable, can cause asthma, chronic respiratory issues, lung cancer
- Primary and secondary pollutants - secondary pollutants produced through reactions between primary pollutants and atmospheric compounds (e.g., ozone = NOx + VOCs + sunlight; photochemical smog)
- Cities located in valleys or topographic basins more susceptible to smog problems

This week's lab: Air Quality

- We will measure concentrations of Particulate Matter (PM) using a device called Dust Trak
- We will measure PM2.5, which means particulates with a diameter smaller to 2.5 um.
- Dust Trak measures those concentrations of PM in mg/m^3.
- Remember to convert those to ug/m3 by multiplying by 1,000. So, you can compare lab measurements with AirQuality reports of PM2.5 such as AirNow or PurpleAir.



Source: purpleair.com



Source: AirNow.gov