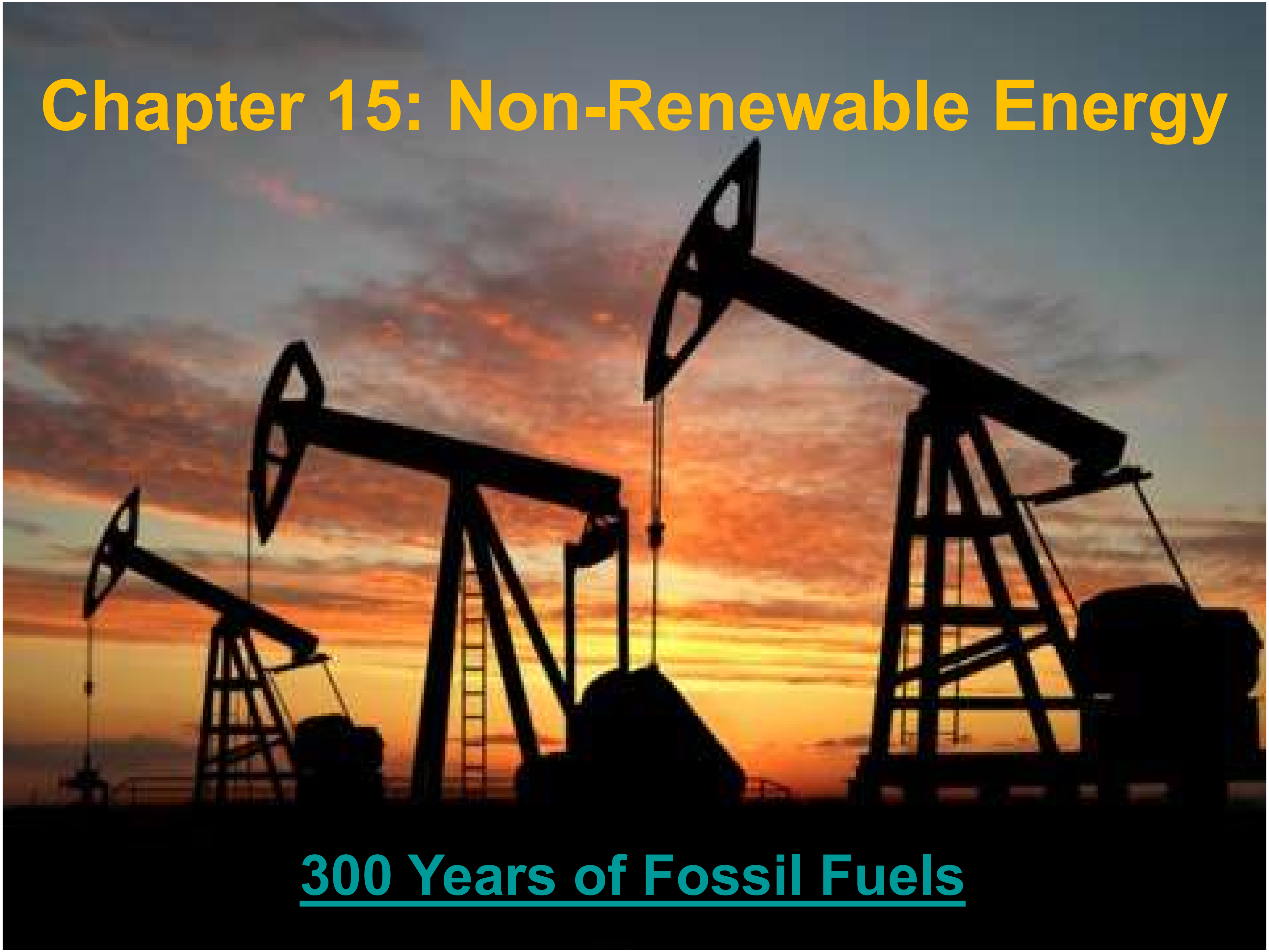
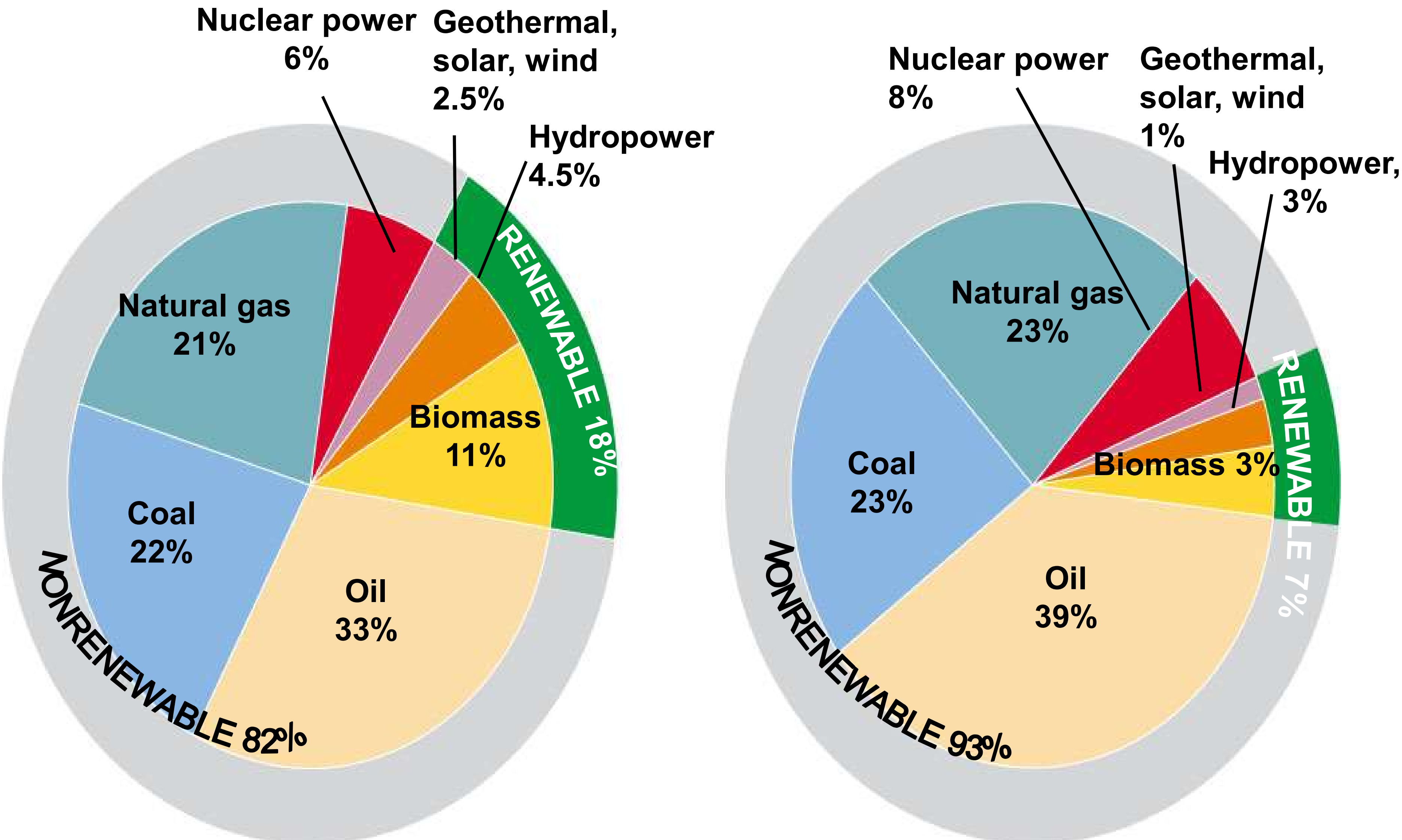

Chapter 15: Non-Renewable Energy
300 Years of Fossil Fuels

SOURCES OF ENERGY USE



World

United States

THE FOSSIL FUELS

Coal

In 2015, **33.2% of U.S. electricity** came from coal—roughly equal to natural gas (32.7%), but greater than nuclear power (20%) or renewable energy sources (13%).

There is an abundant supply of coal in the United States and it's a relatively inexpensive energy source, but it is declining in use.

Oil

America relies on its domestic supplies as well as imports of petroleum—about **one-quarter** of the amount we consume—from a handful of nations.

The United States depends heavily on oil, which accounts for 92% of all consumption in the transportation sector and 26% in the industrial sector.

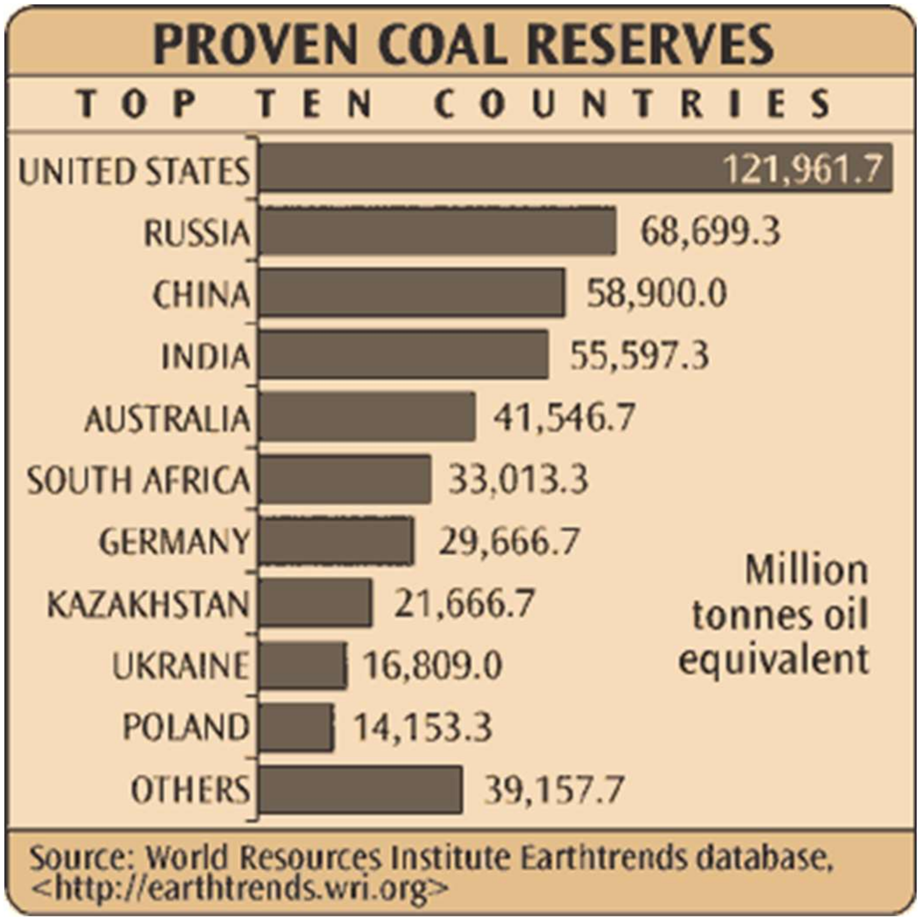
Natural Gas

The United States has abundant deposits of natural gas and imports **less than 4%** of the total amount consumed annually—chiefly from Canada .

In 2015, 29% of the U.S. total energy supply came from natural gas.

Source: http://needtoknow.nas.edu/energy/energy-sources/fossil-fuels/

Coal



TOP 3 PRODUCERS

- US
- Russia
- China

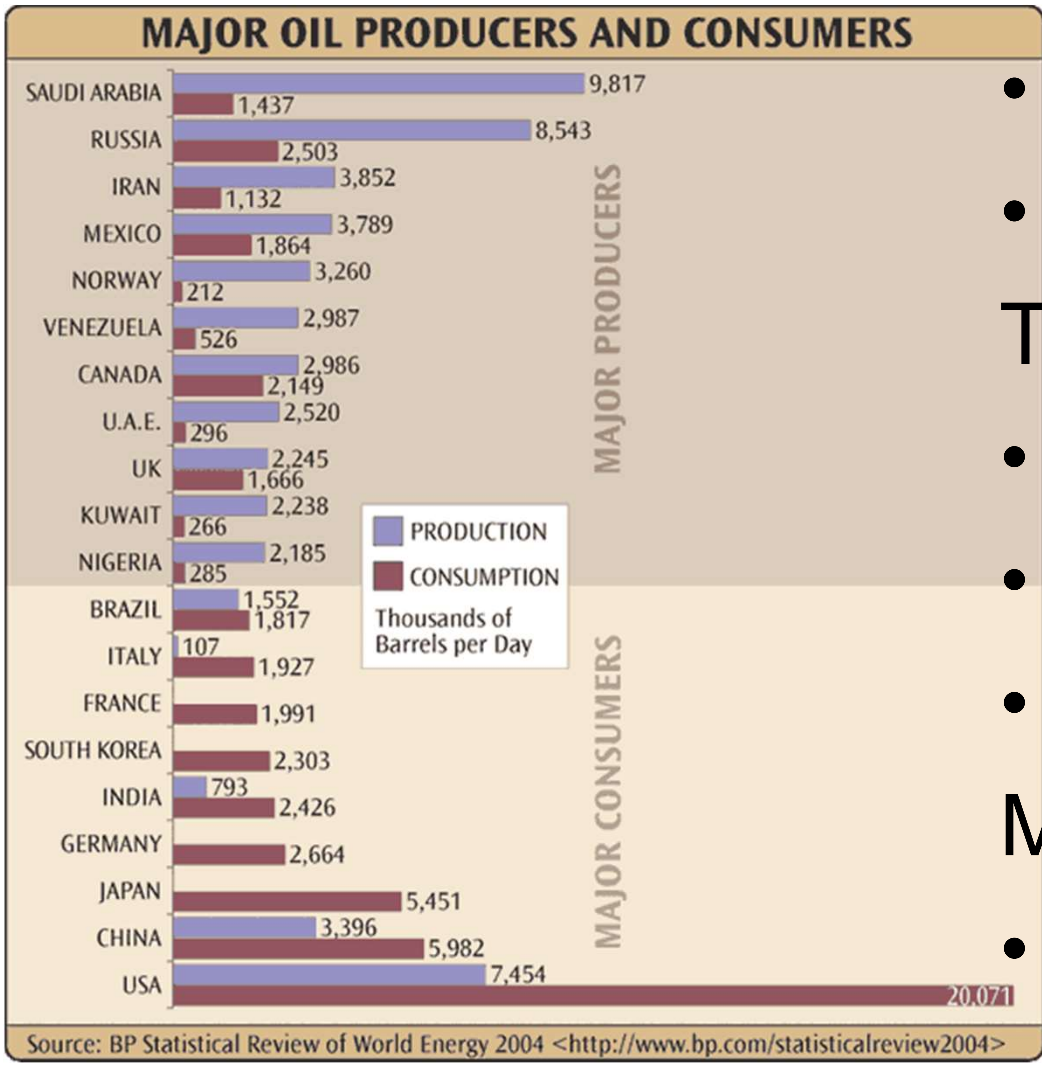
TOP 3 CONSUMERS

- China
- US
- India

MAIN USE

- Electricity

Oil



TOP 3 PRODUCERS

- Saudi Arabia
- Canada
- Iran

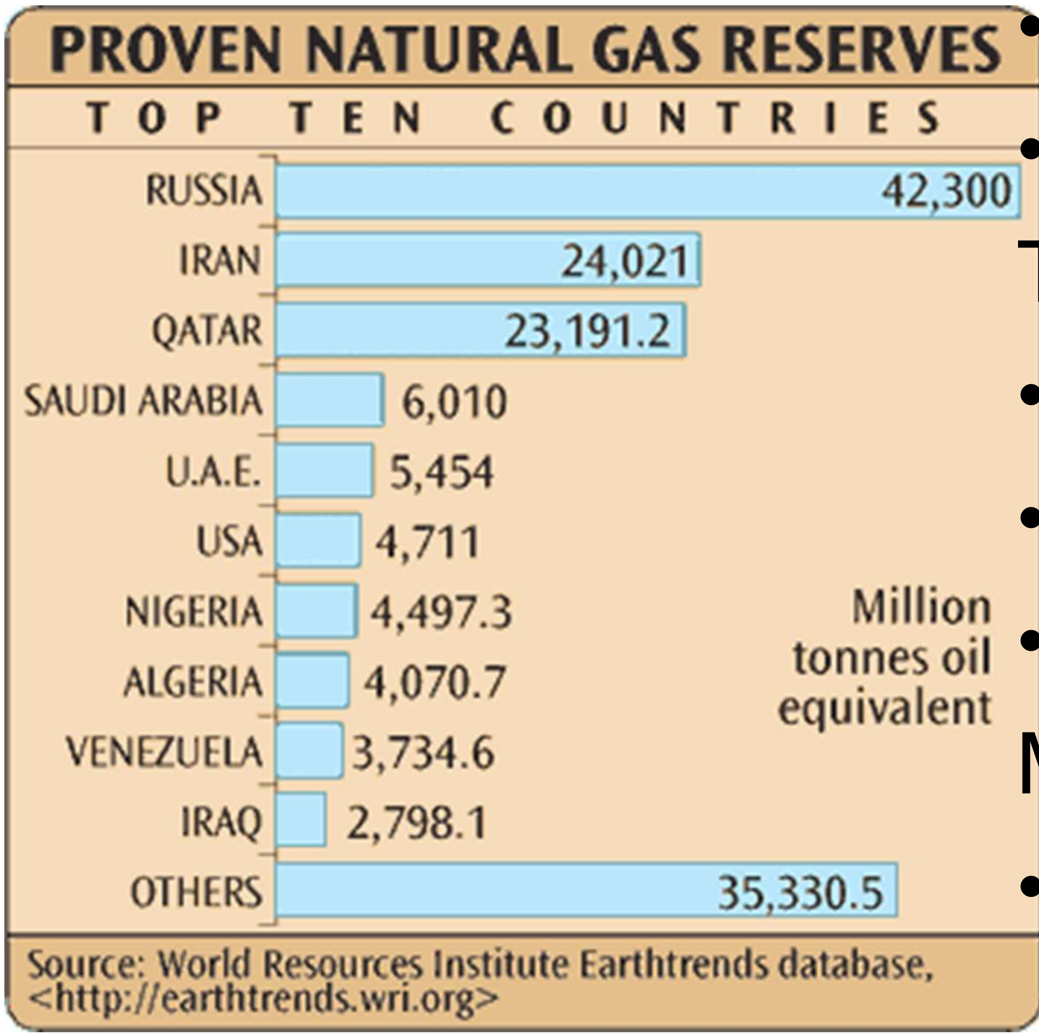
TOP 3 CONSUMERS

- US
- China
- Japan

MAIN USE

- Transportation

Natural Gas



TOP 3 PRODUCERS

- Russia
- Iran
- Qatar

TOP 3 CONSUMERS

- US
- Japan
- China

MAIN USE

- Electricity

Oil Shale

- ⦿Contains kerogen(organic material) which can be converted to oil
- ⦿3 trillion barrels of recoverable oil (750 billion located in US)
- ⦿Largest world reserves in Estonia, Australia, Germany, Israel, and Jordan
- ⦿Moderate net energy yield

- ⦿Environmental Costs

→Surface mining
→Pollution
→Acid rain
→Global warming

Shale is a type of sedimentary rock, formed in watery environments.
Oil shale has a high oil content due to the decomposition of ancient plant and animal life in the water.

Tar Sands (or Oil Sands, if you prefer)

Contain bitumen (semi-solid form of oil that does not flow)

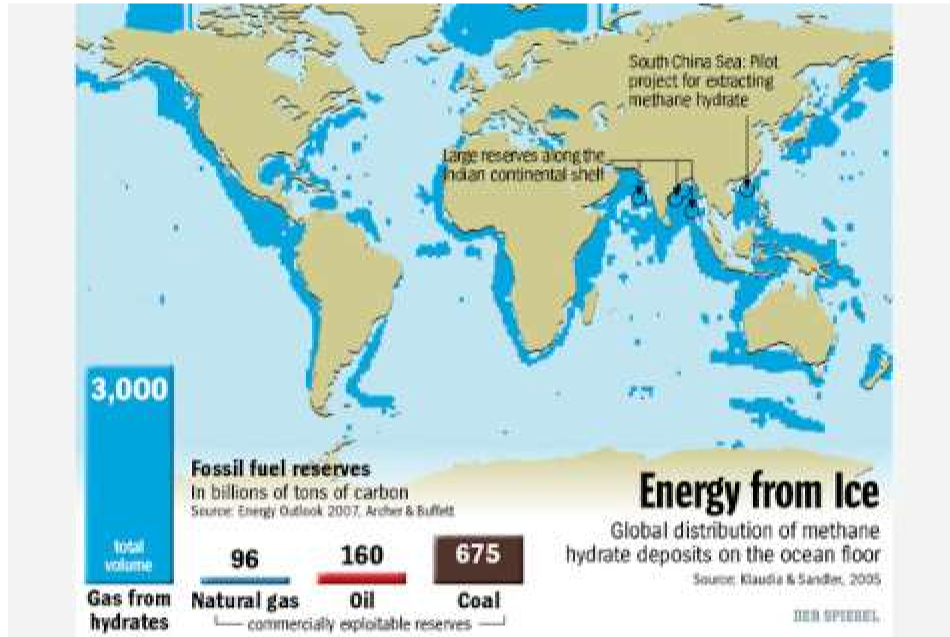
- Specialized refineries can convert bitumen to oil, using high heat and chemicals
- Deposits are mined using strip-mining techniques
- Deposits located in Canada & Venezuela
- Represents 2/3 of the world's total oil reserves
- Moderate net energy yield
- Environmental Costs

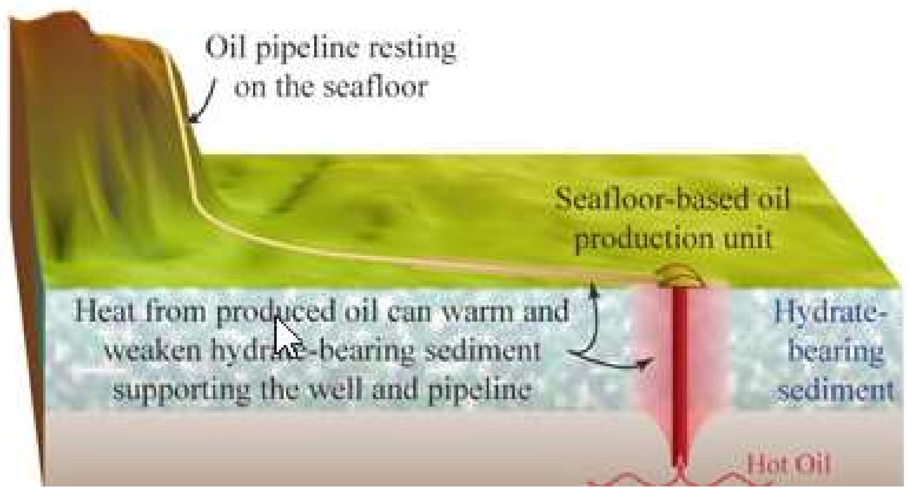
→Air and Water Pollution
→Acid rain
→Global warming

These Canadian tar sands are refined and transported to the US thru the Keystone XL pipeline

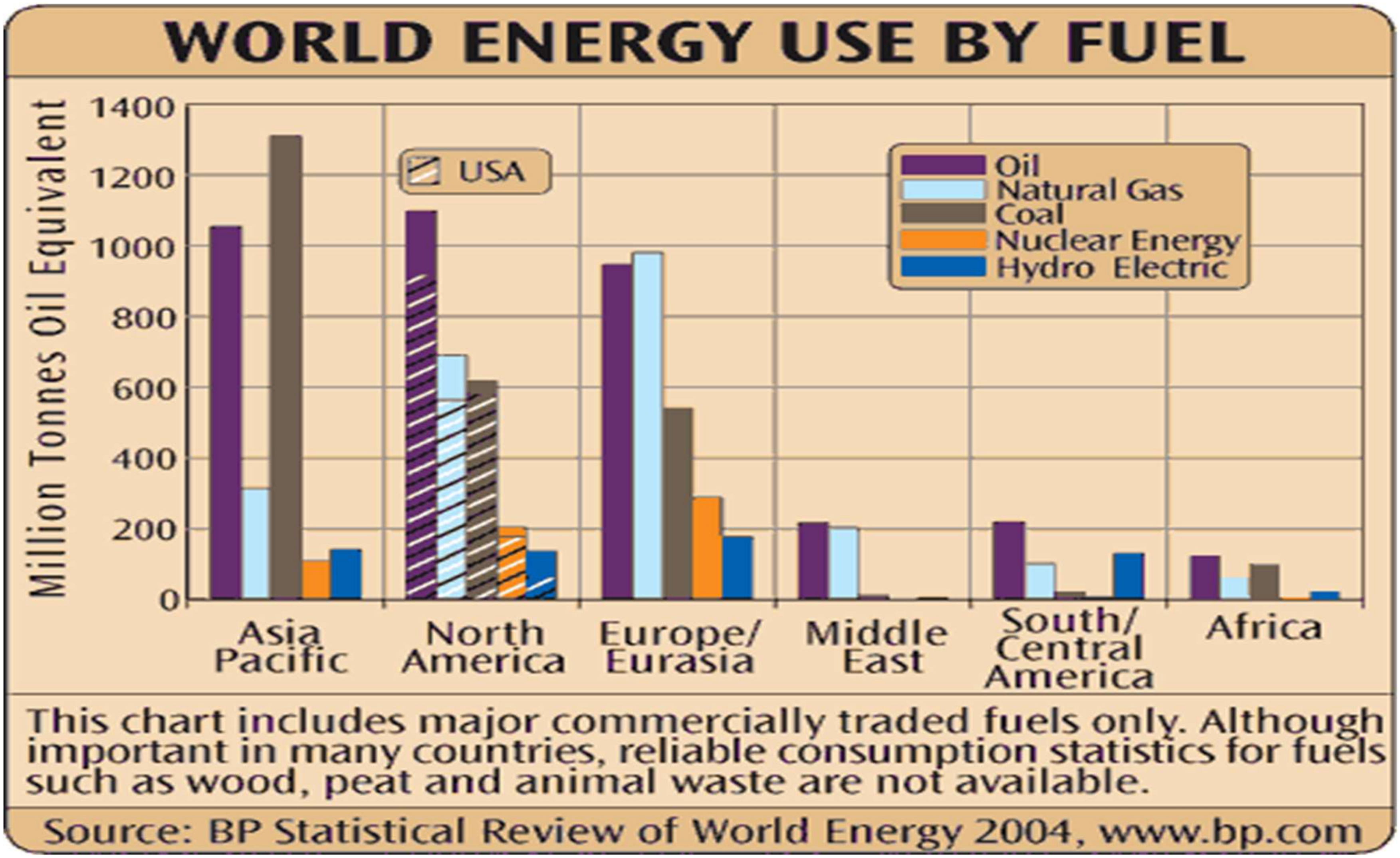
Methane Hydrates

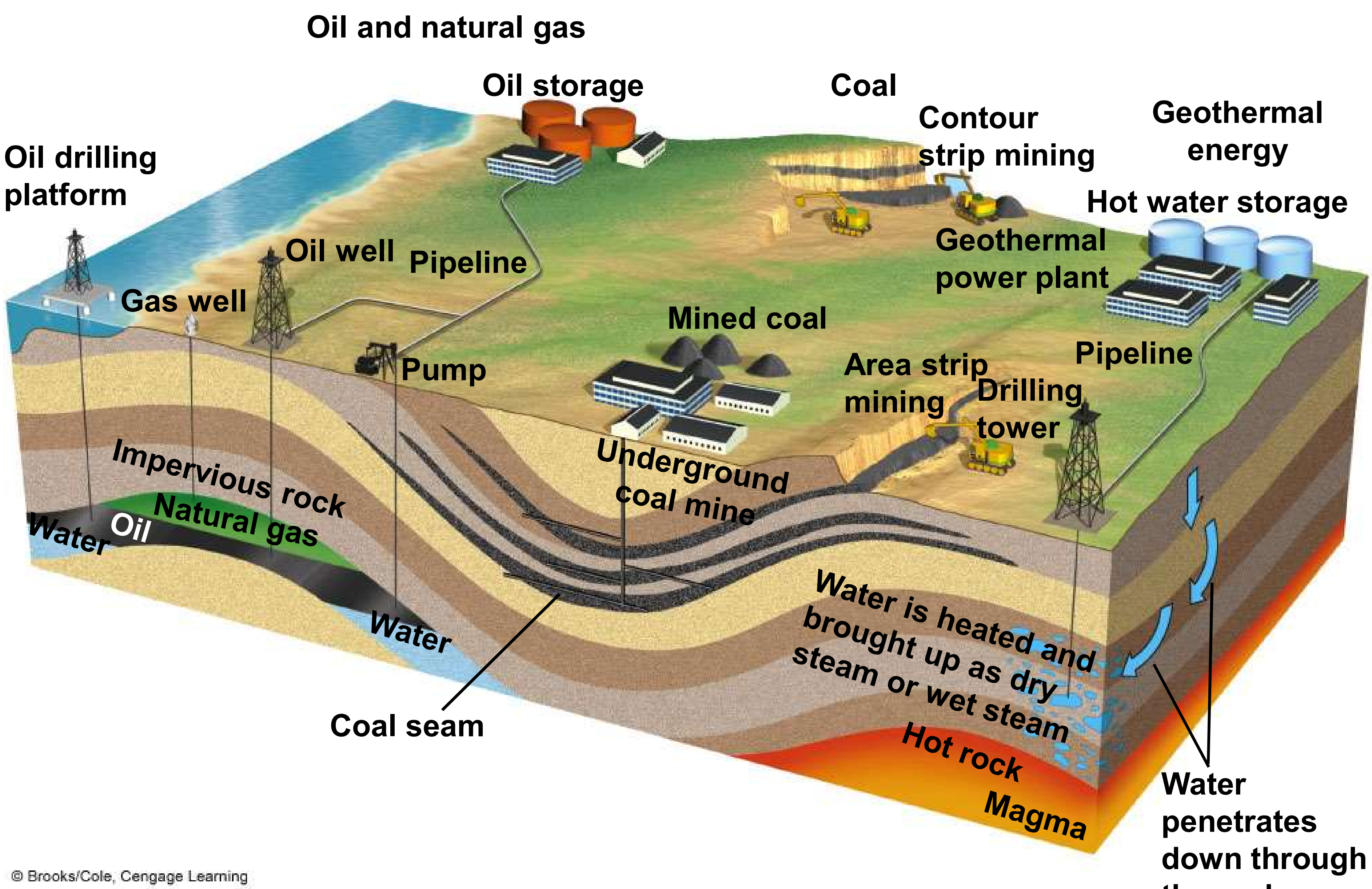
→Methane locked in ice; formed at low temperature & pressure (recent discovery)
→Found on land in permafrost regions & beneath ocean floor
→3000X more than is found in atmosphere
→To date there has been no large-scale commercial production of methane hydrates due to its instability and lack of capture technology. All production has been either small-scale or experimental.





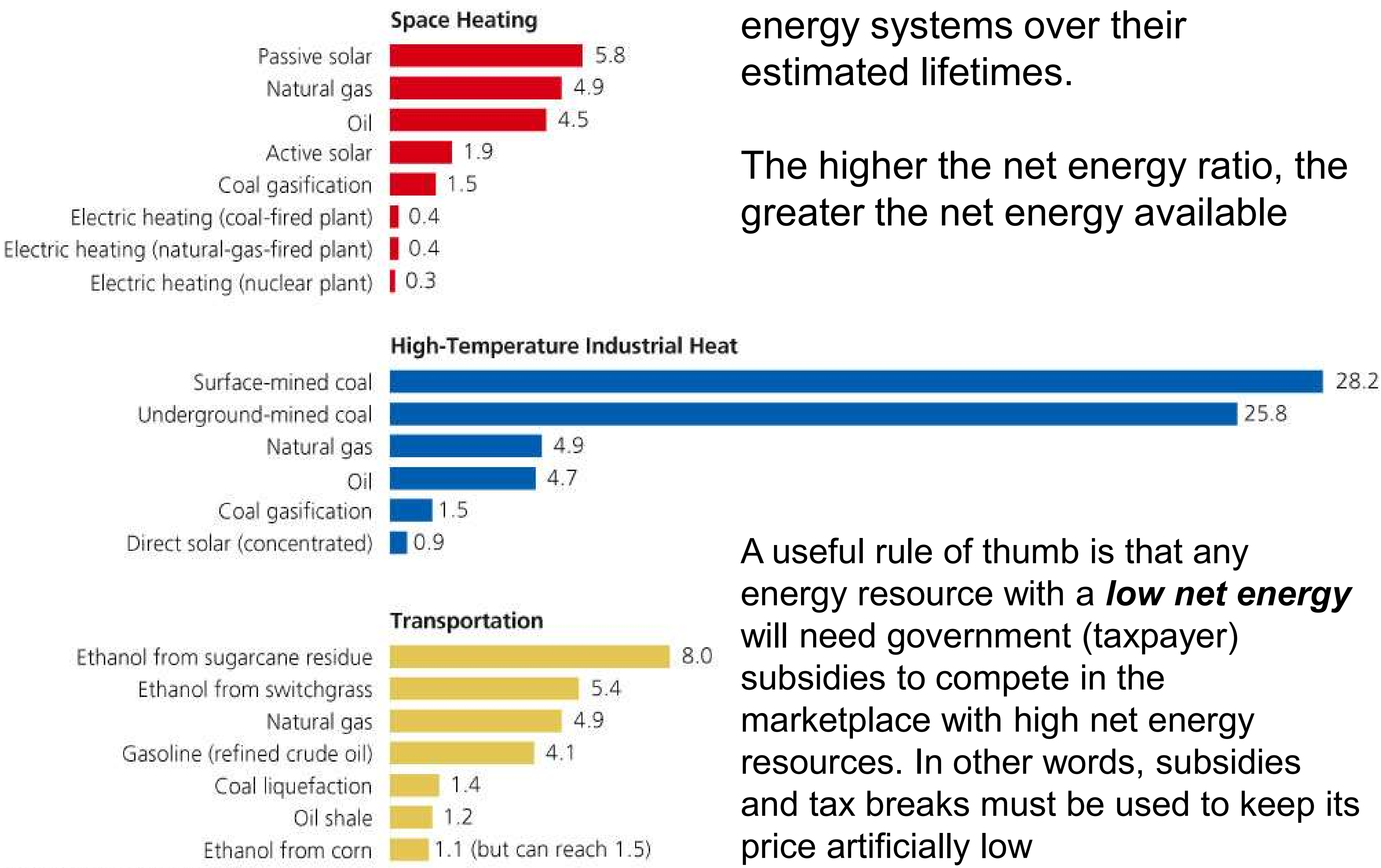
Fuel Source Use





Oil and natural gas
Oil storage
Coal
Contour strip mining
Geothermal energy
Oil drilling platform
Hot water storage
Oil well
Pipeline
Geothermal power plant
Gas well
Mined coal
Pump
Pipeline
Area strip mining
Drilling tower
Underground coal mine
Impervious rock
Natural gas
Oil
Water
Water
Coal seam
Water is heated and brought up as dry steam or wet steam
Hot rock
Magma
Water penetrates down through the rock

Fig. 15-2, p. 372



Net energy ratios for various energy systems over their estimated lifetimes.

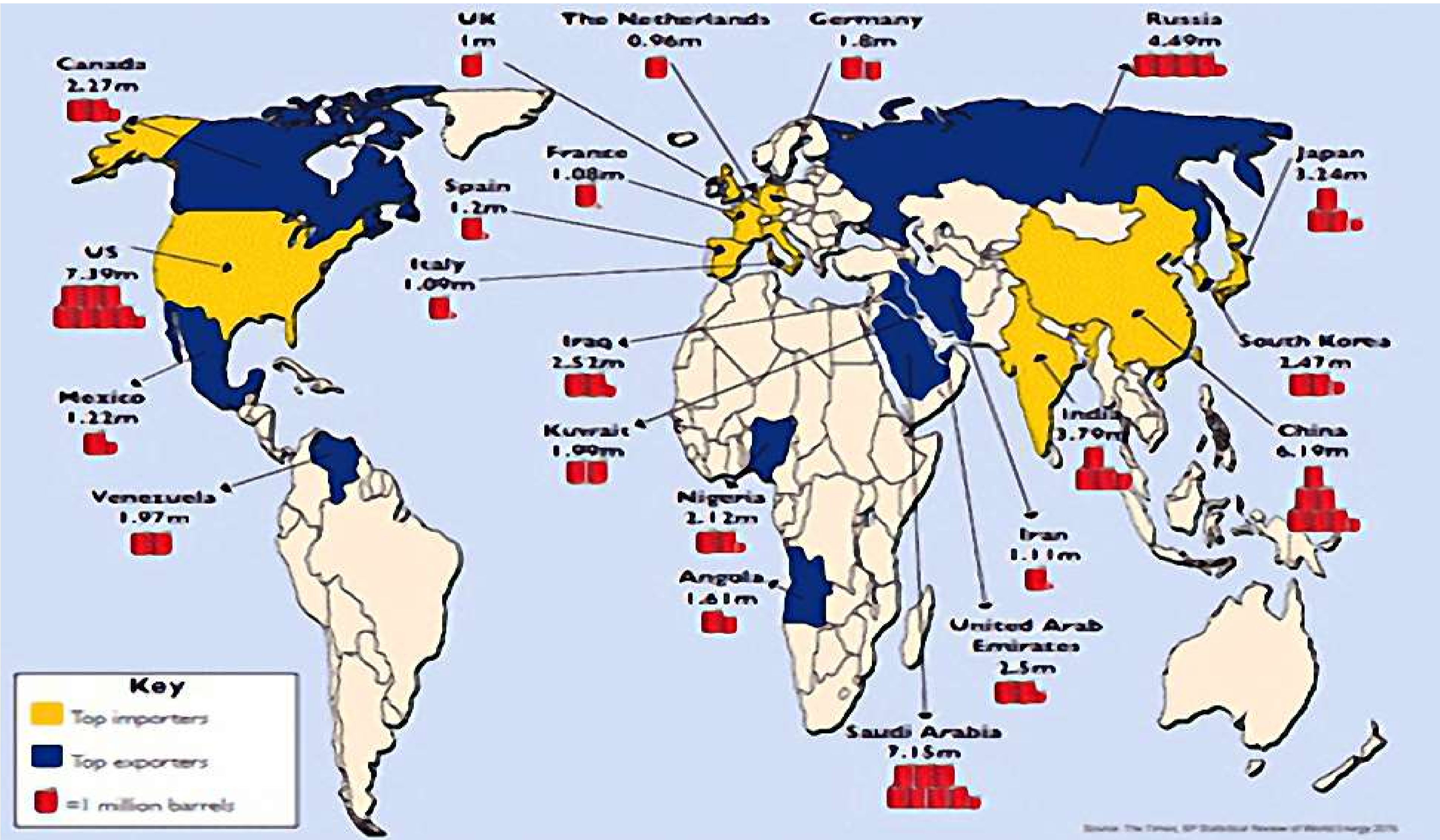
The higher the net energy ratio, the greater the net energy available

A useful rule of thumb is that any energy resource with a ***low net energy*** will need government (taxpayer) subsidies to compete in the marketplace with high net energy resources. In other words, subsidies and tax breaks must be used to keep its price artificially low

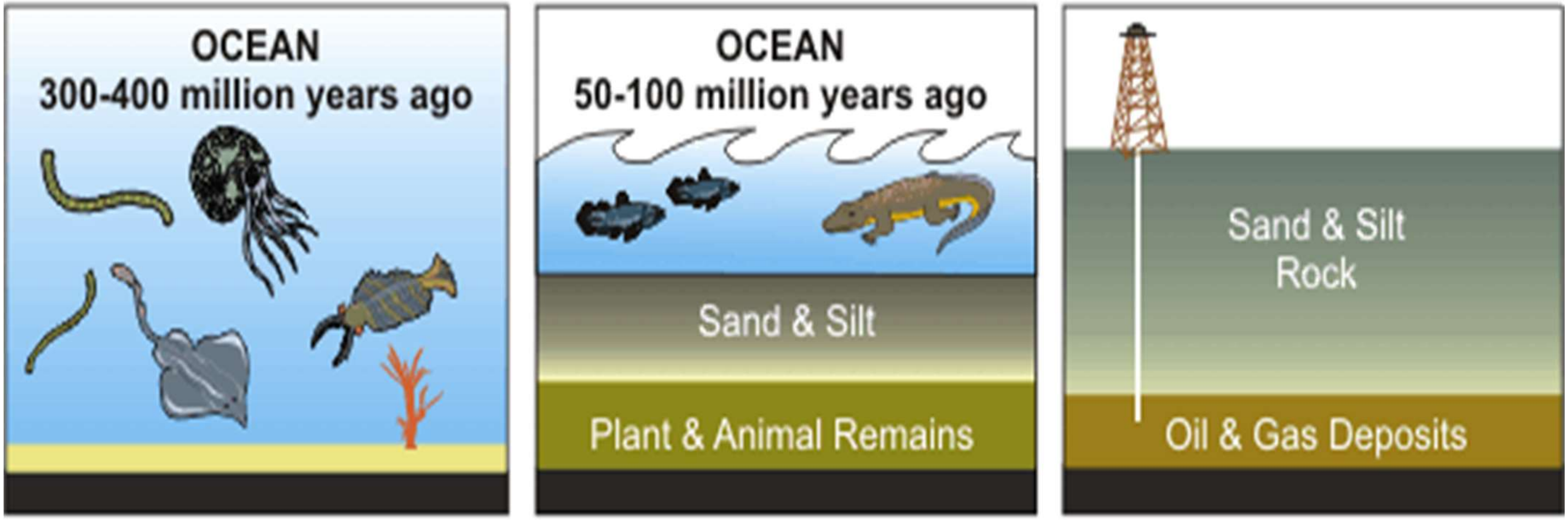
Fig. 15-A, p. 374

Where Do We Get Petroleum?

Top Importers and Exporters



PETROLEUM & NATURAL GAS FORMATION

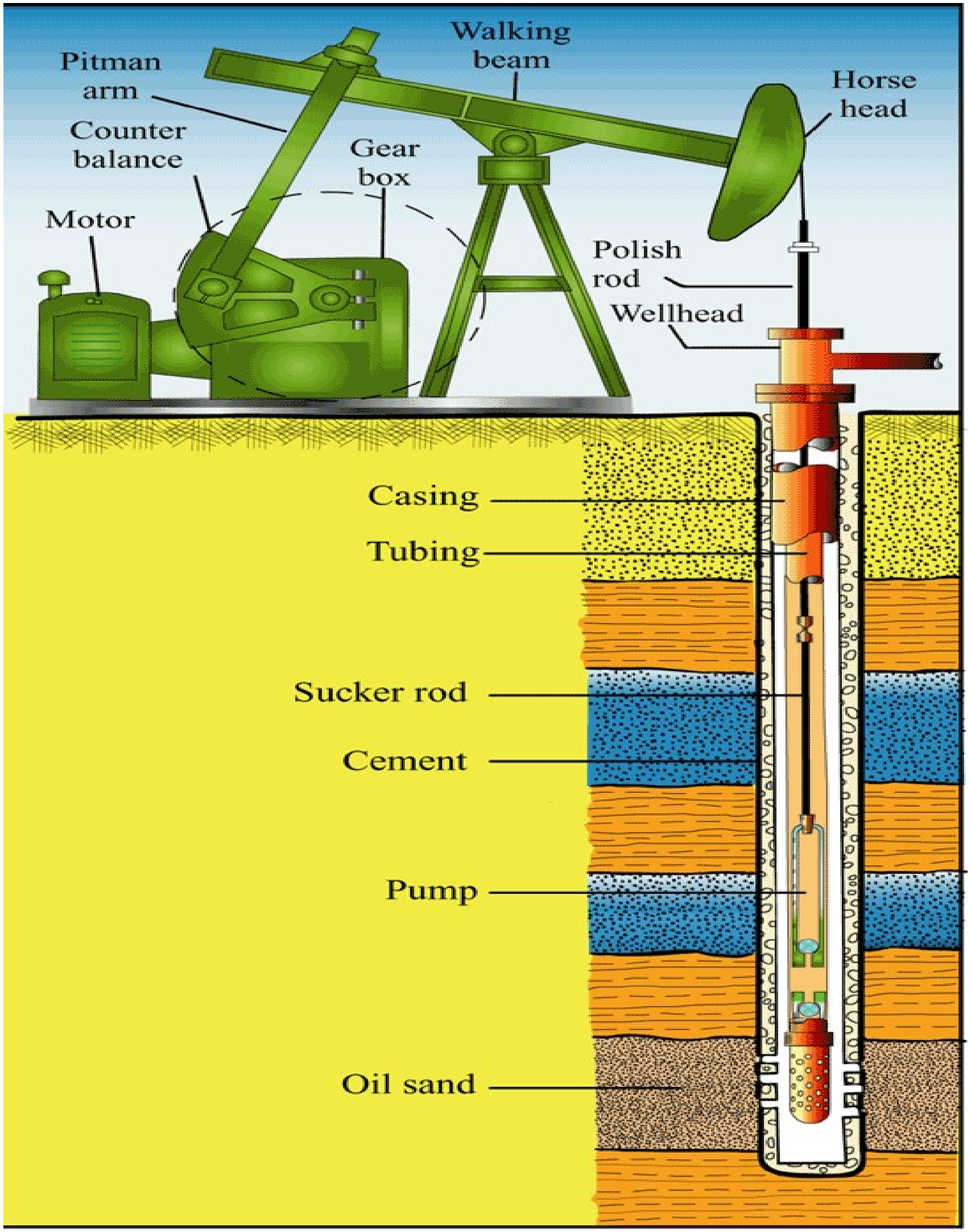


Tiny sea plants and animals died and were buried on the ocean floor. Over time, they were covered by layers of silt and sand.

Over millions of years, the remains were buried deeper and deeper. The enormous heat and pressure turned them into oil and gas.

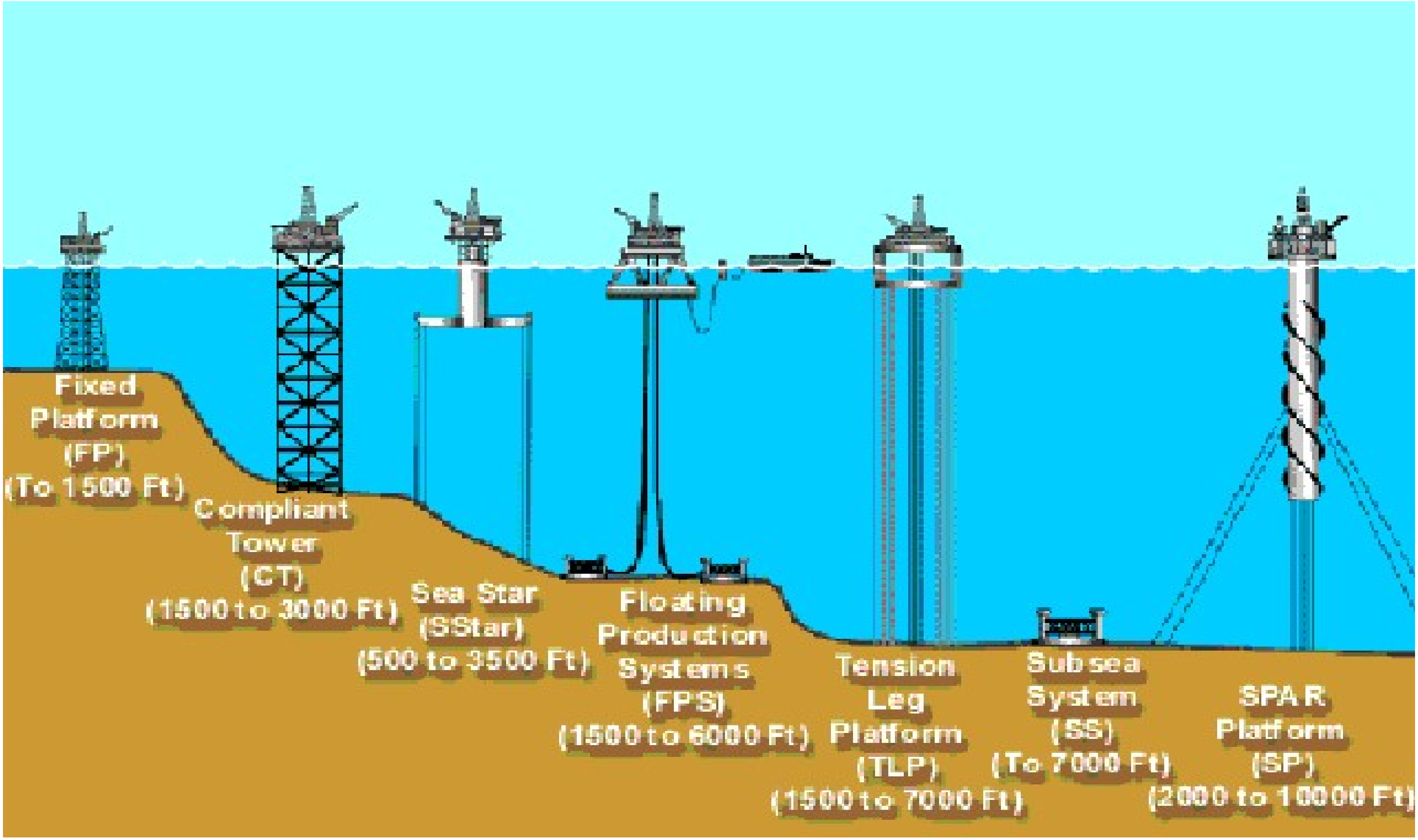
Today, we drill down through layers of sand, silt, and rock to reach the rock formations that contain oil and gas deposits.

HOW DO FOSSIL FUELS FORM?



Typical Oil Pumping System (on land)

Offshore Oil Rigs



Thunder Horse Floating Oil Rig Platform, Gulf of Mexico

Fig. 15-1, p. 370

Refining crude oil: a Distillation Process

Components of petroleum are removed at various levels, depending on their **boiling points**, in a giant distillation column. The most volatile components with the lowest boiling points are removed at the top of the column

Click me for a video

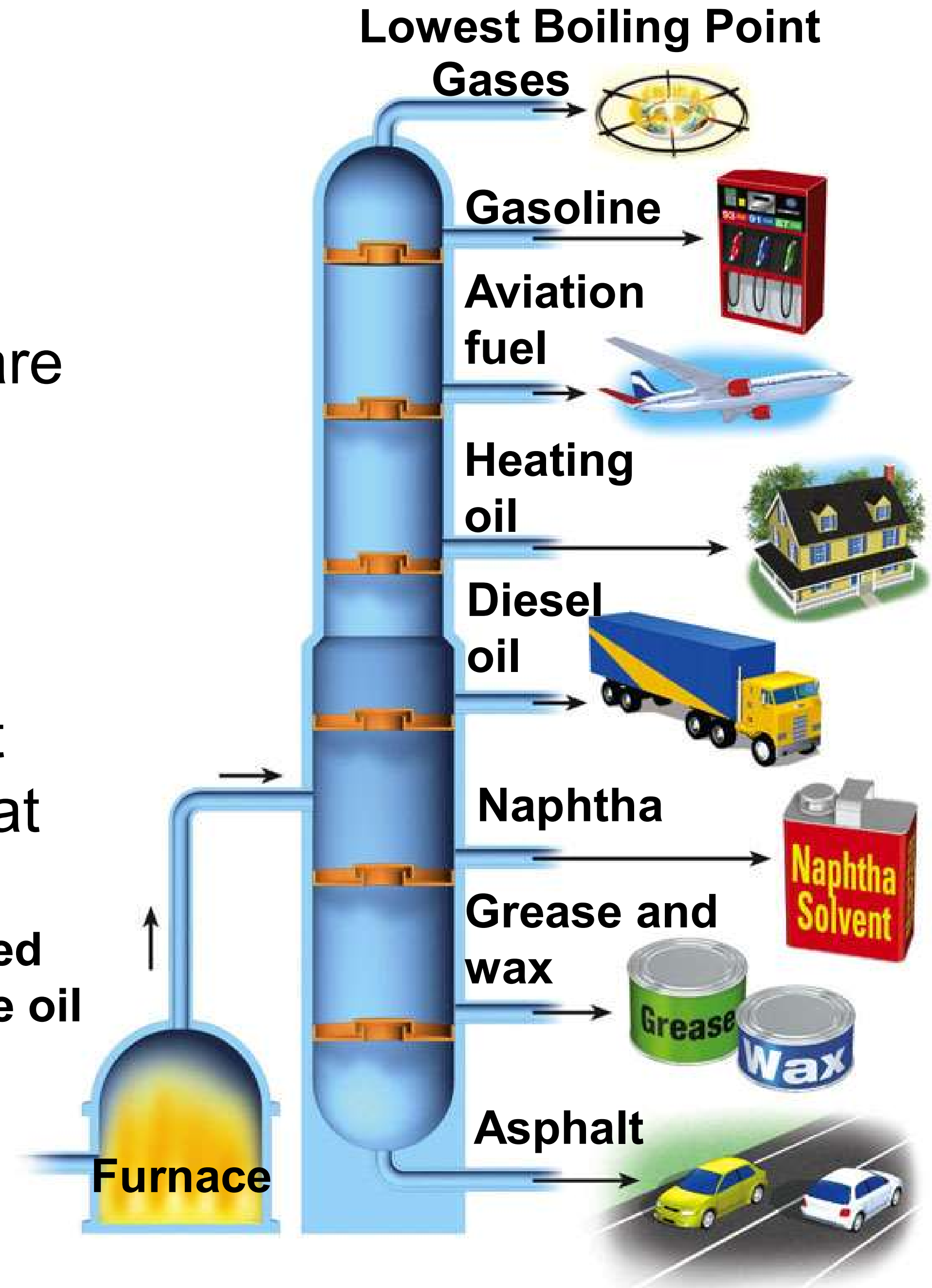
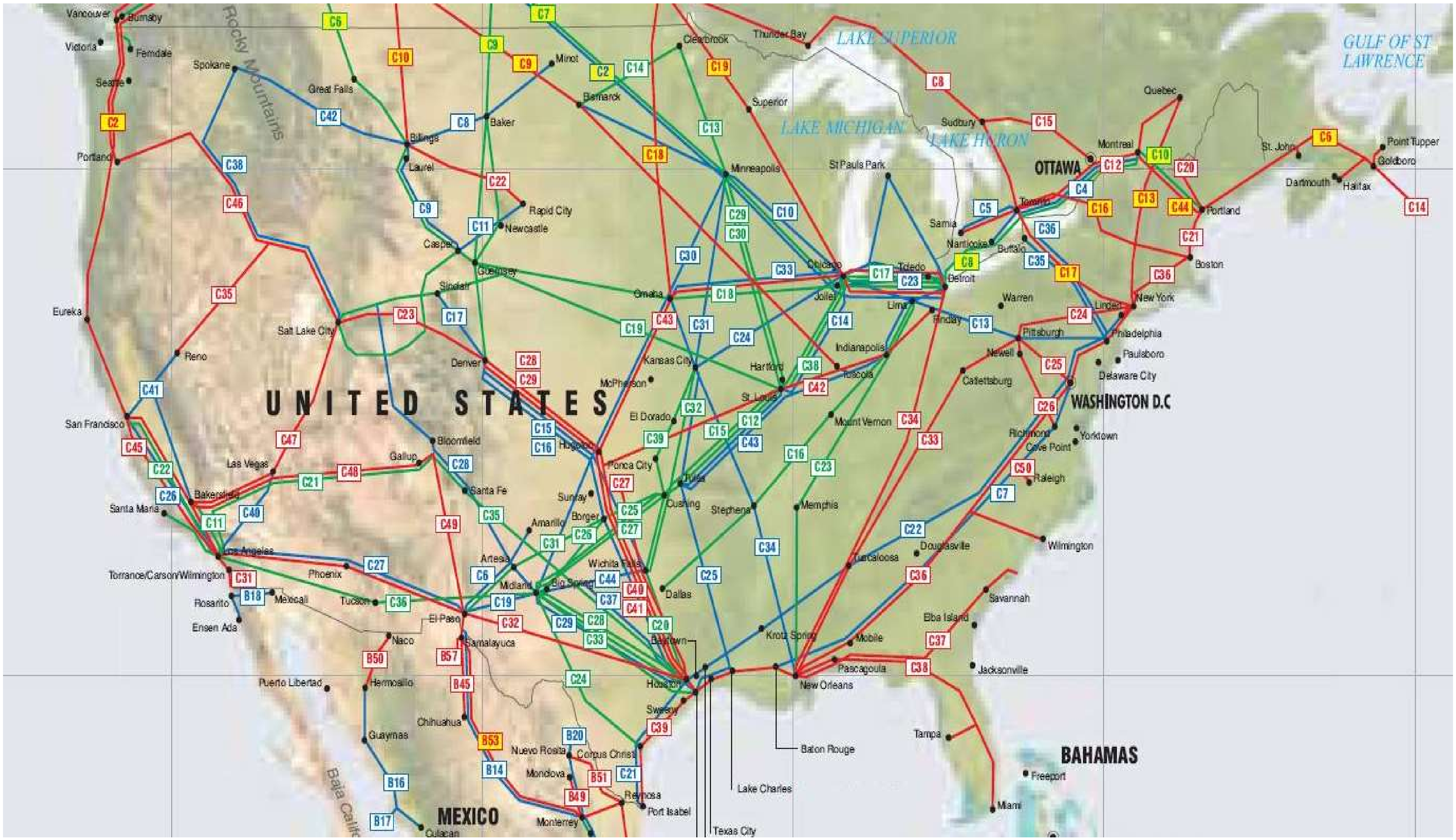


Fig. 15-4a, p. 375

Fig. 15-4b, p. 375

Crude Oil Transportation by Pipeline



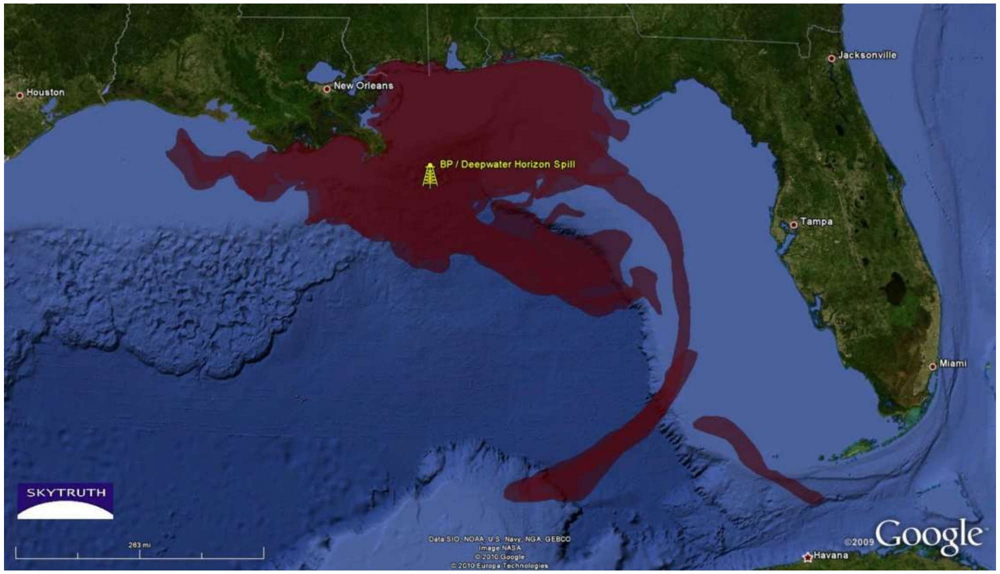
BP Oil Spill - 2010

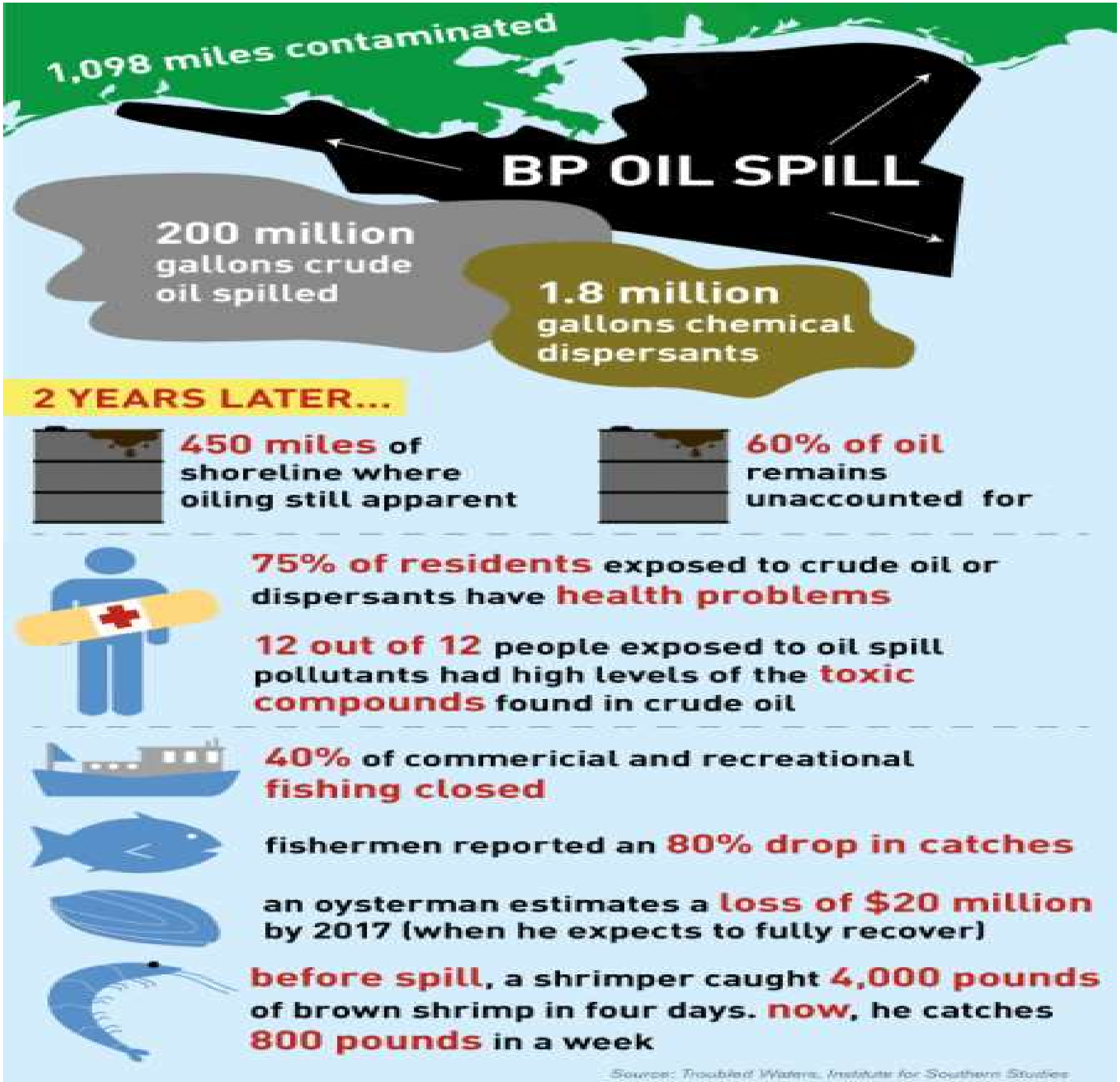
- Deepwater Drilling
  - As technology increases, we're drilling further offshore, in deeper water
  - blowout preventer failure
  - Operate on floating platforms
  - **Very difficult to access the wellhead** (up to 3000m deep!)

- *Deepwater Horizon*
  - Deepest well at the time
  - Blowout and explosion killed 11 people, and sank the rig
  - Riser from wellhead ruptured
  - Oil gushed into Gulf of Mexico – 10,000 m^3 per day

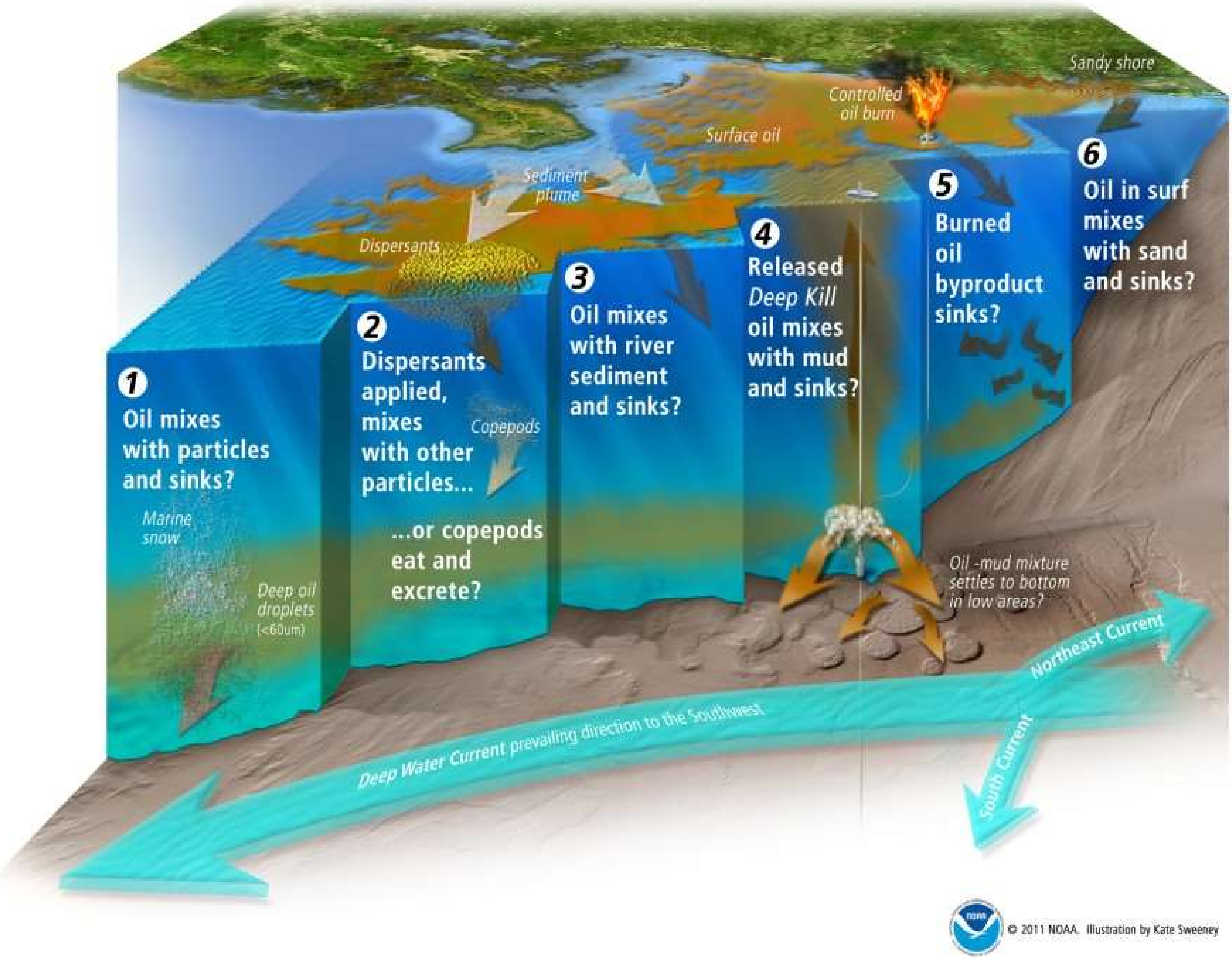
BP Oil Spill - 2010

- Timeline Video   By the Numbers
- So what?
  - Mississippi Delta, Wetlands in Florida – important wildlife areas
  - oil dispersal chemicals sent oil “somewhere”
  - Shrimp, oysters, finfish – big industry
  - Took 3 months to stop the leak
  - Oil came ashore, despite protective booms




1,098 miles contaminated
BP OIL SPILL
200 million gallons crude oil spilled
1.8 million gallons chemical dispersants
2 YEARS LATER...
450 miles of shoreline where oiling still apparent
60% of oil remains unaccounted for
75% of residents exposed to crude oil or dispersants have health problems
12 out of 12 people exposed to oil spill pollutants had high levels of the toxic compounds found in crude oil
40% of commericial and recreational fishing closed
fishermen reported an 80% drop in catches
an oysterman estimates a loss of $20 million by 2017 (when he expects to fully recover)
before spill, a shrimper caught 4,000 pounds of brown shrimp in four days. now, he catches 800 pounds in a week
Source: Troubled Waters, Institute for Southern Studies

Potential Pathways for Oil to Reach Bottom Sediments



Cleaning Up an Oil Spill

- Booms

Bioremediation

- Skimmer Boats

Chemical dispersants

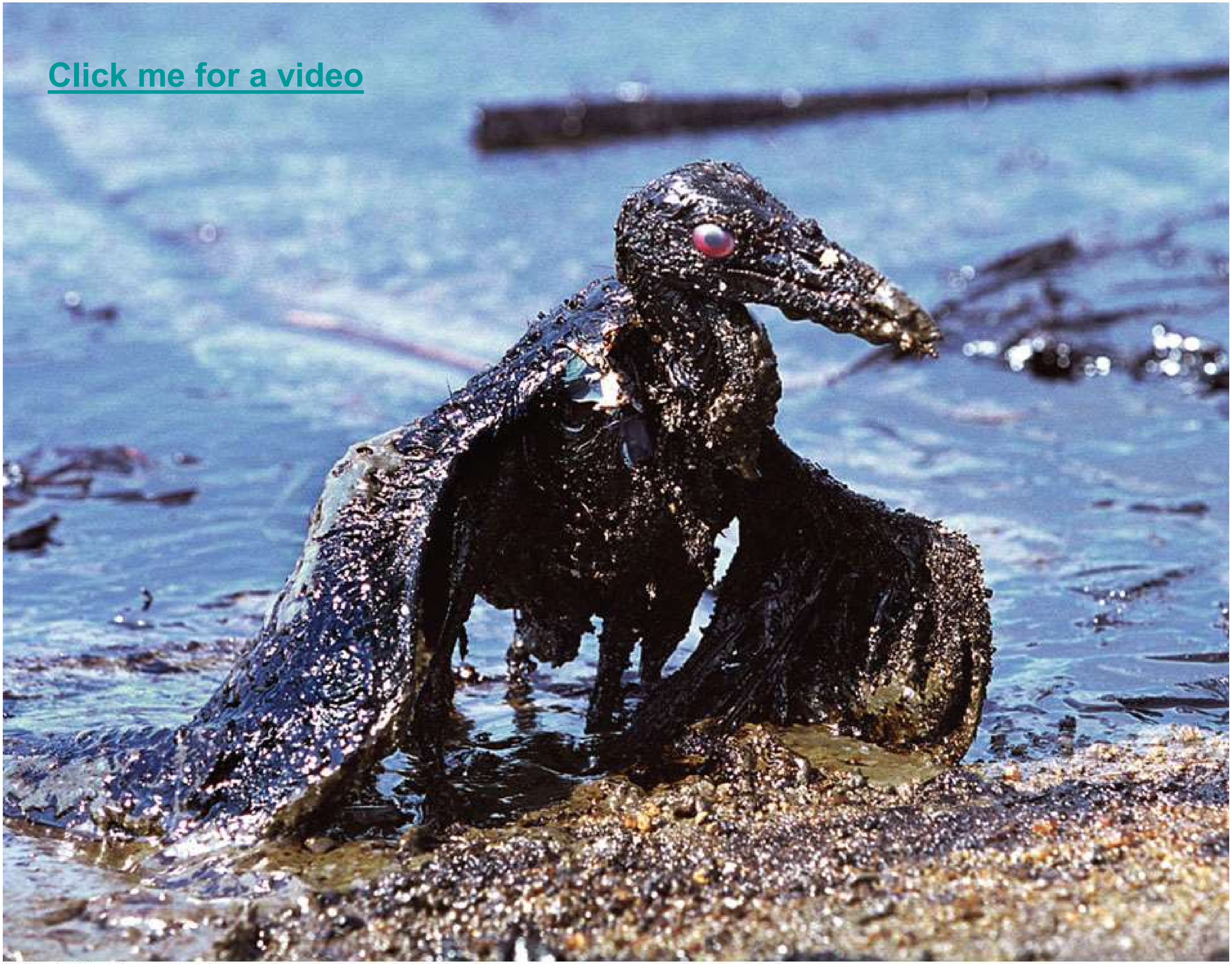
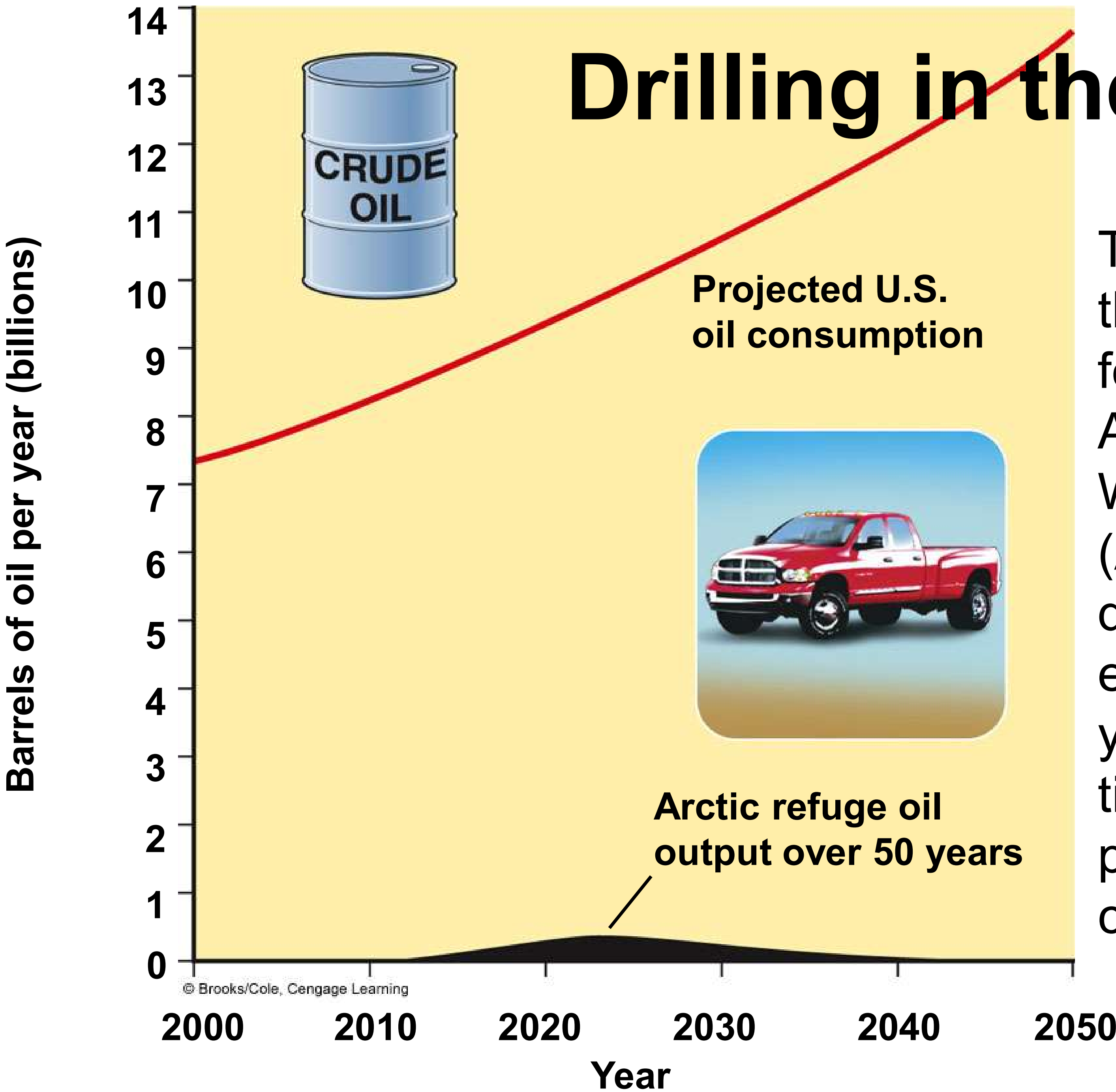


Fig. 15-7, p. 379

Drilling in the ANWR



video

The amount of oil that might be found in the Arctic National Wildlife Refuge (ANWR), if developed and extracted over 50 years, is only a tiny fraction of projected U.S. oil consumption.

Click me

TRADE-OFFS

Conventional Oil

Advantages

Ample supply for 42–93 years

Low cost

High net energy yield

Easily transported within and between countries

Low land use

Technology is well developed

Efficient distribution system

Disadvantages

Need to find substitutes within 50 years

Large government subsidies

Environmental costs not included in market price

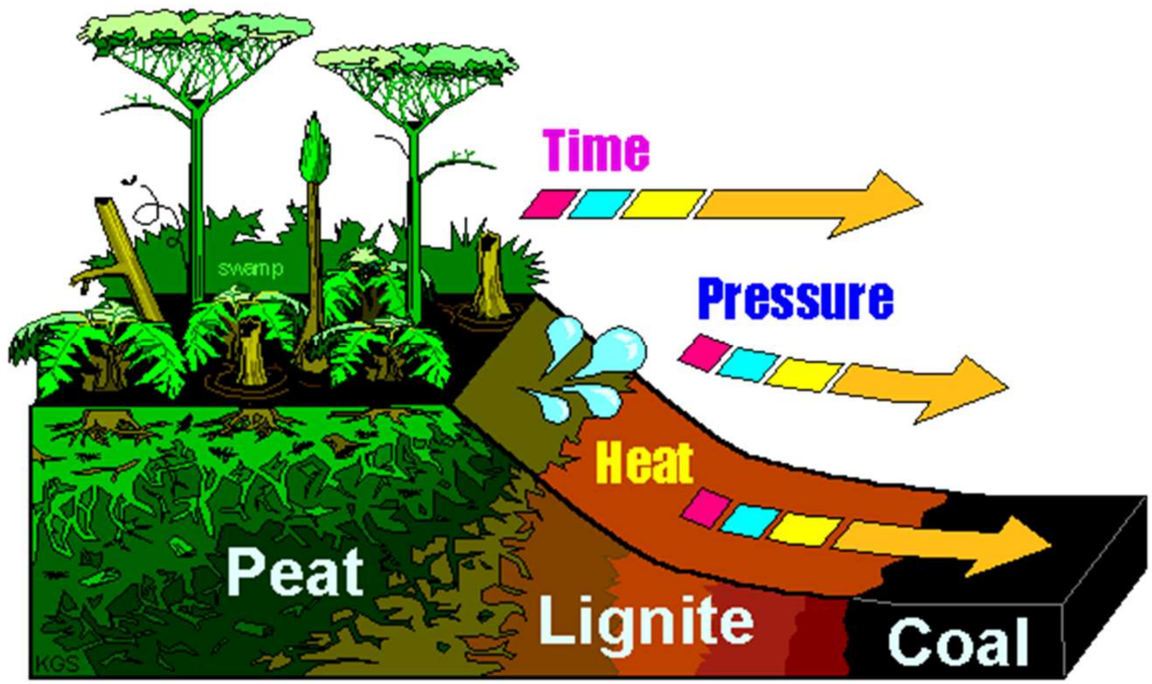
Artificially low price encourages waste and discourages search for alternatives

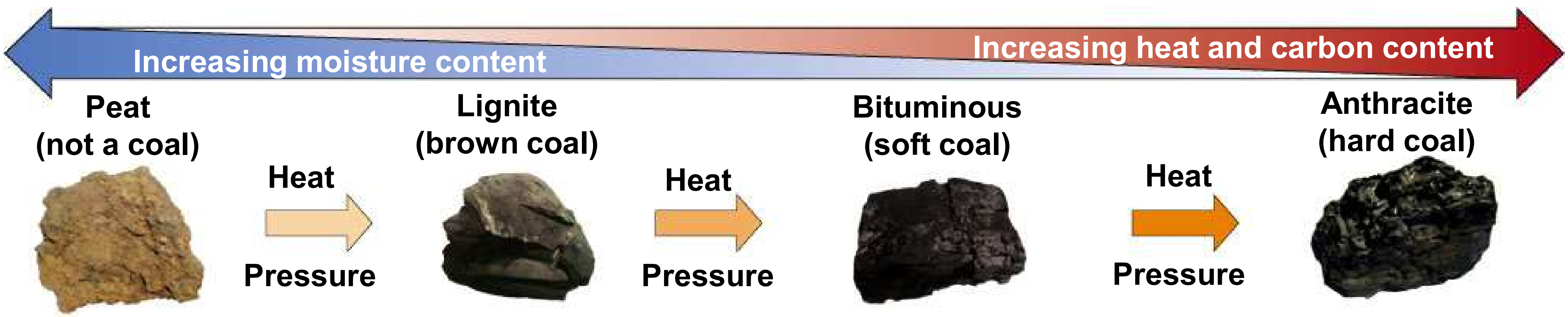
Pollutes air when produced and burned

Releases CO_2 when burned

Can cause water pollution

How coal is formed





Partially decayed plant matter in swamps and bogs; low heat content

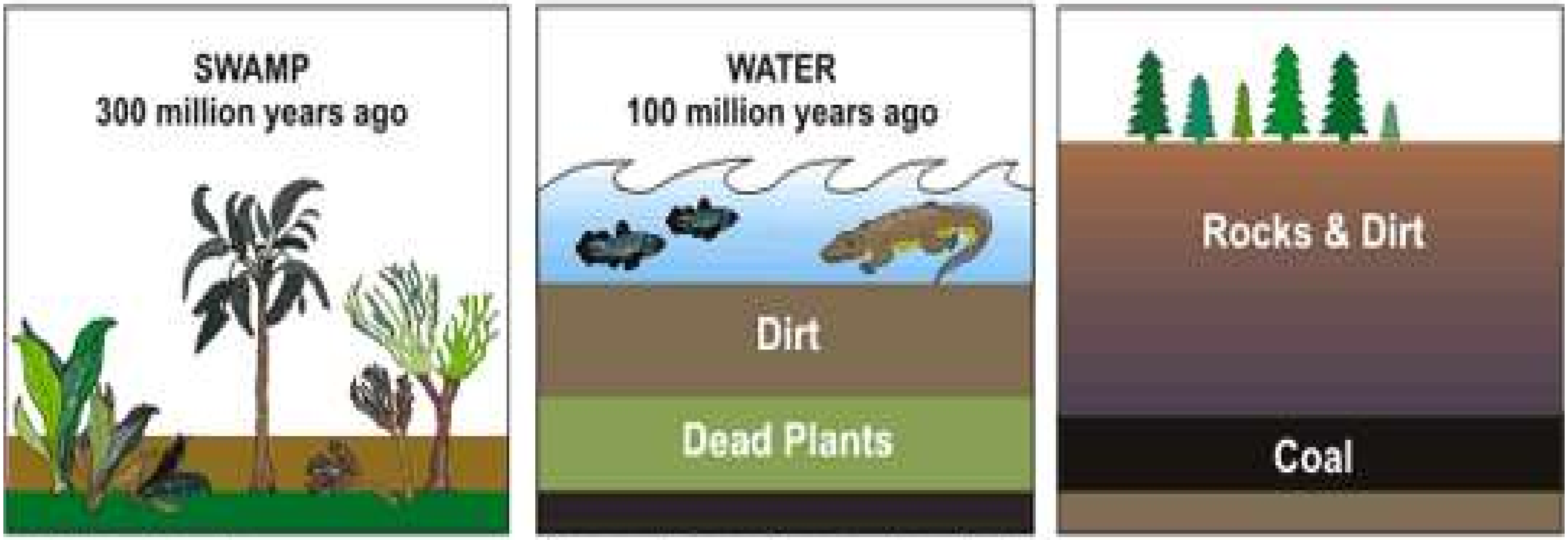
Low heat content; low sulfur content; limited supplies in most areas

Extensively used as a fuel because of its high heat content and large supplies; normally has a high sulfur content

Highly desirable fuel because of its high heat content and low sulfur content; supplies are limited in most areas

Fig. 15-11, p. 383

HOW COAL WAS FORMED



Before the dinosaurs, many giant plants died in swamps.

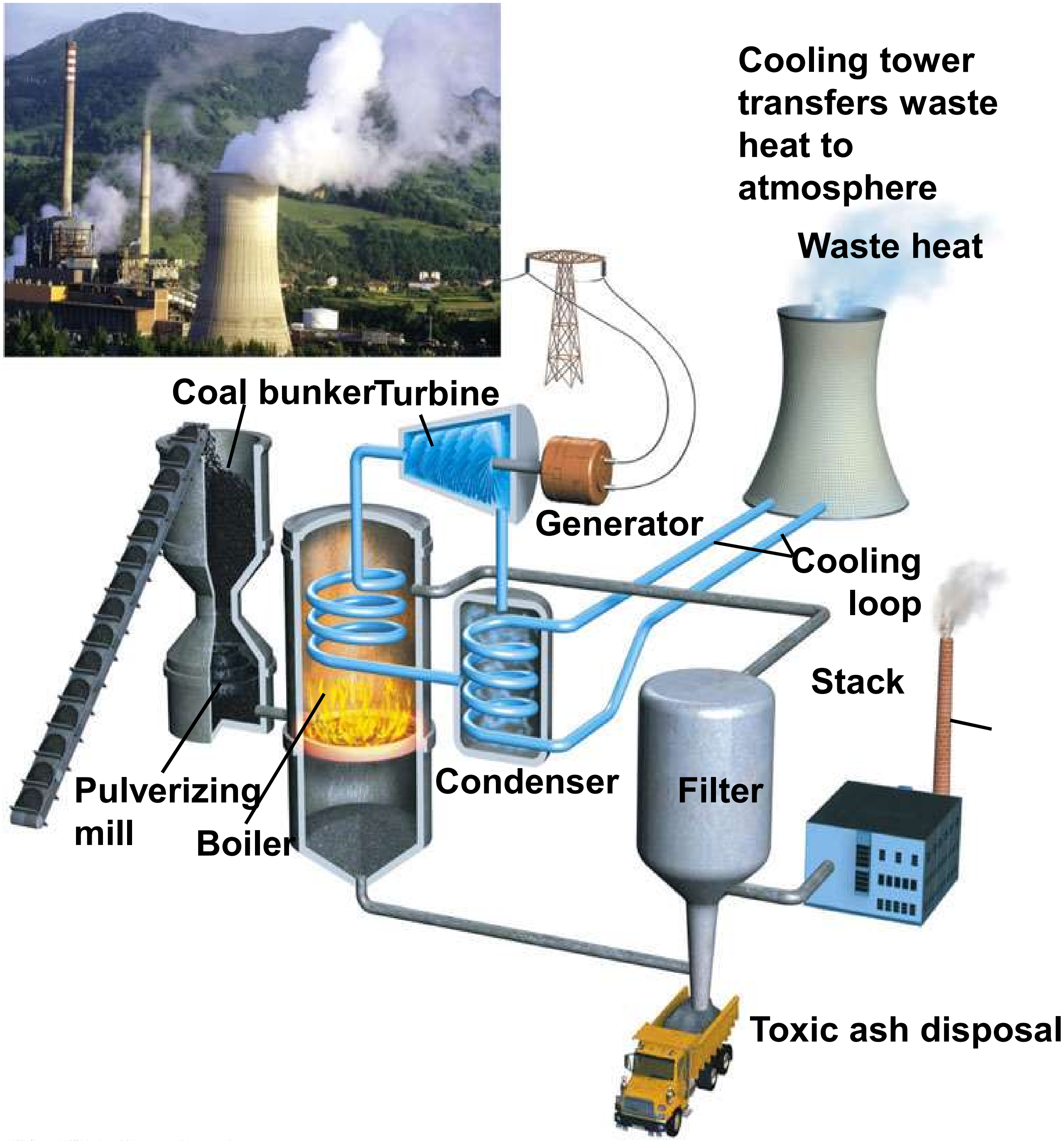
Over millions of years, the plants were buried under water and dirt.

Heat and pressure turned the dead plants into coal.

How Coal is Removed: Mountain top removal, West Virginia

COAL MINING VIDEO

Strip Mining, Powder River Basin Wyoming



Coal-burning power plant.

Heat produced by burning pulverized coal in a furnace boils water to produce steam that spins a turbine to produce electricity. The steam is cooled, condensed, and returned to the boiler for reuse. Waste heat can be transferred to the atmosphere or to a nearby source of water. Water is pumped through a condenser and back to the water source to remove the waste heat.

Fig. 15-12, p. 383

How Do Power Plants Work?

click me!

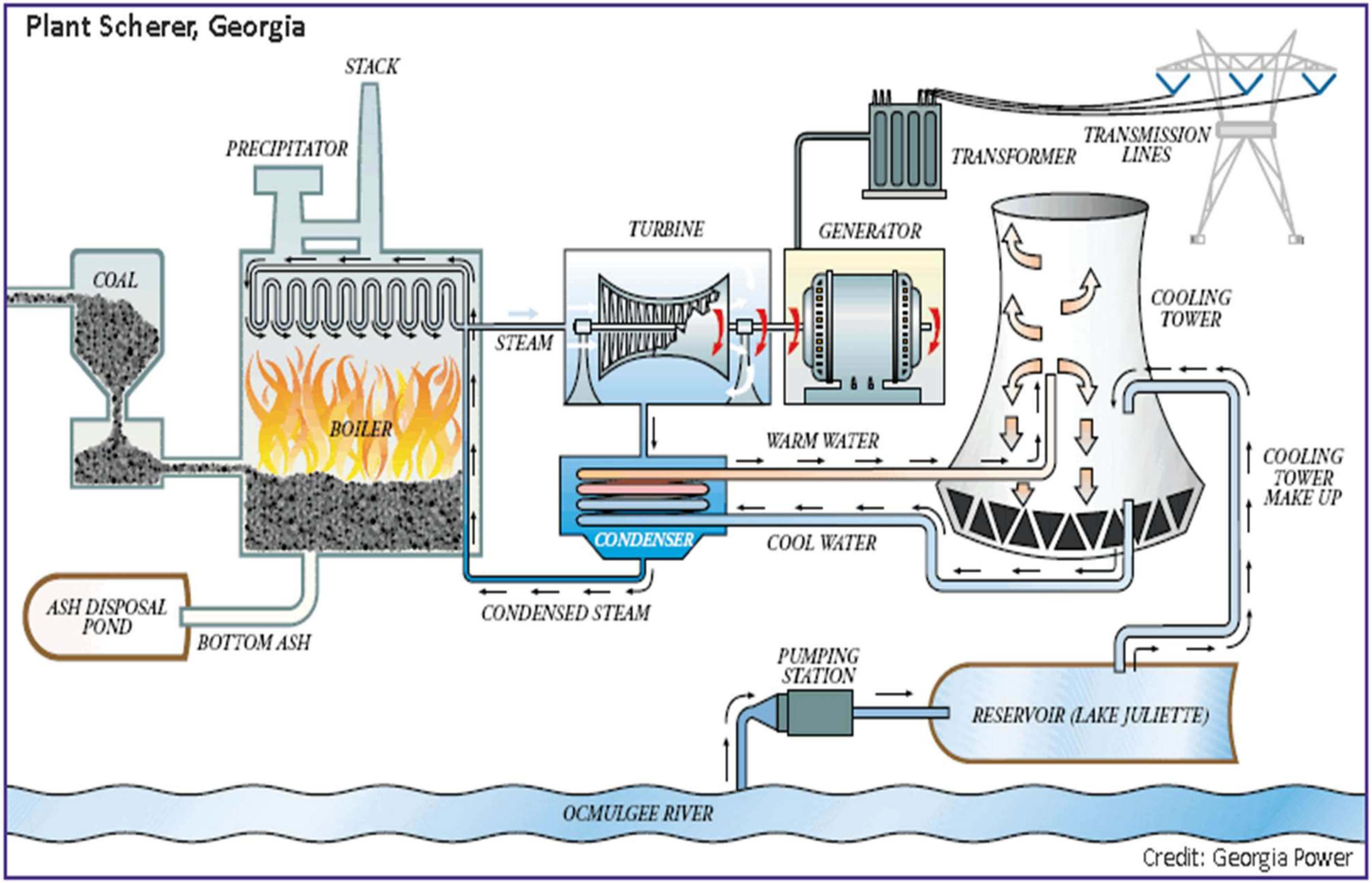
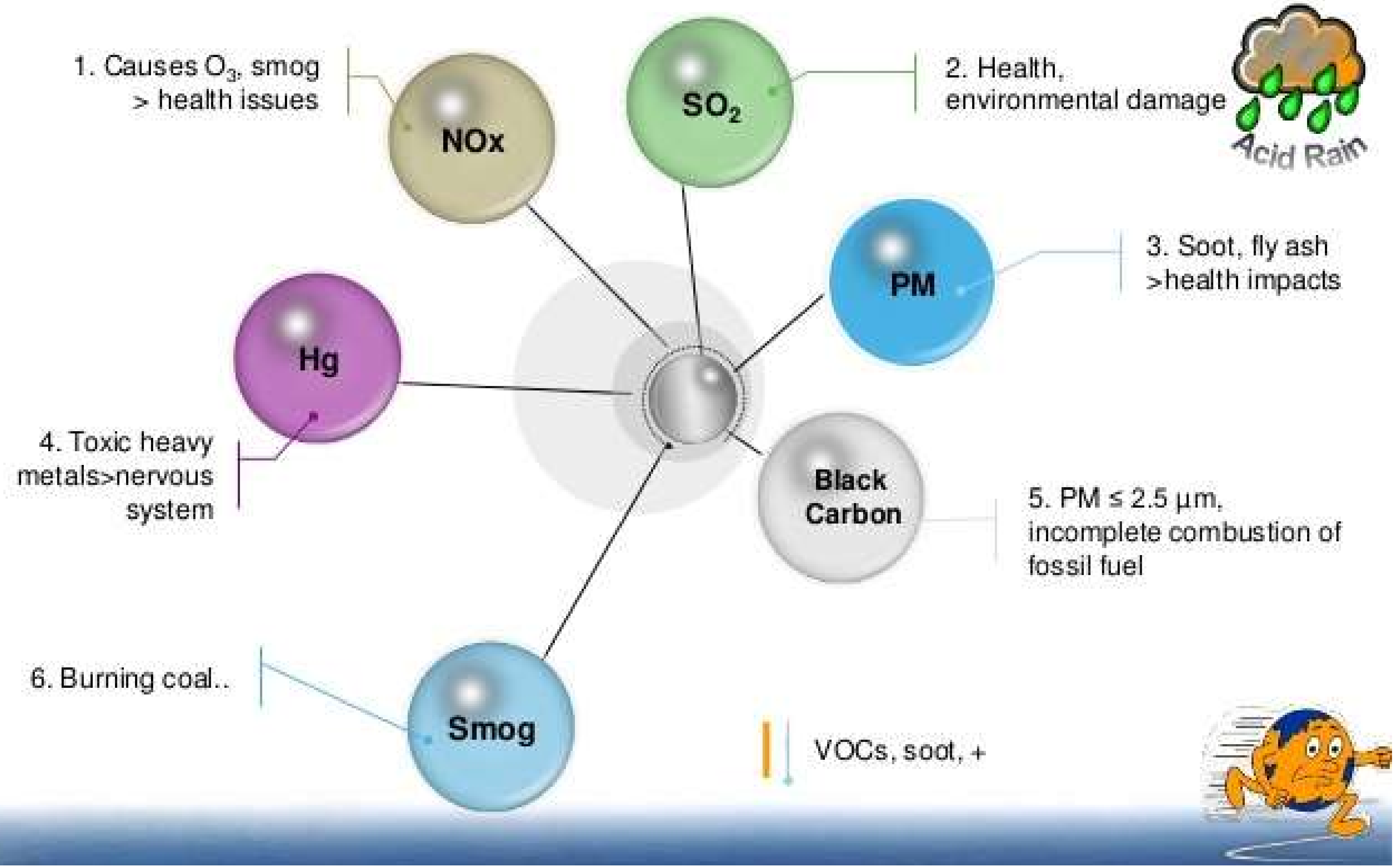


Fig. 15-12b, p. 383

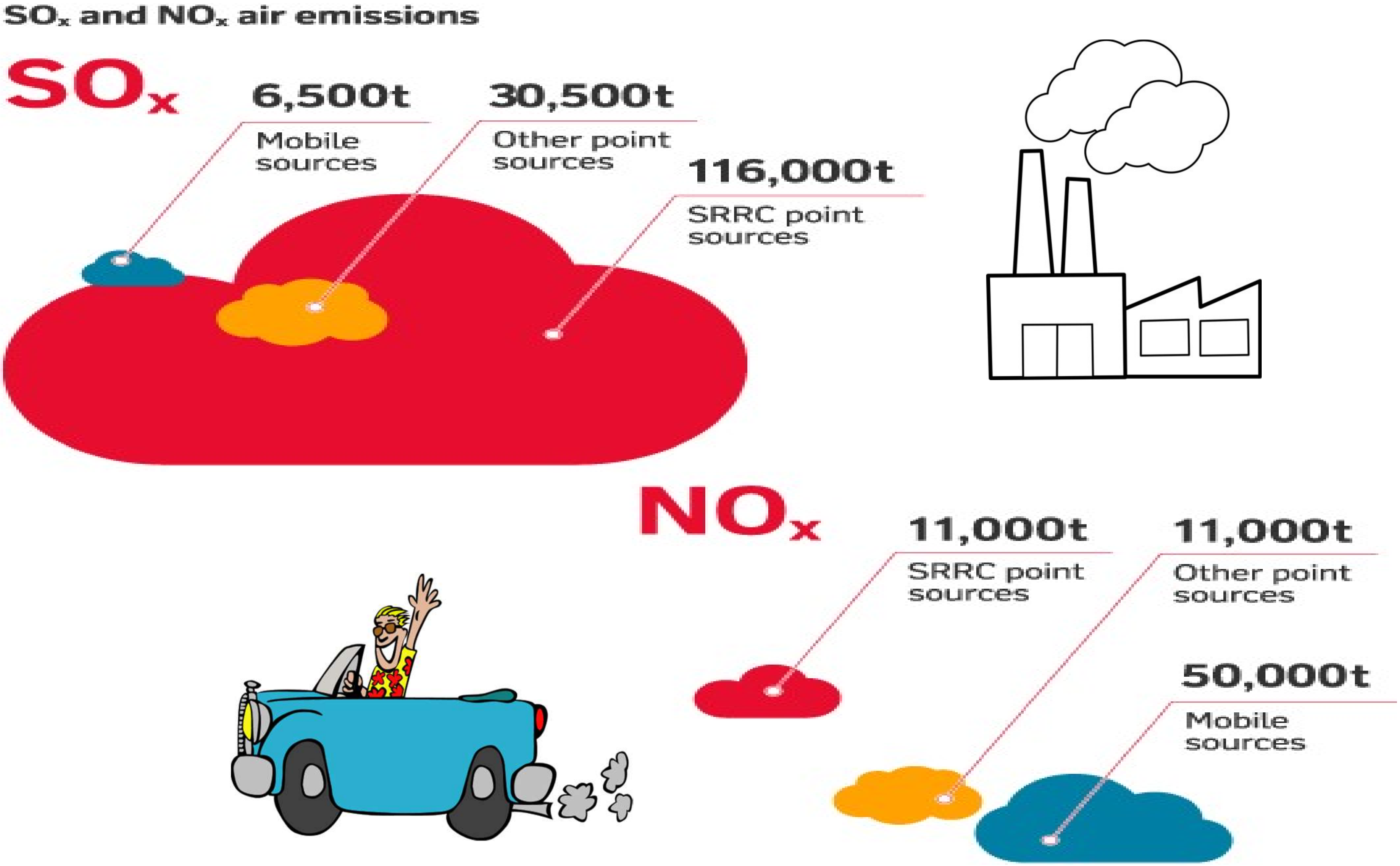
HUMAN HEALTH EFFECTS OF BURNING COAL

Fig. 15-13, p. 384

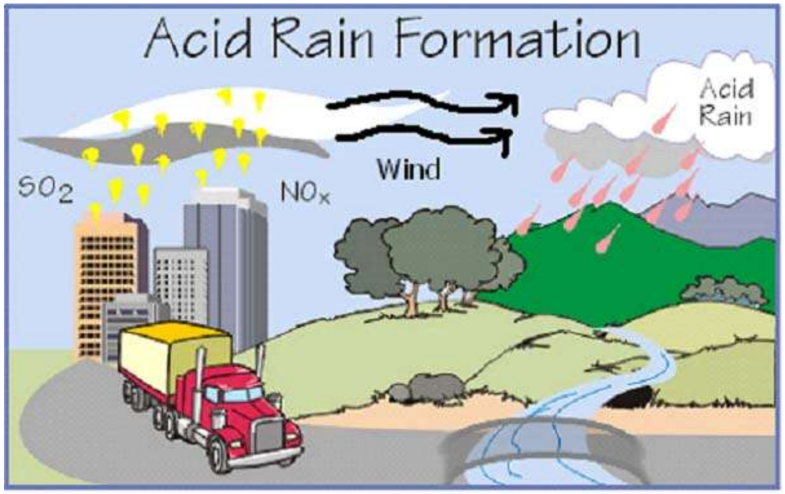
Pollutants of coal-fired power plant



SOx & NOx: Where do they come from?

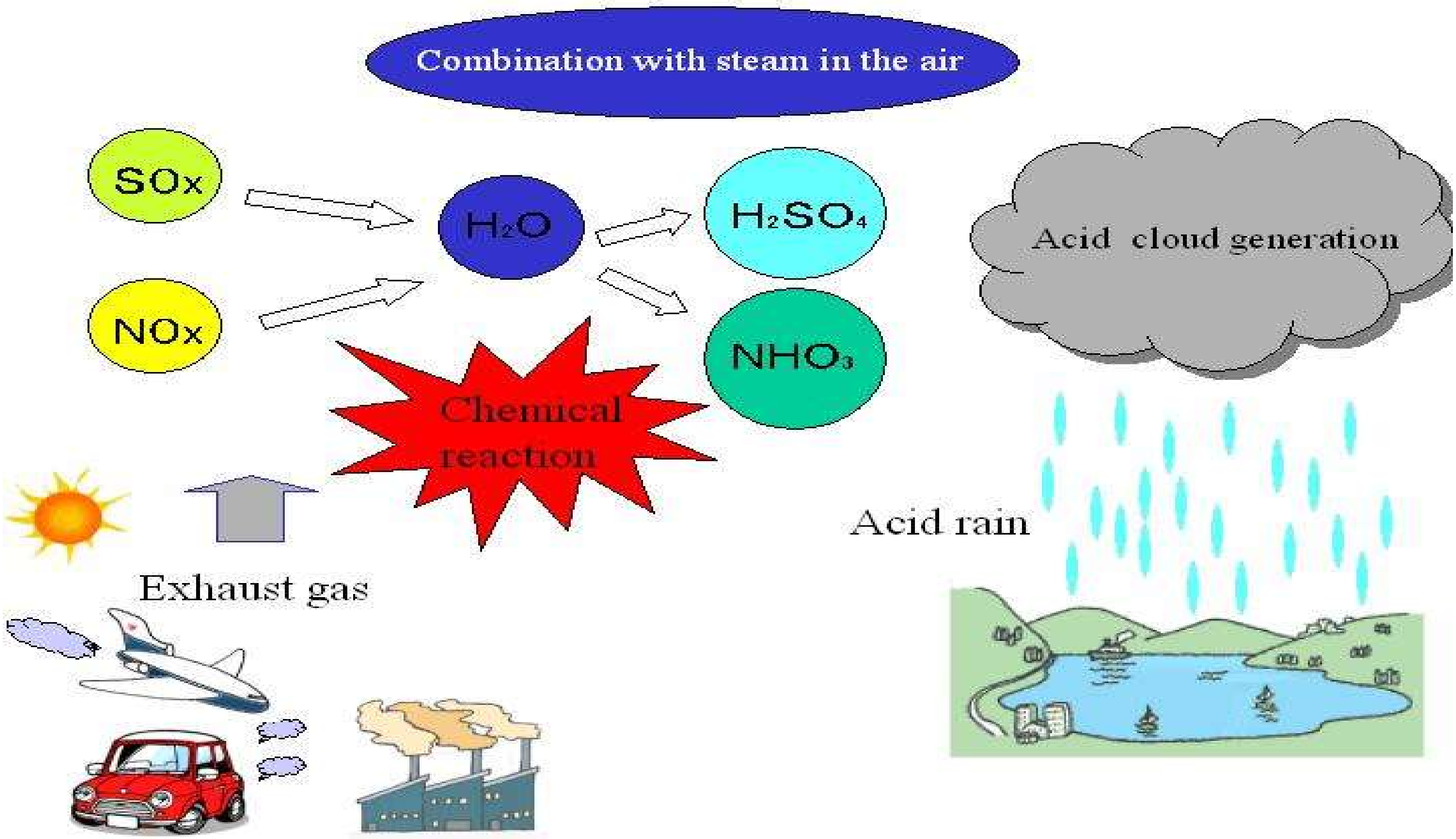


Why are SOx and NOx a problem?

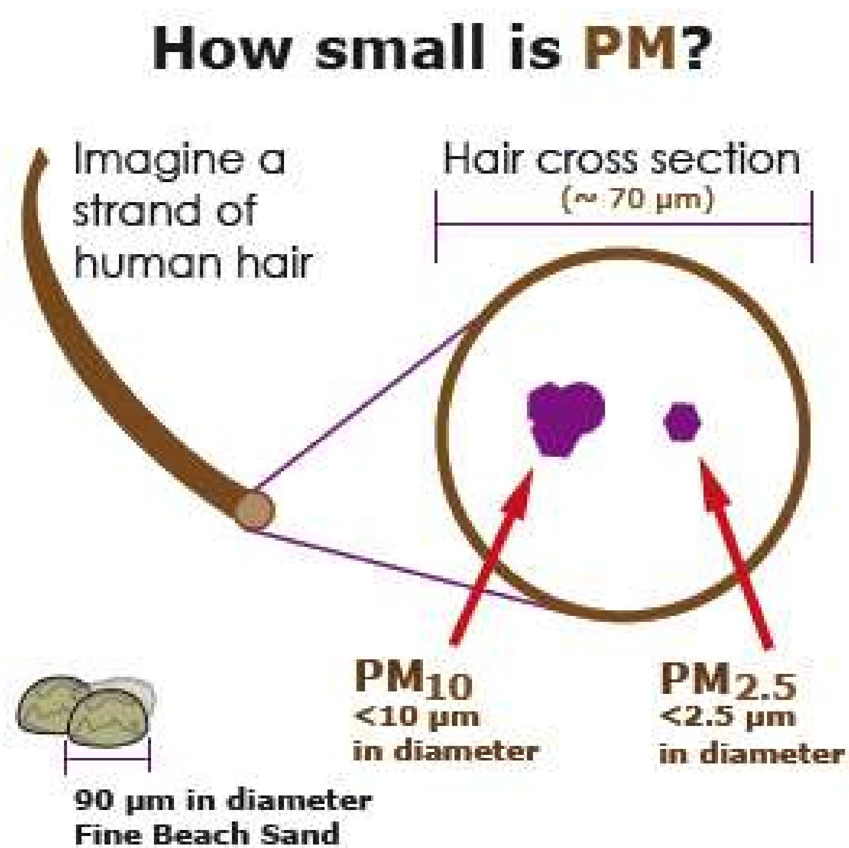


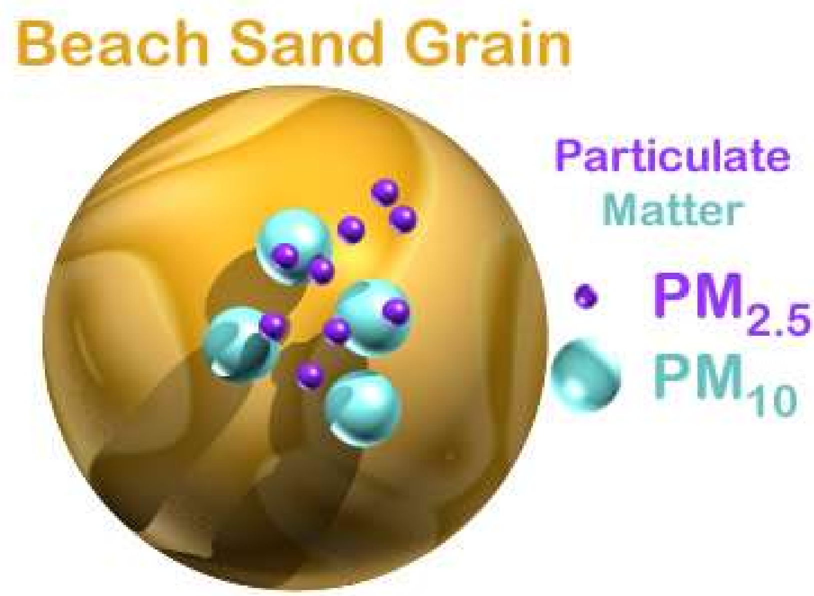
Click me

SOx and NOx combine with Water for form Sulfuric Acid and Nitric Acid.

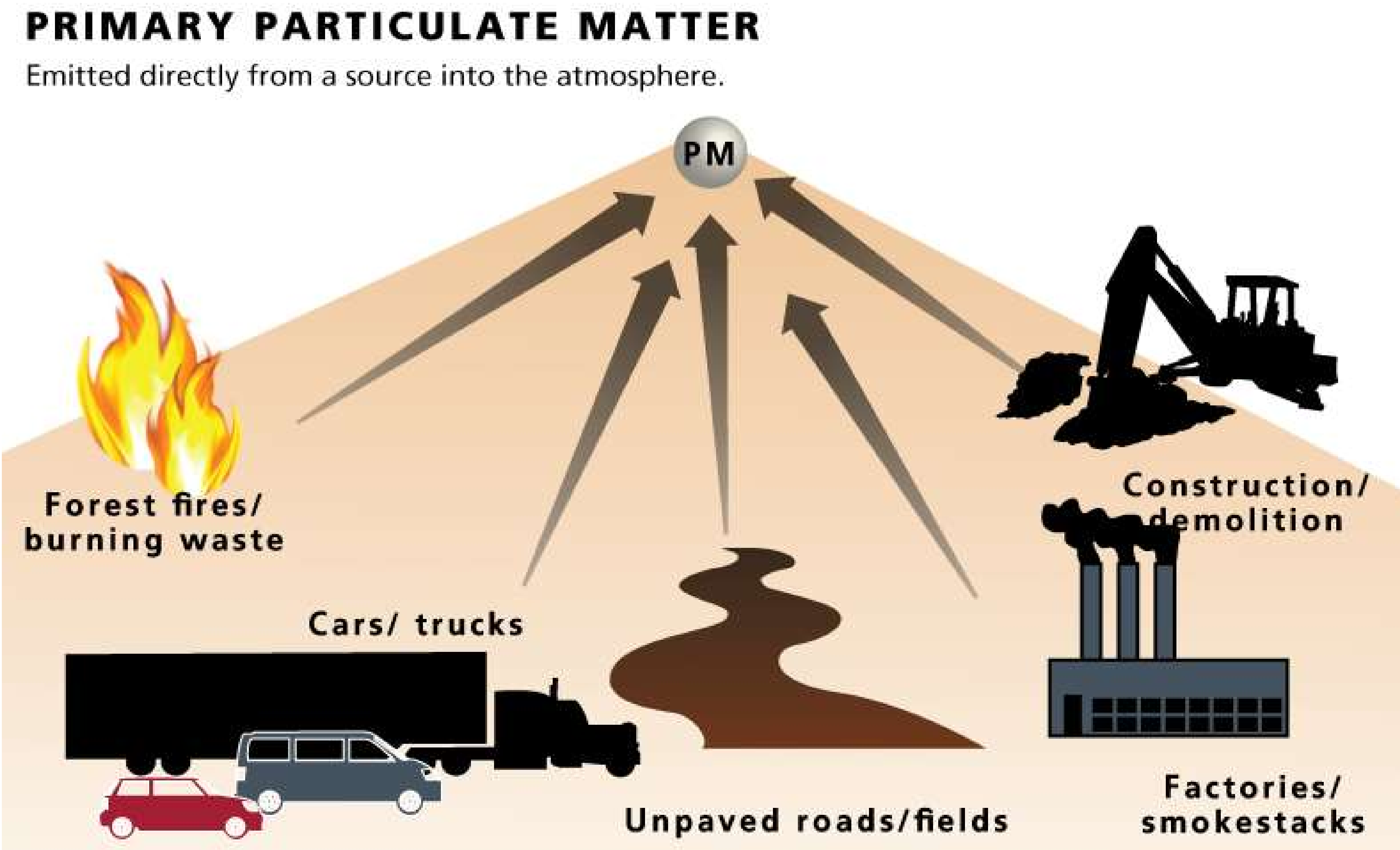


PM (Particulate Matter)





Where does it come from?



WHAT ARE THE HEALTH RISKS OF PARTICULATE MATTER?

Particulate matter poses a serious health risk because it can travel into the respiratory tract. PM2.5 is especially dangerous because it can penetrate deep into the lungs and sometimes even into the bloodstream.

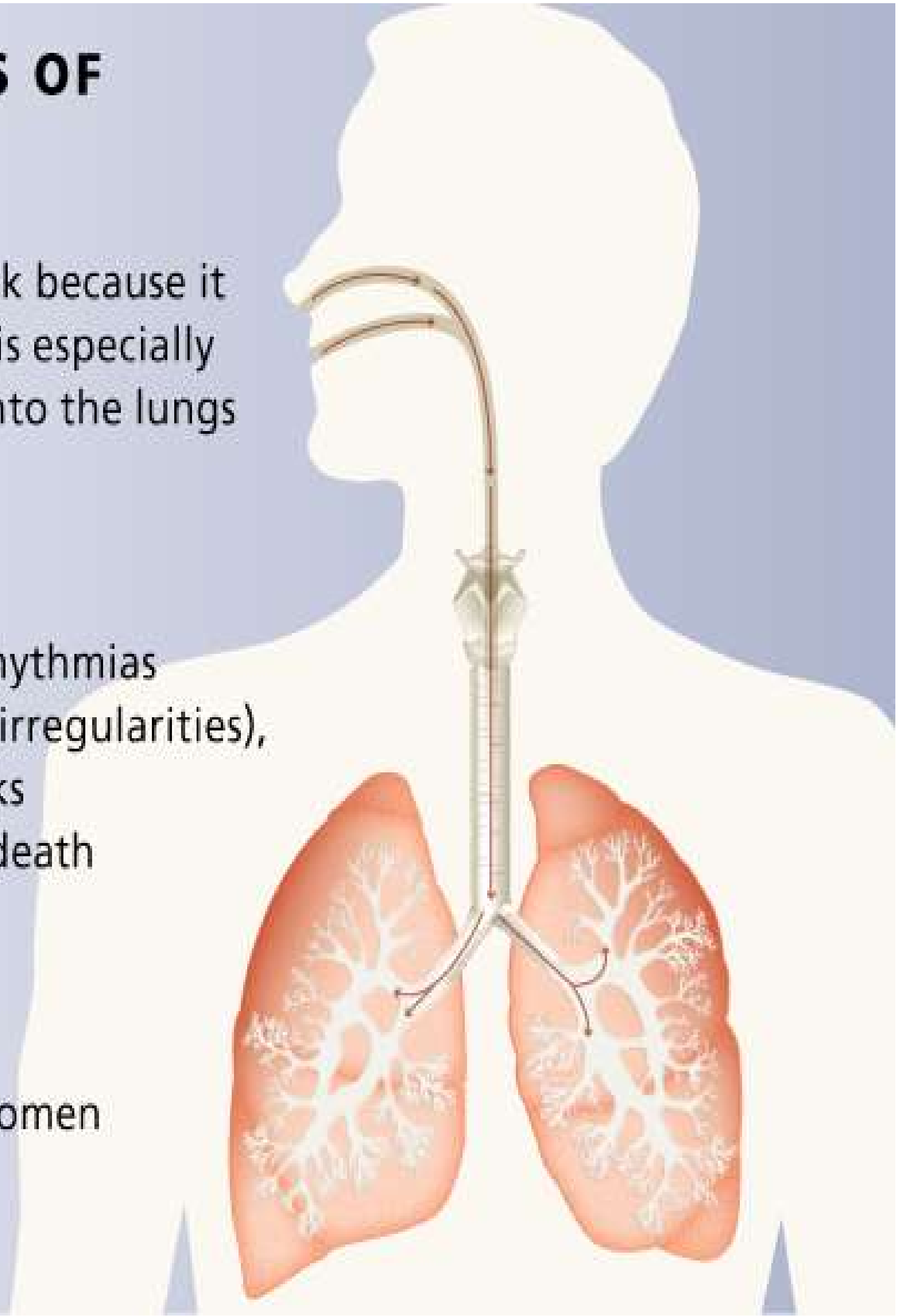
HEALTH EFFECTS

- Decreased lung function
- Chronic bronchitis
- Increased respiratory symptoms
- Cardiac arrhythmias (heartbeat irregularities),
- Heart attacks
- Premature death

GROUPS SENSITIVE TO PM2.5

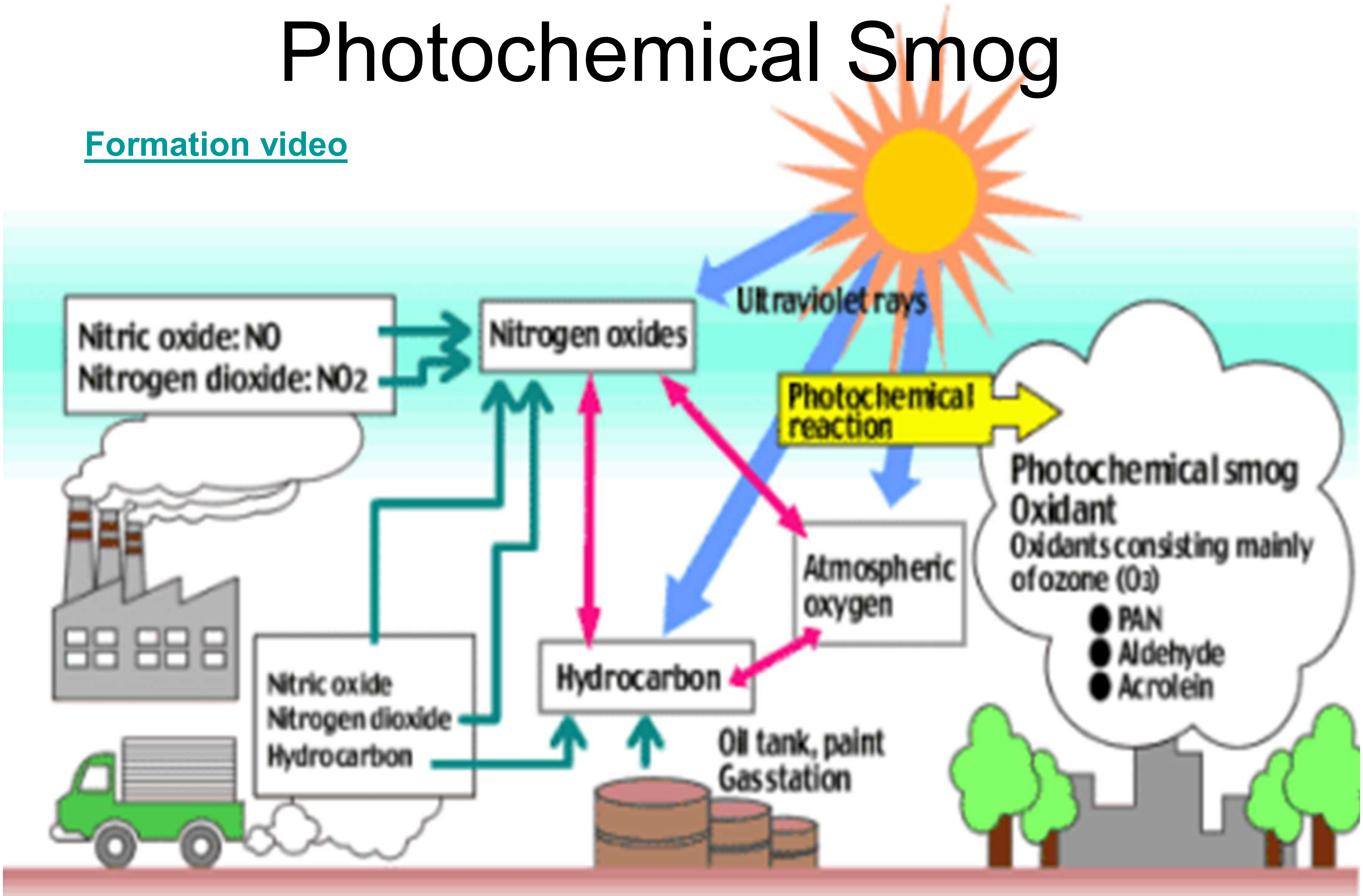
- People with heart or lung disease
- Older adults
- Children
- Pregnant women

Source: www.epa.gov

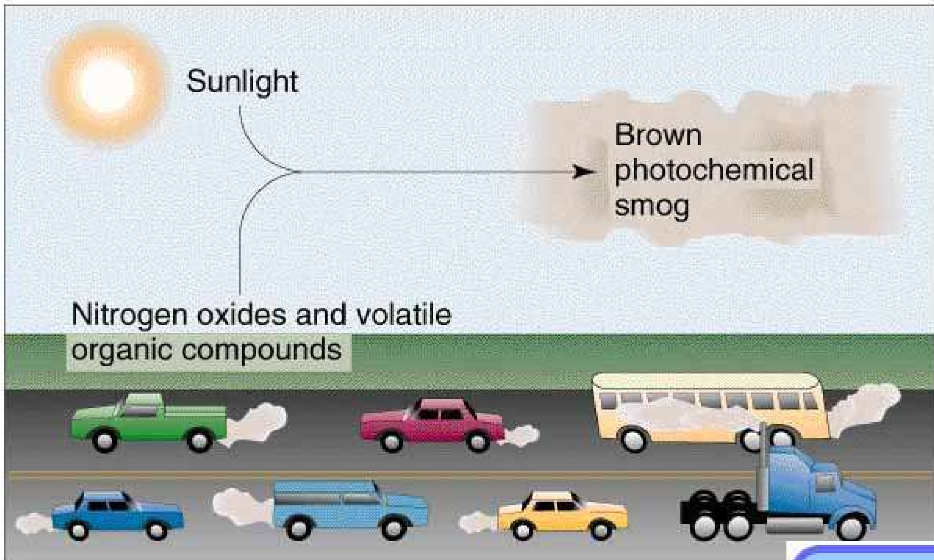


Photochemical Smog

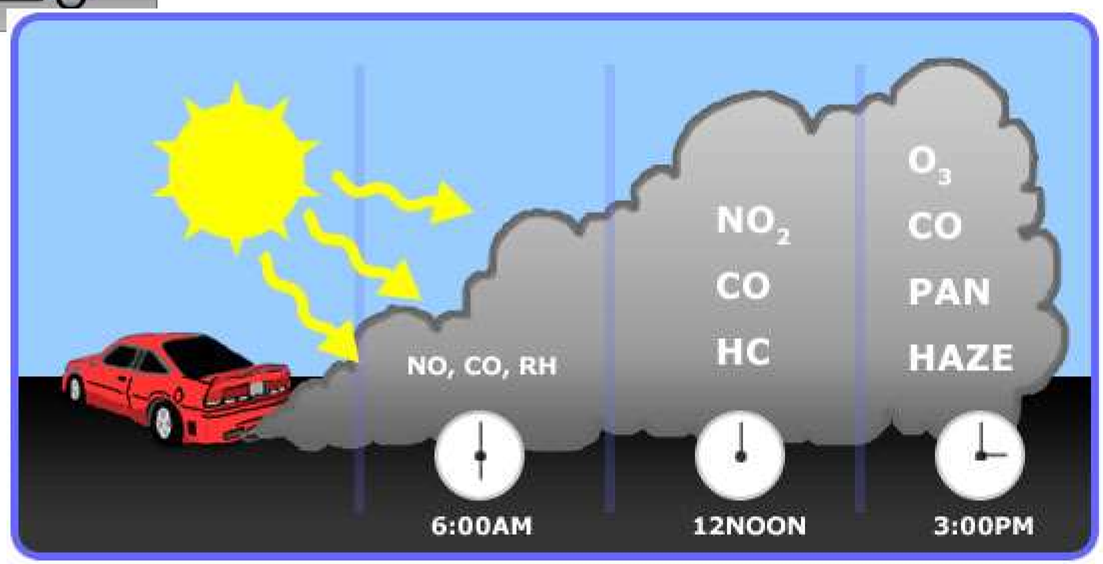
[Formation video]

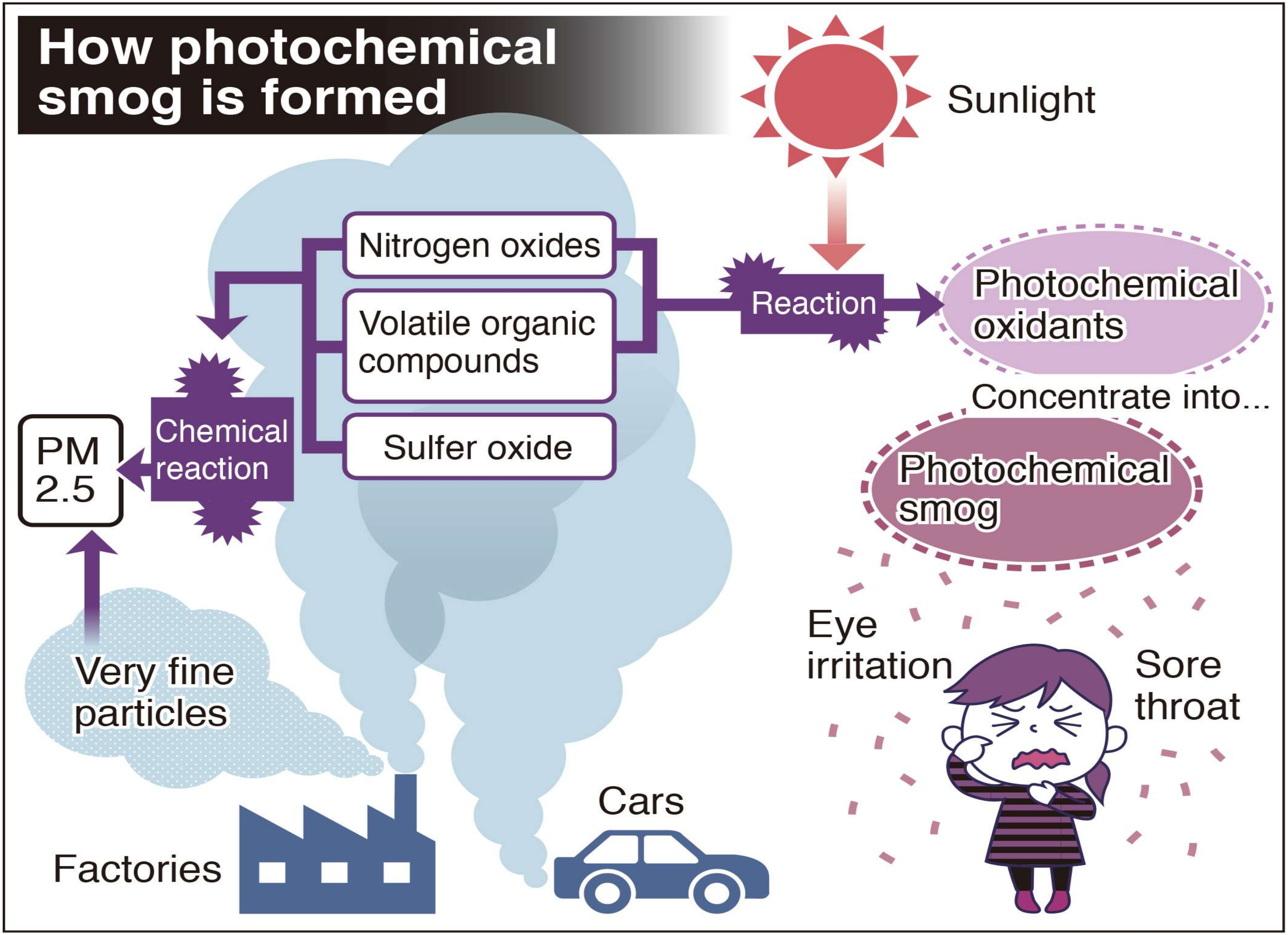


By-products change over time and exposure to UV



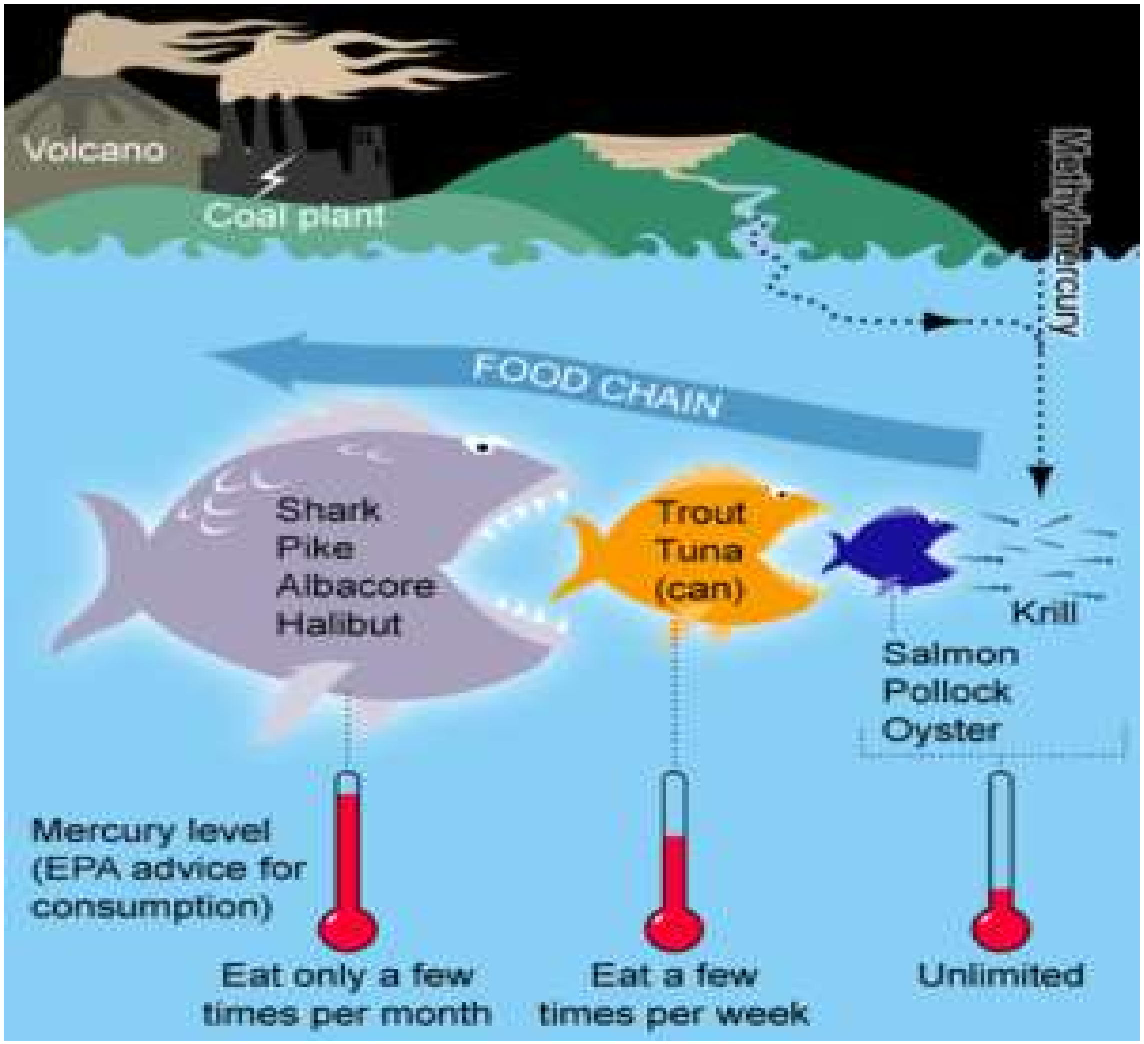
(b) Photochemical smog

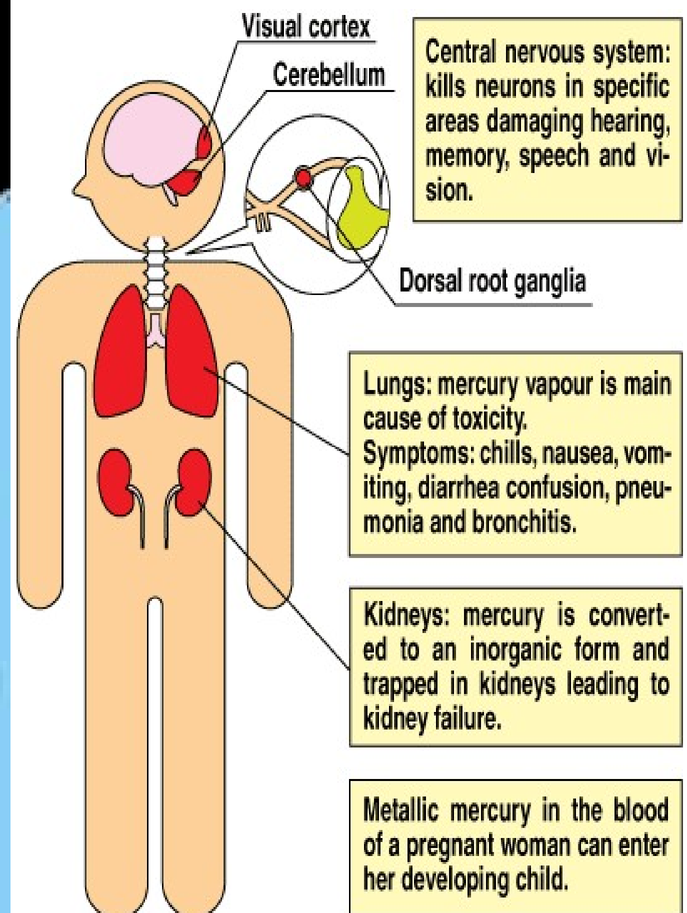




KYODO GRAPHIC

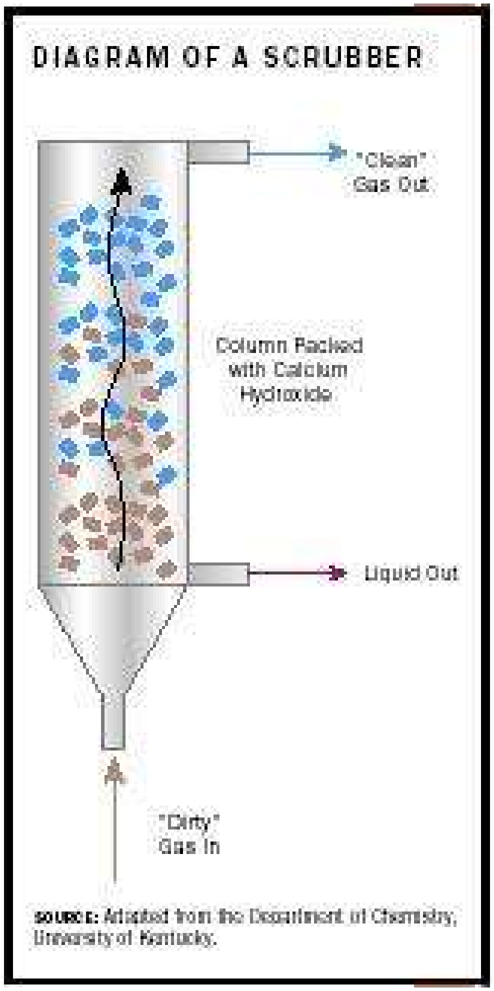
Atmospheric Mercury enters the Food Chain as Methylmercury from Burning Coal to Generate Electricity.



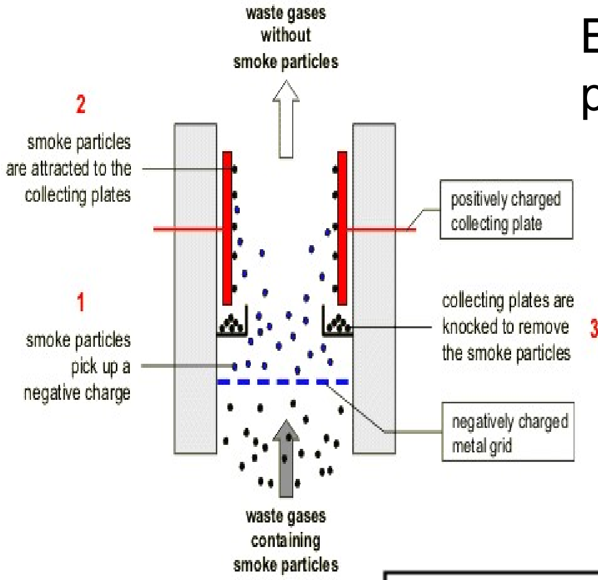


Cleaning Up Coal

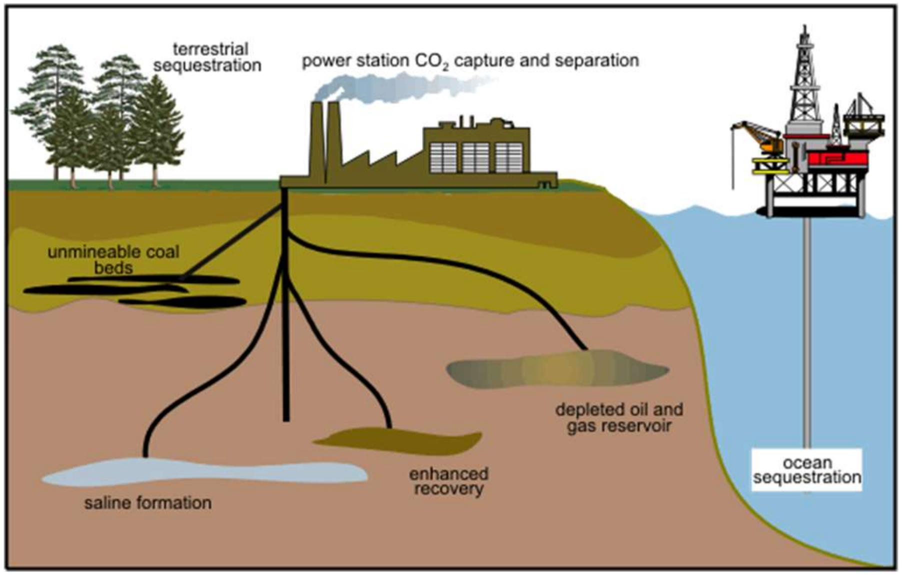
Smokestack scrubber



Electrostatic precipitator



Carbon capture & sequestration



TRADE-OFFS

Coal

Advantages

Ample supplies (225–900 years)

High net energy yield

Low cost

Well-developed technology

Air pollution can be reduced with improved technology

Disadvantages

Severe land disturbance, air pollution, and water pollution

Severe threat to human health when burned

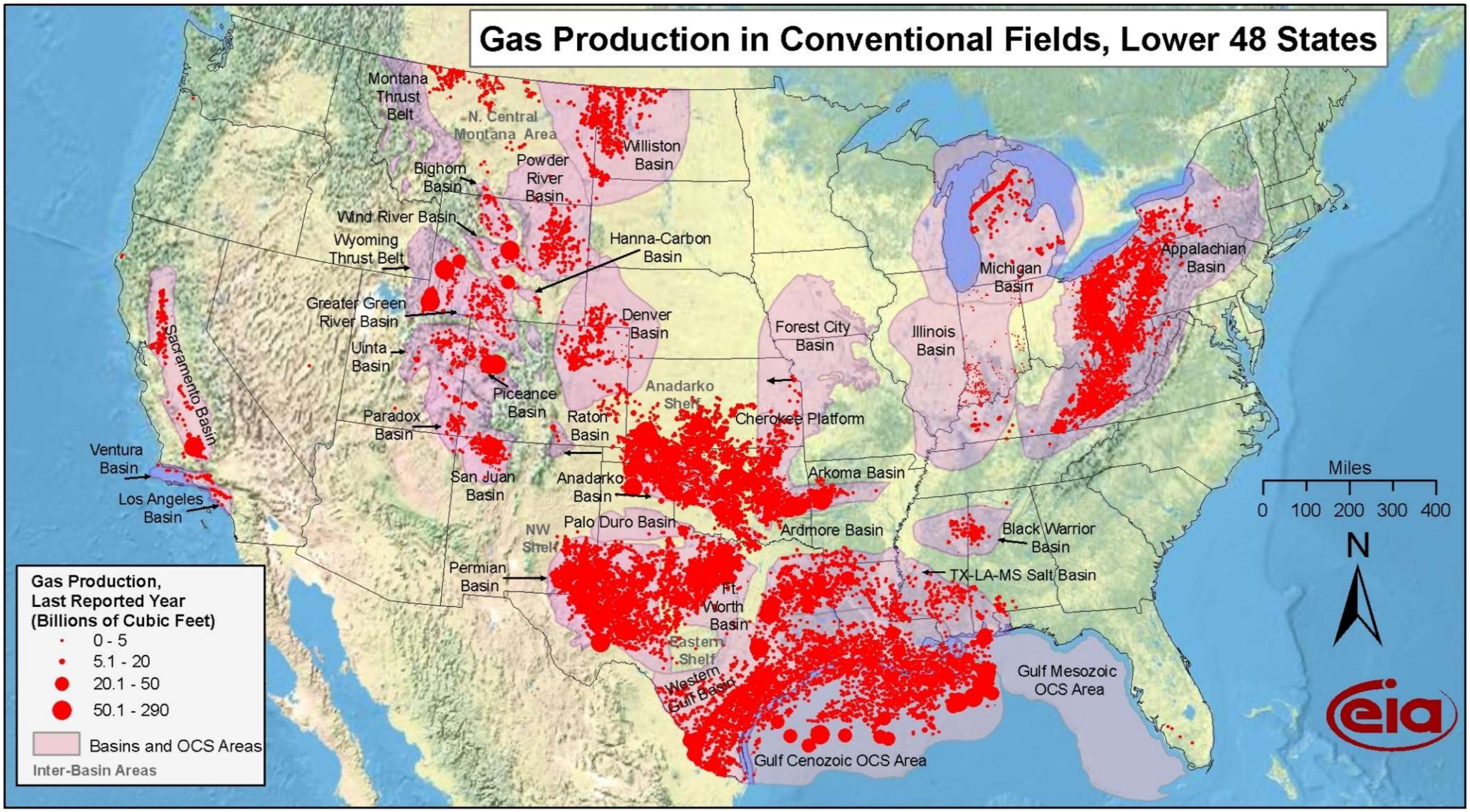
Environmental costs not included in market price

Large government subsidies

High CO_2 emissions when produced and burned

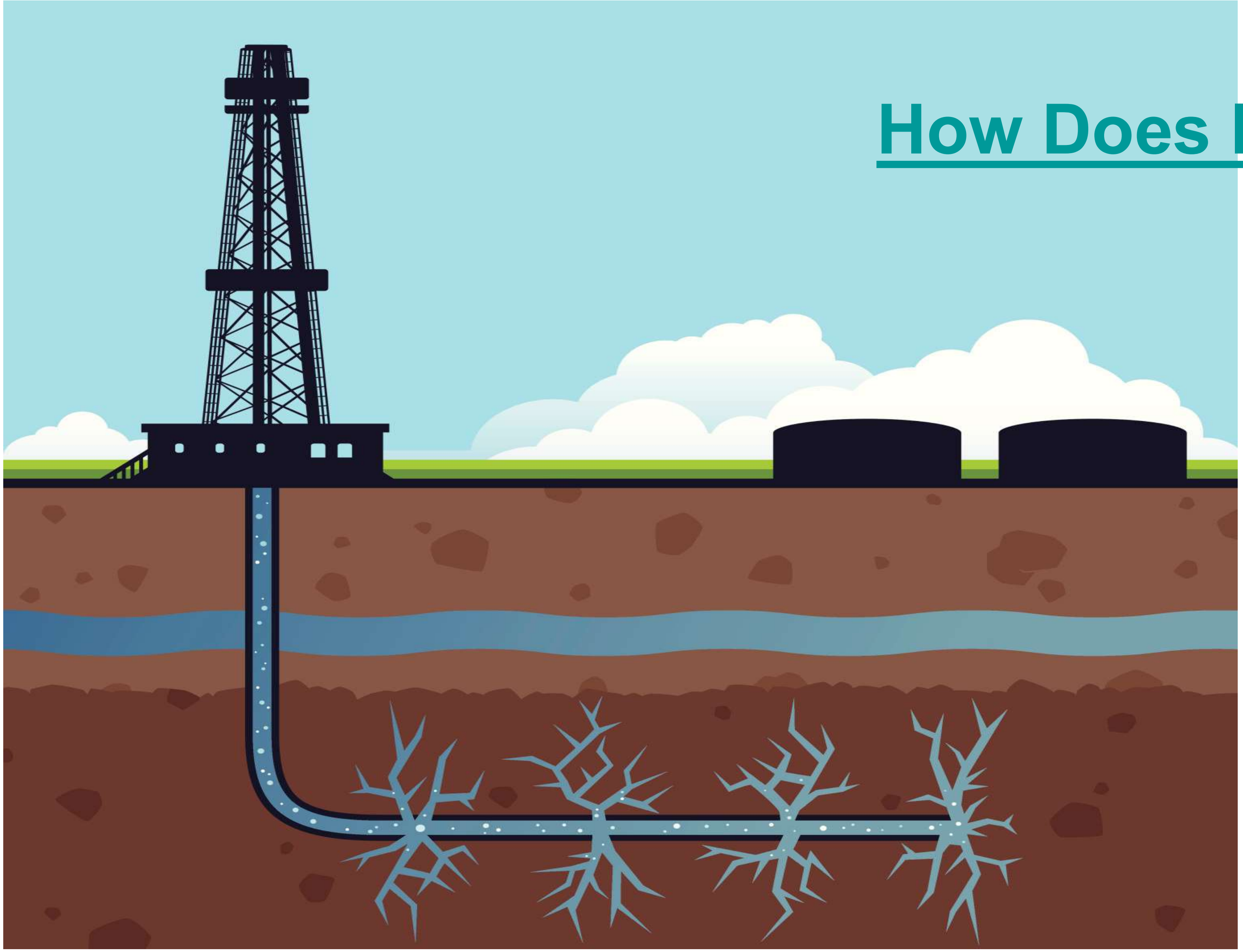
Radioactive particle and toxic mercury emissions

Natural Gas Production Methane and other hydrocarbons

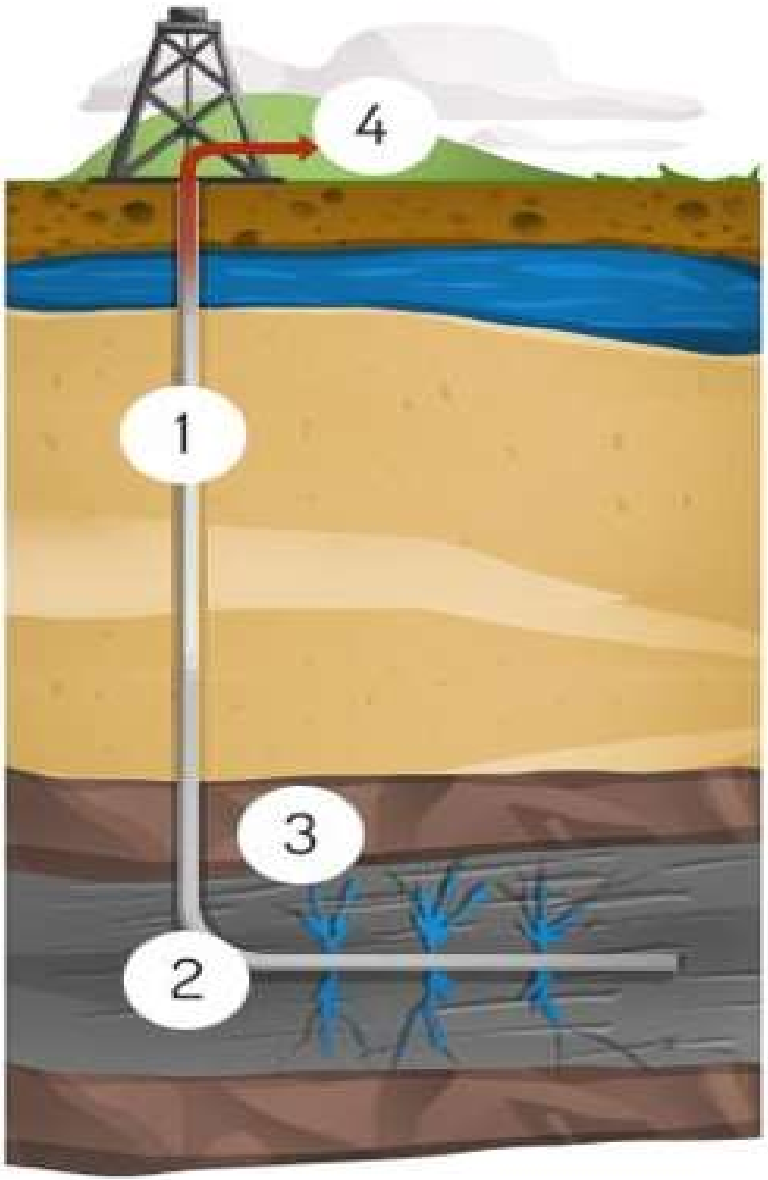


Source: Energy Information Administration based on data from HPDI, IN Geological Survey, USGS
Updated: April 8, 2009

How do we get Natural Gas?
Fracking: short for "hydraulic fracturing"



[How Does It Work?]



Drilling in 4 steps

1. A vertical well is drilled until the shale layer is reached

2. The drill then runs horizontally through the shale formation

3. The fractures created are kept open through the high-pressure injection of water (90%), with sand (9.5%) and other chemicals (acids, chlorides, salts, etc. 0.5%), allowing the flow of gas.

4. After the gas is extracted, the pressure is released and the water returns to the surface

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What is fracking?

Hydraulic fracturing, or fracking, is a method of forcing natural gas or oil from rock layer deep below the Earth's surface.

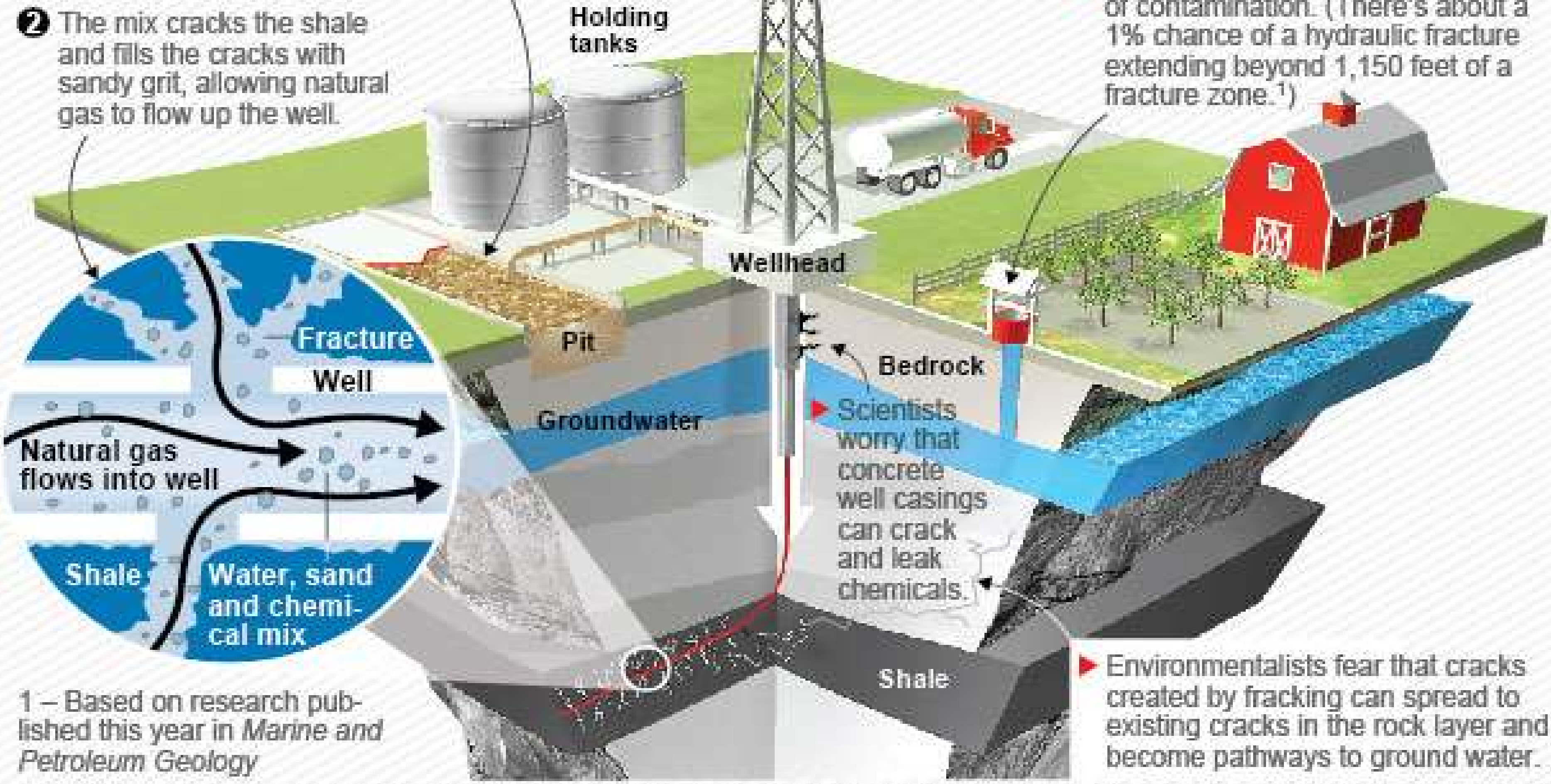
How fracking works ...

1. A pressurized mixture of sand, water and chemicals is injected into a horizontally drilled well.
2. The mix cracks the shale and fills the cracks with sandy grit, allowing natural gas to flow up the well.
3. The recovered water is stored in lined pits or taken to a treatment plant.

... and why it's controversial

Much of the water used in fracking is collected from the well and processed, but some communities have raised concerns that potentially carcinogenic chemicals can escape into drinking water.

- Nearby water wells face a slight risk of contamination. (There's about a 1% chance of a hydraulic fracture extending beyond 1,150 feet of a fracture zone.[1])

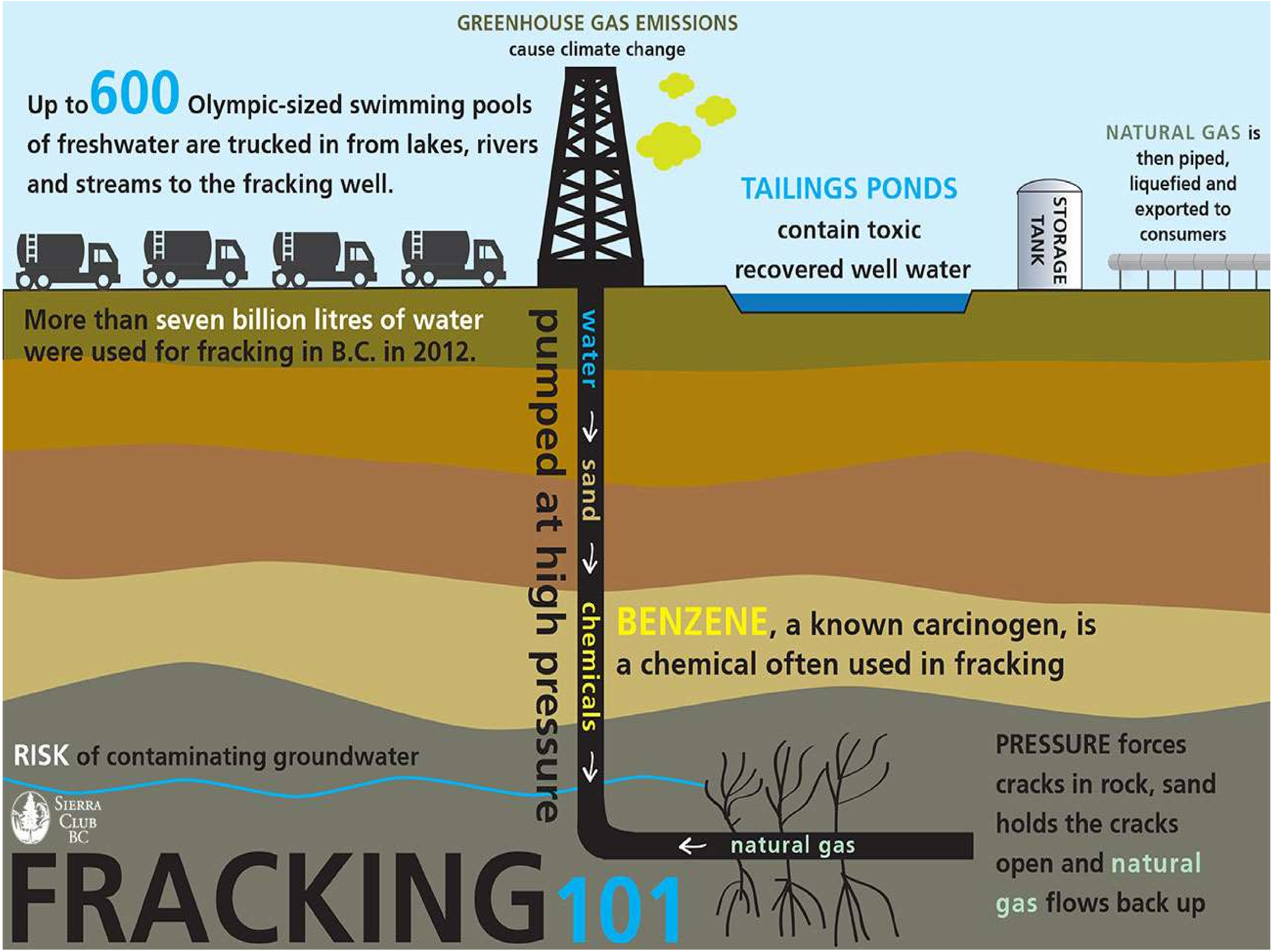


- Scientists worry that concrete well casings can crack and leak chemicals.
- Environmentalists fear that cracks created by fracking can spread to existing cracks in the rock layer and become pathways to ground water.

1 – Based on research published this year in *Marine and Petroleum Geology*

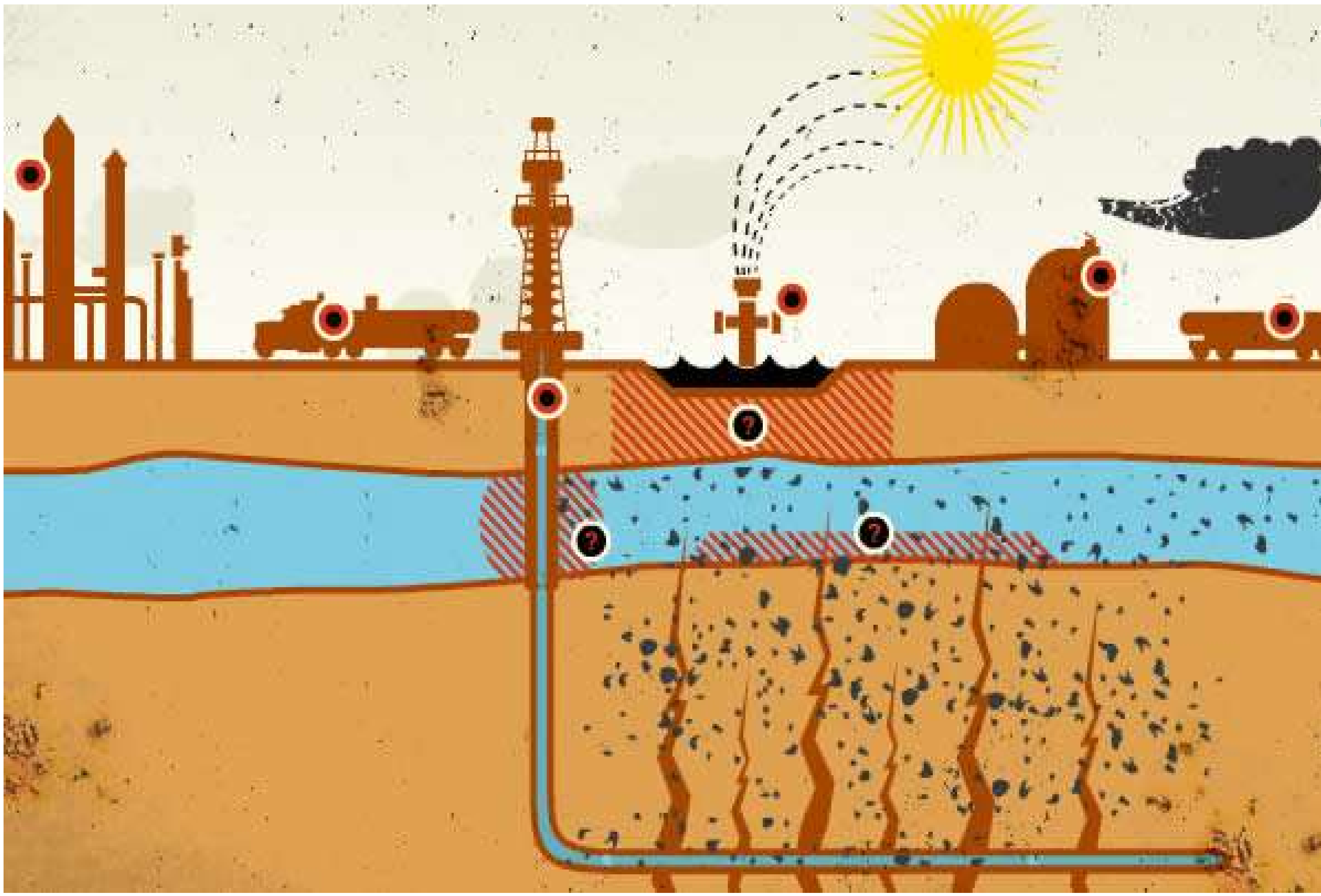
Sources: Duke University; U.S. Energy Information Administration; National Research Council; *Marine and Petroleum Geology*

By Dan Vergano and Karl Gelles, USA TODAY


GREENHOUSE GAS EMISSIONS
cause climate change
Up to 600 Olympic-sized swimming pools of freshwater are trucked in from lakes, rivers and streams to the fracking well.
TAILINGS PONDS
contain toxic recovered well water
STORAGE TANK
NATURAL GAS is then piped, liquefied and exported to consumers
More than seven billion litres of water were used for fracking in B.C. in 2012.
pumped at high pressure
water
sand
chemicals
BENZENE, a known carcinogen, is a chemical often used in fracking
RISK of contaminating groundwater
PRESSURE forces cracks in rock, sand holds the cracks open and natural gas flows back up
natural gas
SIERRA CLUB BC
FRACKING 101

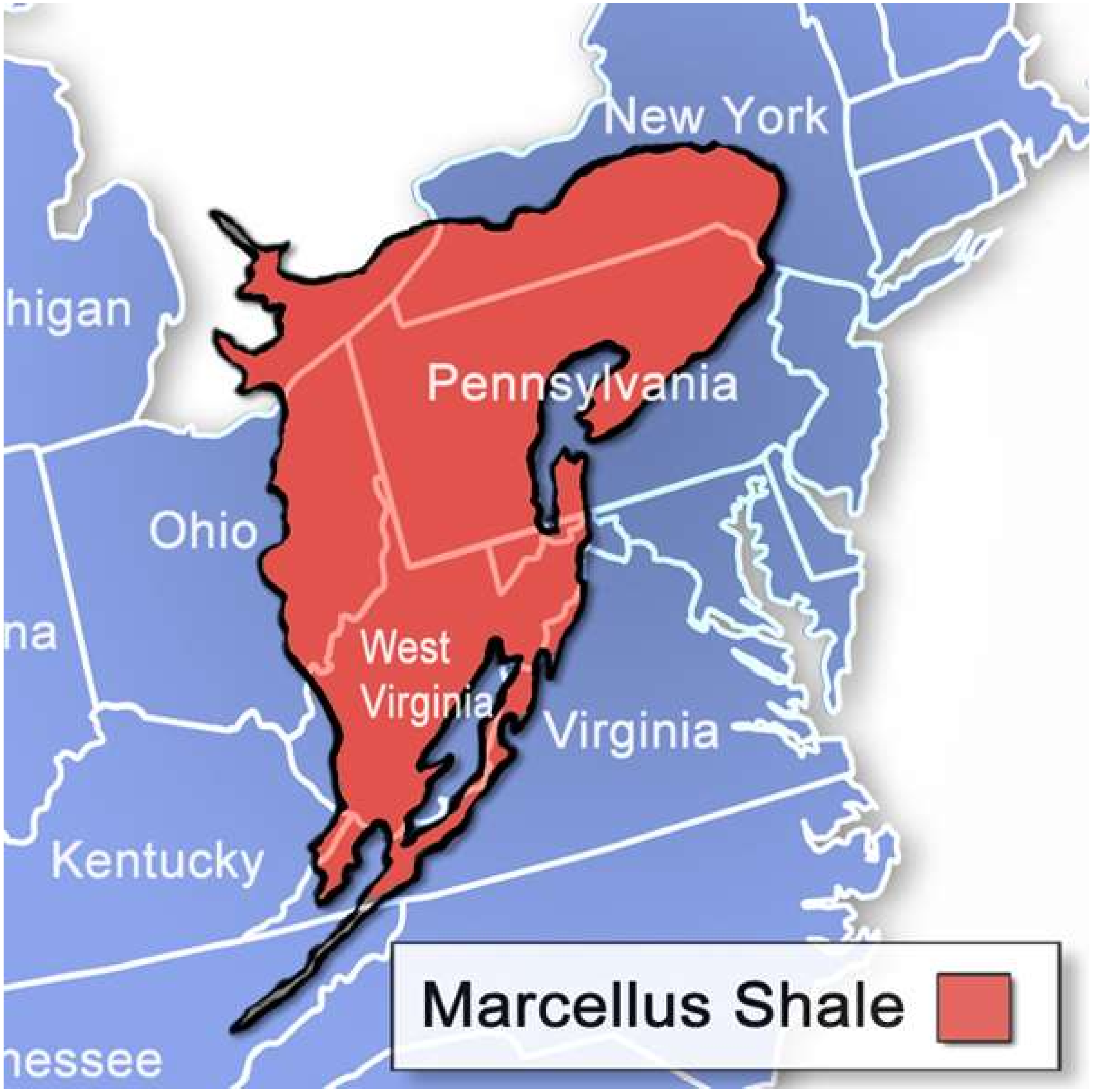
Methane gas can seep into cracks and contaminate water supplies

“My Water’s on Fire Tonight”



Seriously, watch me light it on fire!

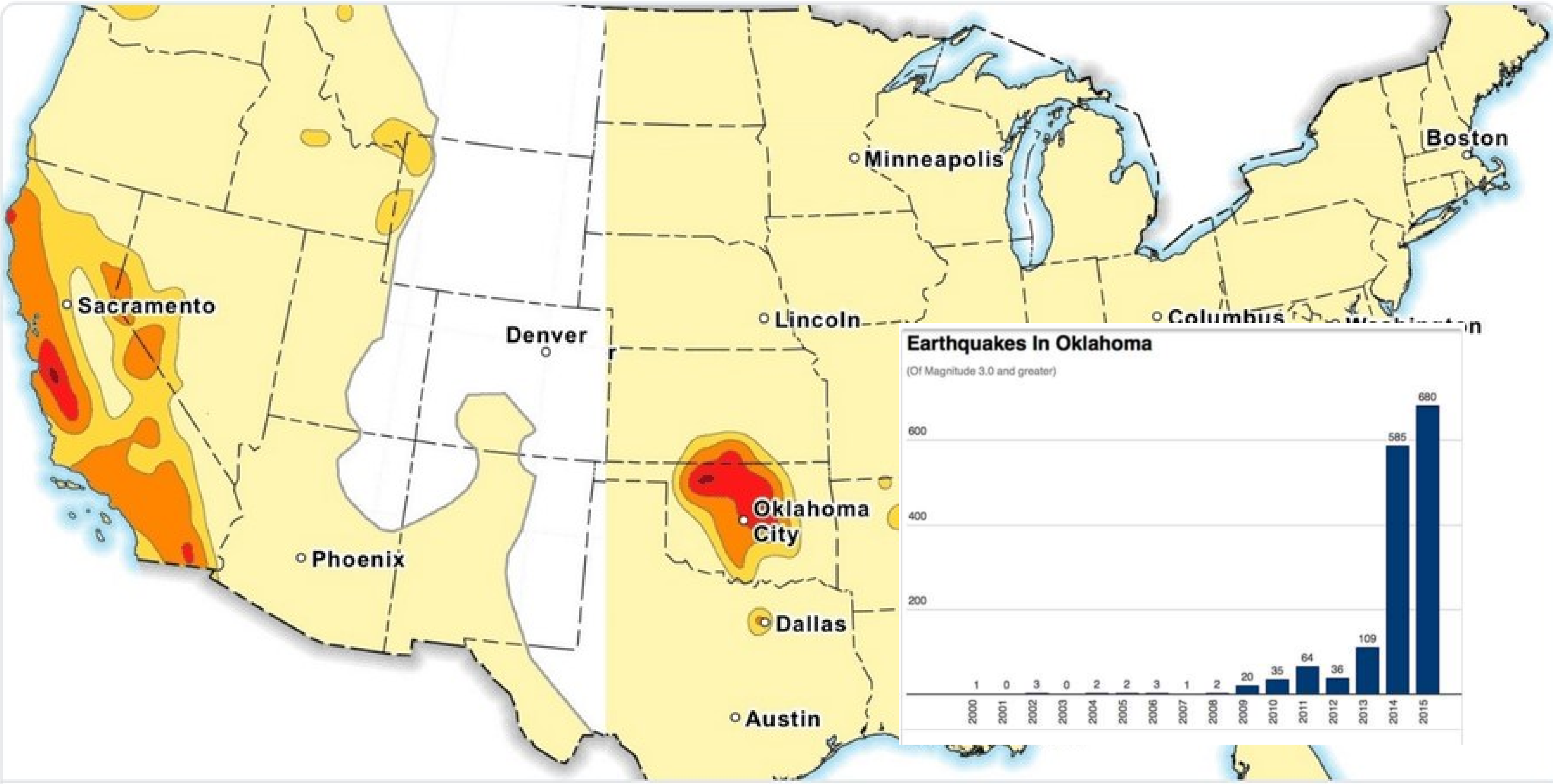
The Truth about Fracking



Fracking comes to the East Coast: high population density

Can Fracking Cause Earthquakes?

[Click me to find out!]



7 million Americans at risk of man-made earthquakes, USGS says

New hazard map includes man-made quakes for the first time

TRADE-OFFS

Conventional Natural Gas

Advantages

Ample supplies

High net energy yield

Low cost

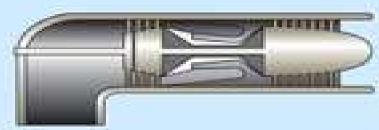
Less air pollution than other fossil fuels

Lower CO_2 emissions than other fossil fuels

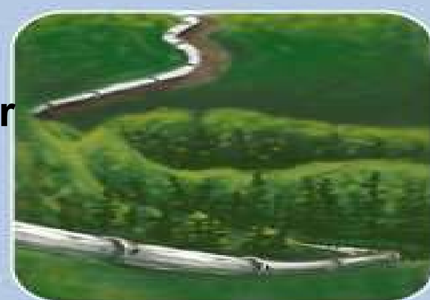
Easily transported by pipeline

Low land use

Good fuel for fuel cells, gas turbines, and motor vehicles



Gas turbine



Disadvantages

Nonrenewable resource

Releases CO_2 when burned

Government subsidies

Environmental costs not included in market price

Methane (a greenhouse gas) can leak from pipelines

Difficult to transfer from one country to another

Can be shipped across ocean only as highly explosive LNG

TRADE-OFFS

Synthetic fuels

Advantages

Large potential supply

Vehicle fuel

Moderate cost

Lower air pollution than coal when burned

Disadvantages

Low to moderate net energy yield

Higher cost than coal

Requires mining 50% more coal

Environmental costs not included in market price

High environmental impact

Large government subsidies

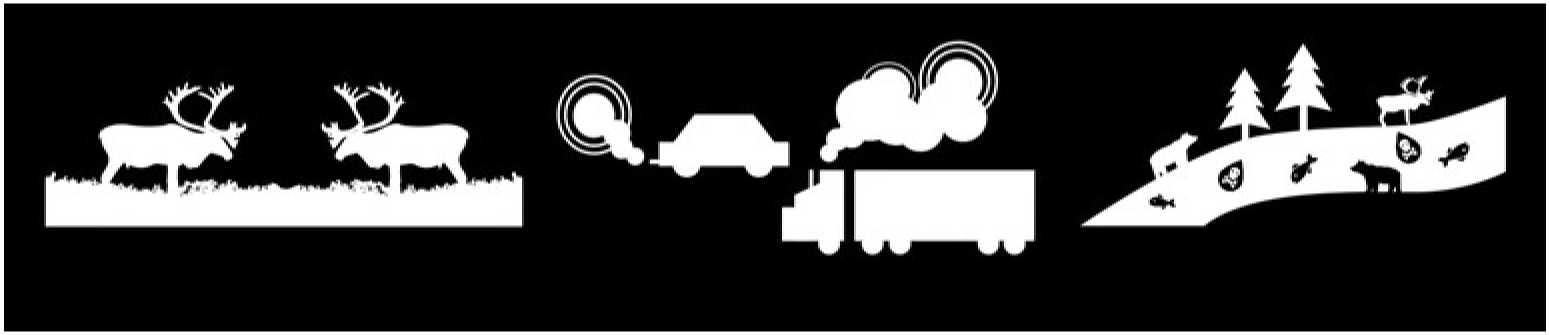
High water use

Higher CO_2 emissions than coal

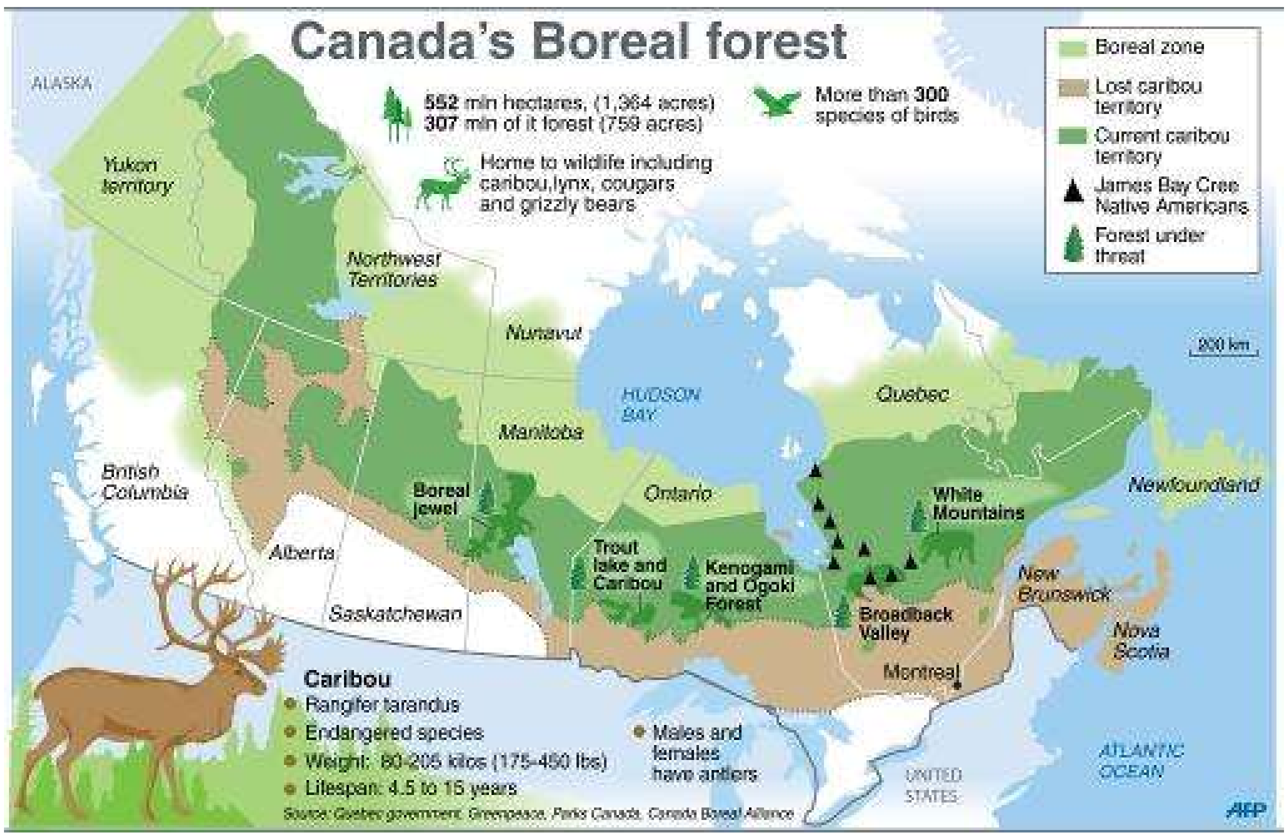
Fig. 15-16, p. 386

Tar Sands of Alberta

What are Tar Sands? Also called Oil Sands



What are some of the environmental effects of mining for tar sands?



Dirty Tar Sands Video

Keystone Pipeline

[Tar Sands Timmy]

- Transports unrefined oil from oil sands in Canada (largest producer) to refineries in SE United States
- Replaces older pipeline
- Allows for higher capacity of oil transport
- Possible water contamination – part goes over the Ogallala Aquifer
- Habitat degradation issues – goes through sensitive sandhill ecosystem in Nebraska
- Less incentive to develop sustainable energy

Sandhills, Nebraska

An ancient, fragile ecosystem that is a key migratory layover for dozens of bird species

Local Residents Speak Out

Oil Shale rock (left) and the Shale Oil (right) extracted from it. Producing shale oil has a low net energy yield and a very high environmental impact. It also requires considerable amounts of water and money

Fig. 15-8, p. 380

TRADE-OFFS

Heavy Oils from Oil Shale and Oil Sand

Advantages

Moderate cost (oil sand)

Large potential supplies, especially oil sands in Canada

Easily transported within and between countries

Efficient distribution system in place

Technology well-developed (oil sand)

Disadvantages

High cost (oil shale)

Low net energy yield

Environmental costs not included in market price

Large amounts of water needed for processing

Severe land disruption

Severe water pollution

Air pollution and CO_2 emissions when produced and burned

Nuclear Power Plant

HOW DOES IT WORK?

EXPLAIN THAT AGAIN?

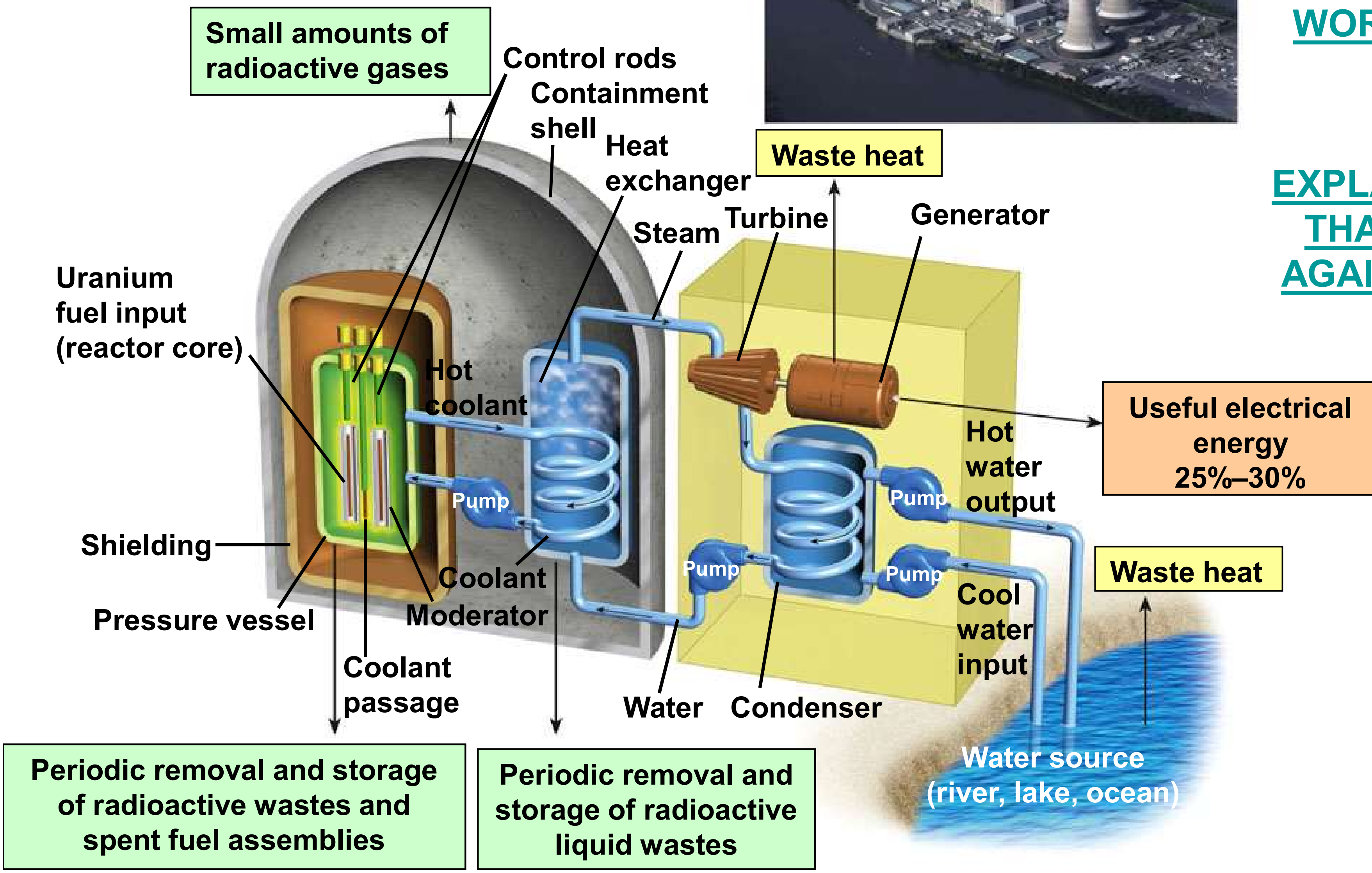
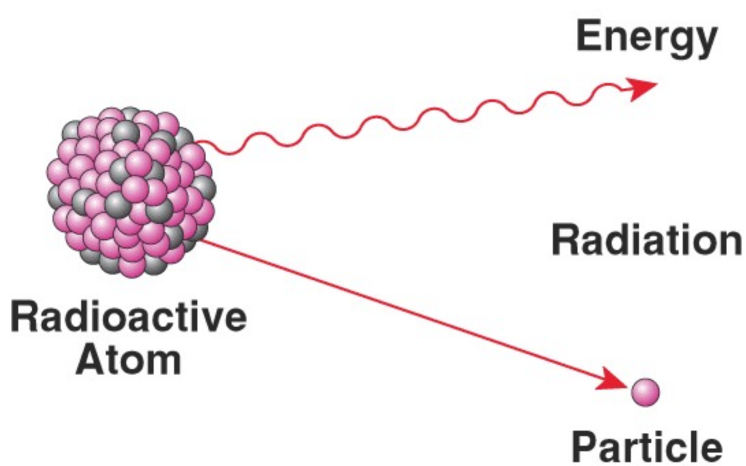
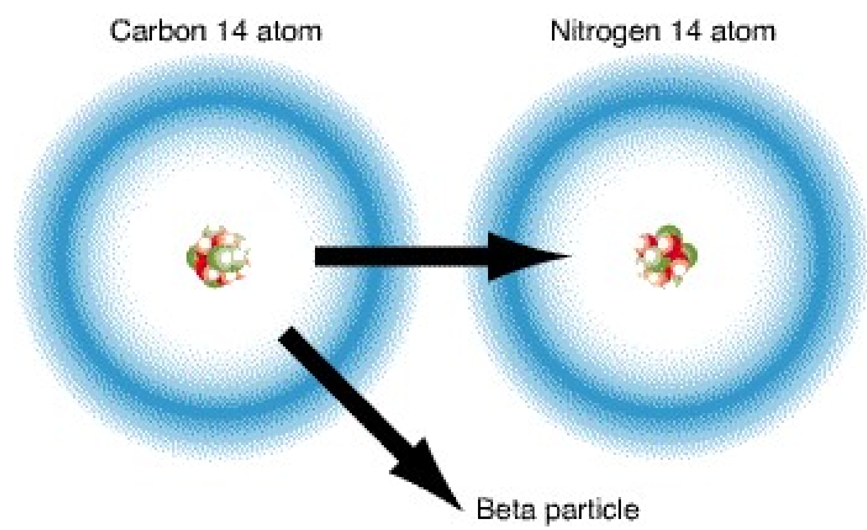


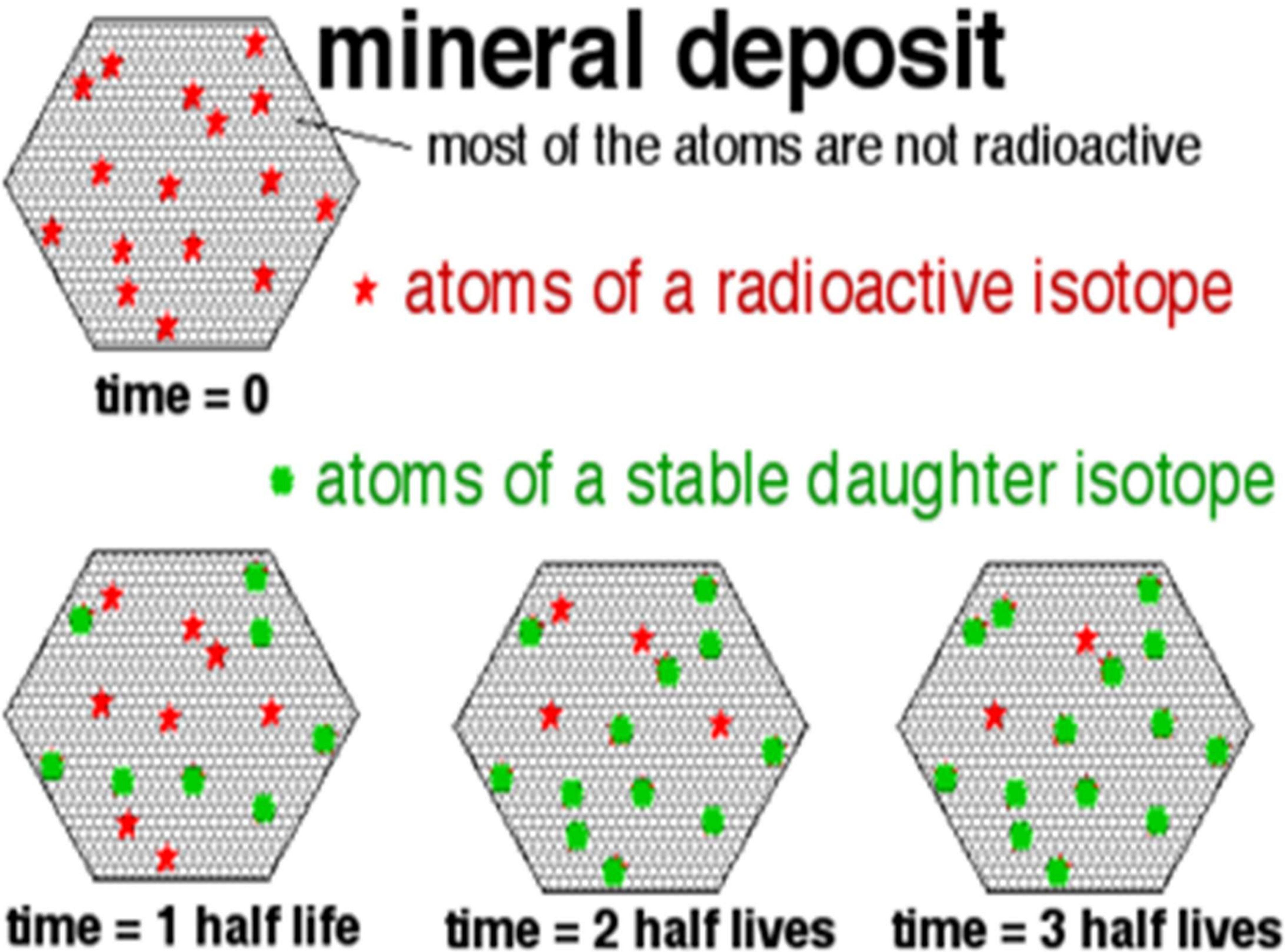
Fig. 15-17, p. 387

Radioactive Decay

General Idea: An element loses atomic material at a steady rate. If you know this rate, you can determine how long it took for one material to degrade into another.

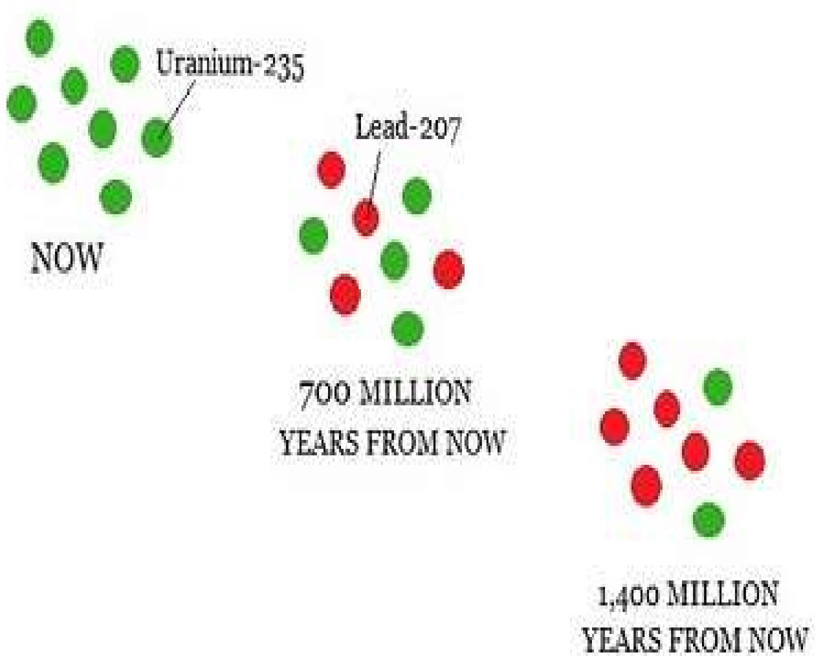





mineral deposit
most of the atoms are not radioactive
atoms of a radioactive isotope
atoms of a stable daughter isotope
time = 0
time = 1 half life
time = 2 half lives
time = 3 half lives

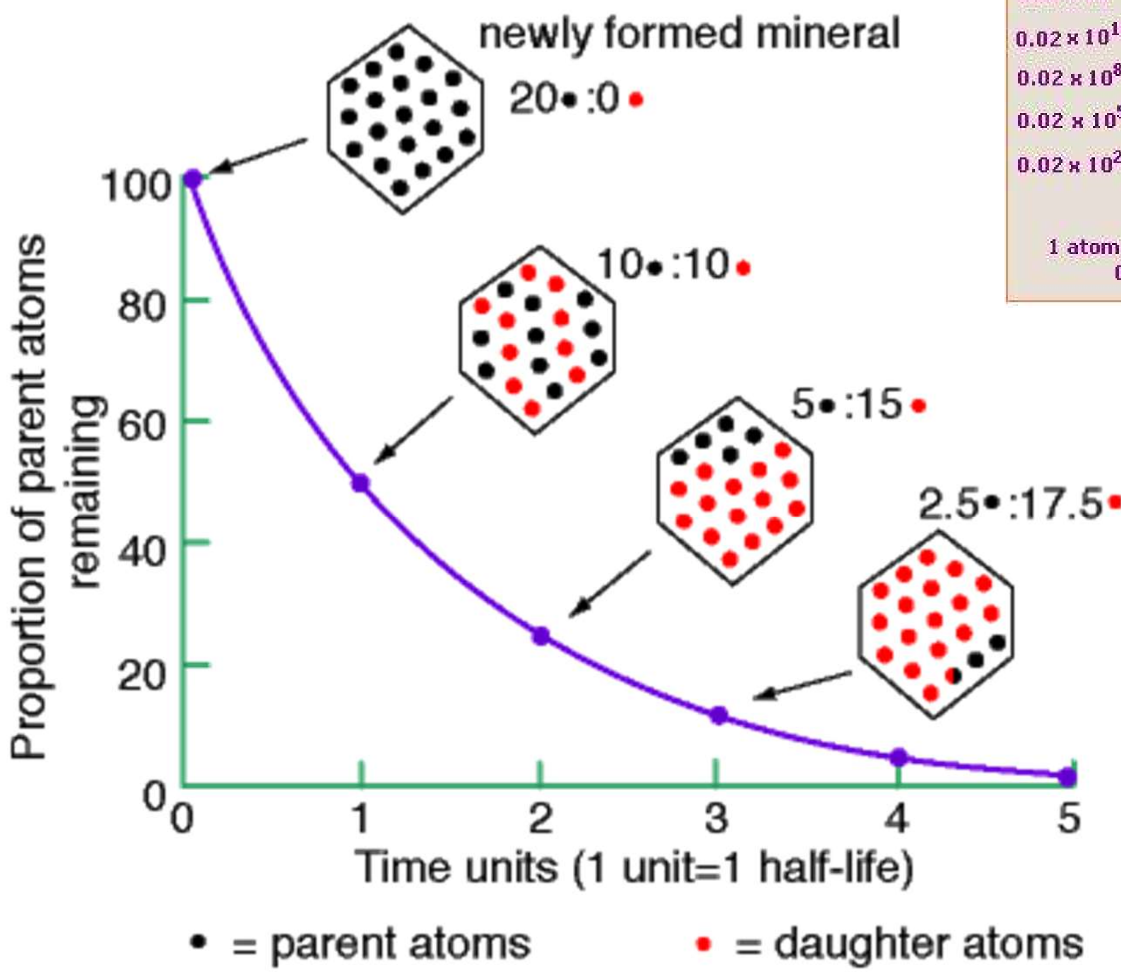
What is a half life?

Time required for half of the atoms of a substance to radiate away/decay

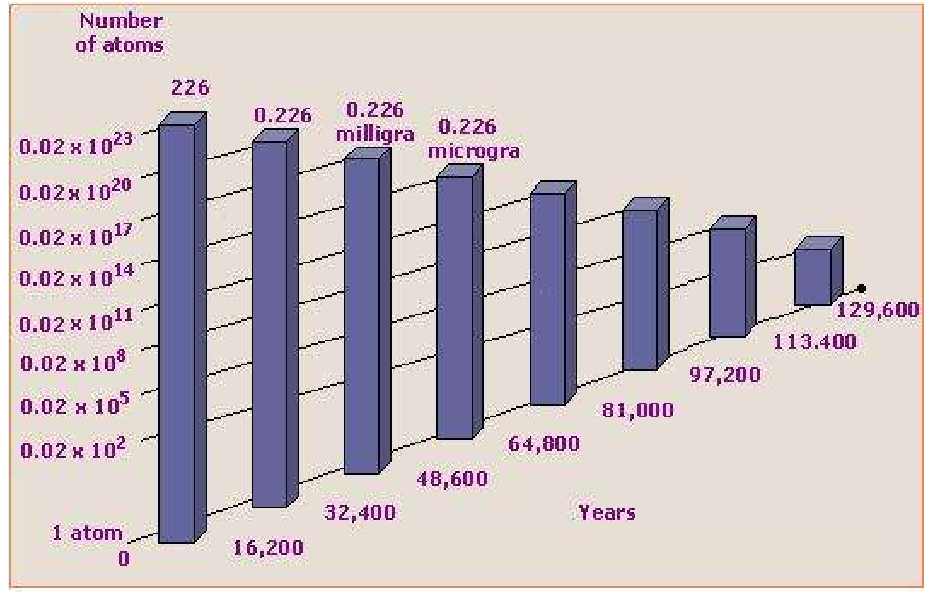


Number of half-lives elapsed	Fraction remaining	Percentage remaining
0	$^1/_1$	100
1	$^1/_2$	50
2	$^1/_4$	25
3	$^1/_8$	12.5
4	$^1/_{16}$	6.25
5	$^1/_{32}$	3.125
6	$^1/_{64}$	1.563
7	$^1/_{128}$	0.781
...	...	...

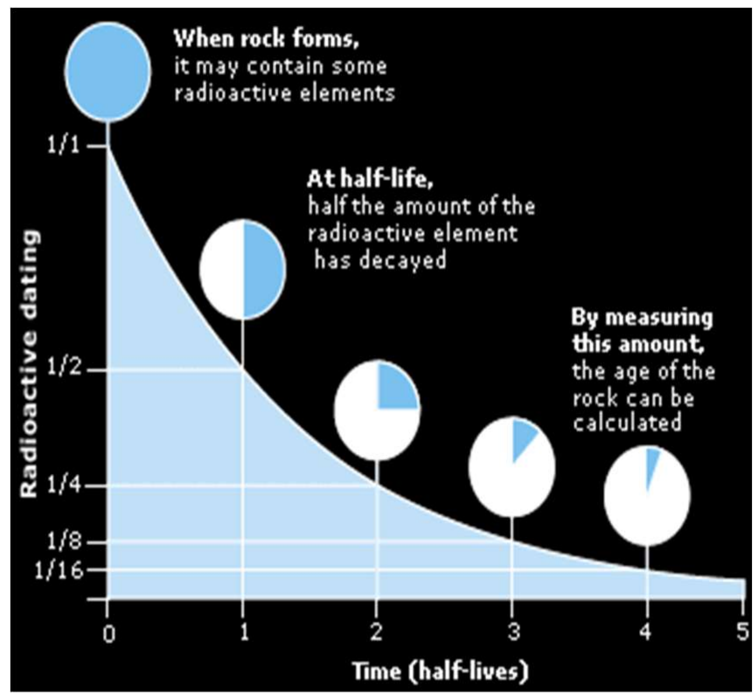
Half-life



newly formed mineral
20•:0•
10•:10•
5•:15•
2.5•:17.5•
Proportion of parent atoms remaining
100
80
60
40
20
0
0 1 2 3 4 5
Time units (1 unit=1 half-life)
• = parent atoms
• = daughter atoms



Number of atoms
226
0.226
0.226 milligra
0.226 microgra
0.02 x 10^23
0.02 x 10^20
0.02 x 10^17
0.02 x 10^14
0.02 x 10^11
0.02 x 10^8
0.02 x 10^5
0.02 x 10^2
1 atom
0
16,200
32,400
48,600
64,800
81,000
97,200
113.400
129,600
Years



When rock forms, it may contain some radioactive elements
At half-life, half the amount of the radioactive element has decayed
By measuring this amount, the age of the rock can be calculated
Radioactive dating
1/1
1/2
1/4
1/8
1/16
0 1 2 3 4 5
Time (half-lives)

Light-water–moderated and –cooled nuclear power plant with a pressurized water reactor. Some nuclear plants withdraw water for cooling from a nearby source of water and return the heated water to such a source, as shown here. Other nuclear plants that do not have access to a source of cooling water transfer the waste heat to the atmosphere by using one or more gigantic cooling towers, as shown in the insert photo of the Three Mile Island nuclear power plant near Harrisburg, Pennsylvania (USA).

Fig. 15-17b, p. 387

After 3 or 4 years in a reactor, spent fuel rods are removed and stored in a deep pool of water contained in a steel-lined concrete basin (left). After they have cooled considerably, some fuel rods are stored upright on concrete pads (right) in dry-storage containers made of steel or concrete.

Fig. 15-18a, p. 388

After 3 or 4 years in a reactor, spent fuel rods are removed and stored in a deep pool of water contained in a steel-lined concrete basin (left). After they have cooled considerably, some fuel rods are stored upright on concrete pads (right) in dry-storage containers made of steel or concrete.

Fig. 15-18b, p. 388

The nuclear fuel cycle As long as a plant is operating safely, this fuel cycle has a fairly low environmental impact and a very low risk of an accident. But costs are high, radioactive wastes must be stored safely for thousands of years, and facilities are vulnerable to terrorist attack. Also, the technology can be used to produce material for use in nuclear weapons, and an amount equal to about 92% of the energy content of the nuclear fuel is wasted in producing nuclear power.

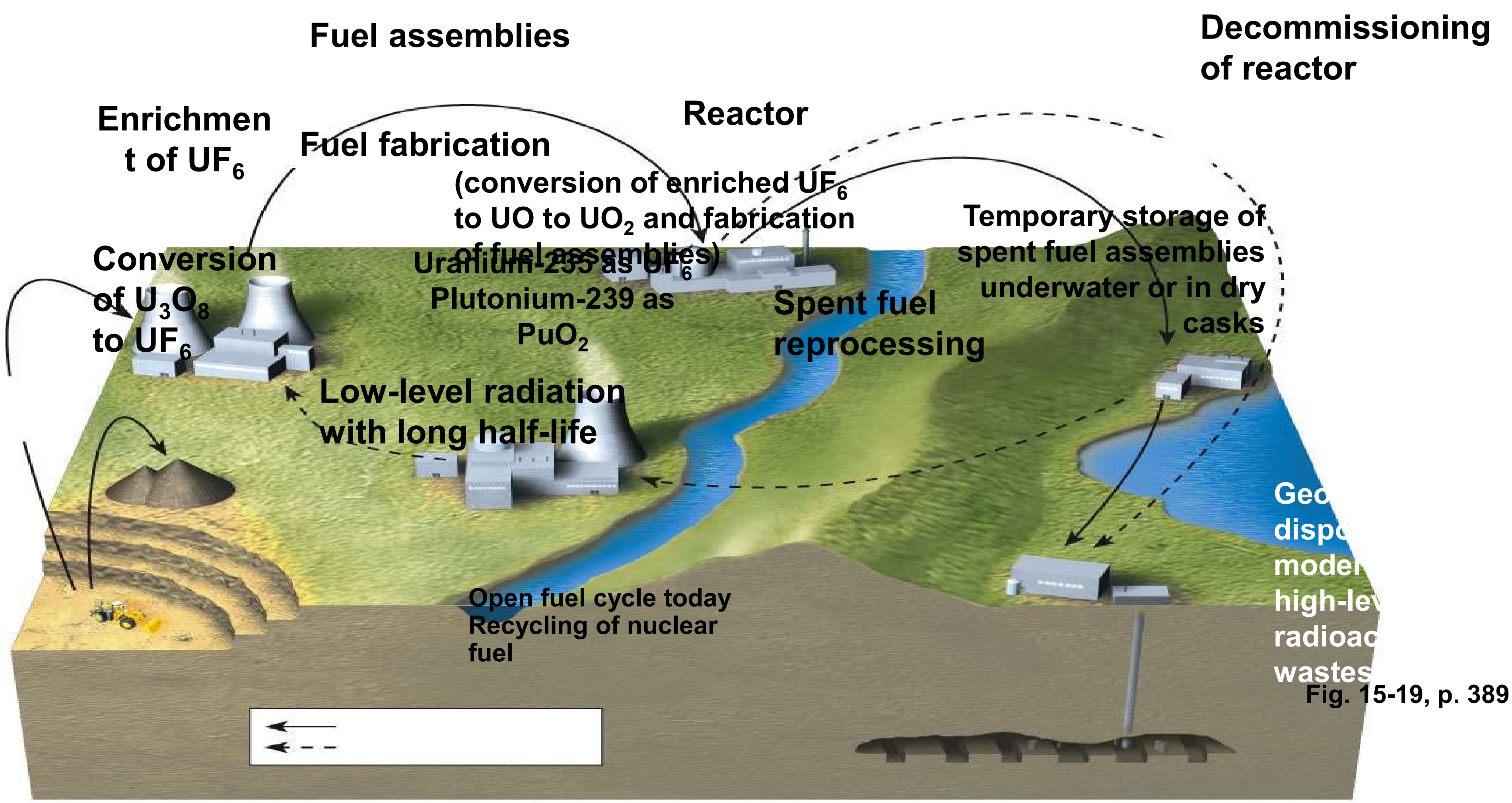
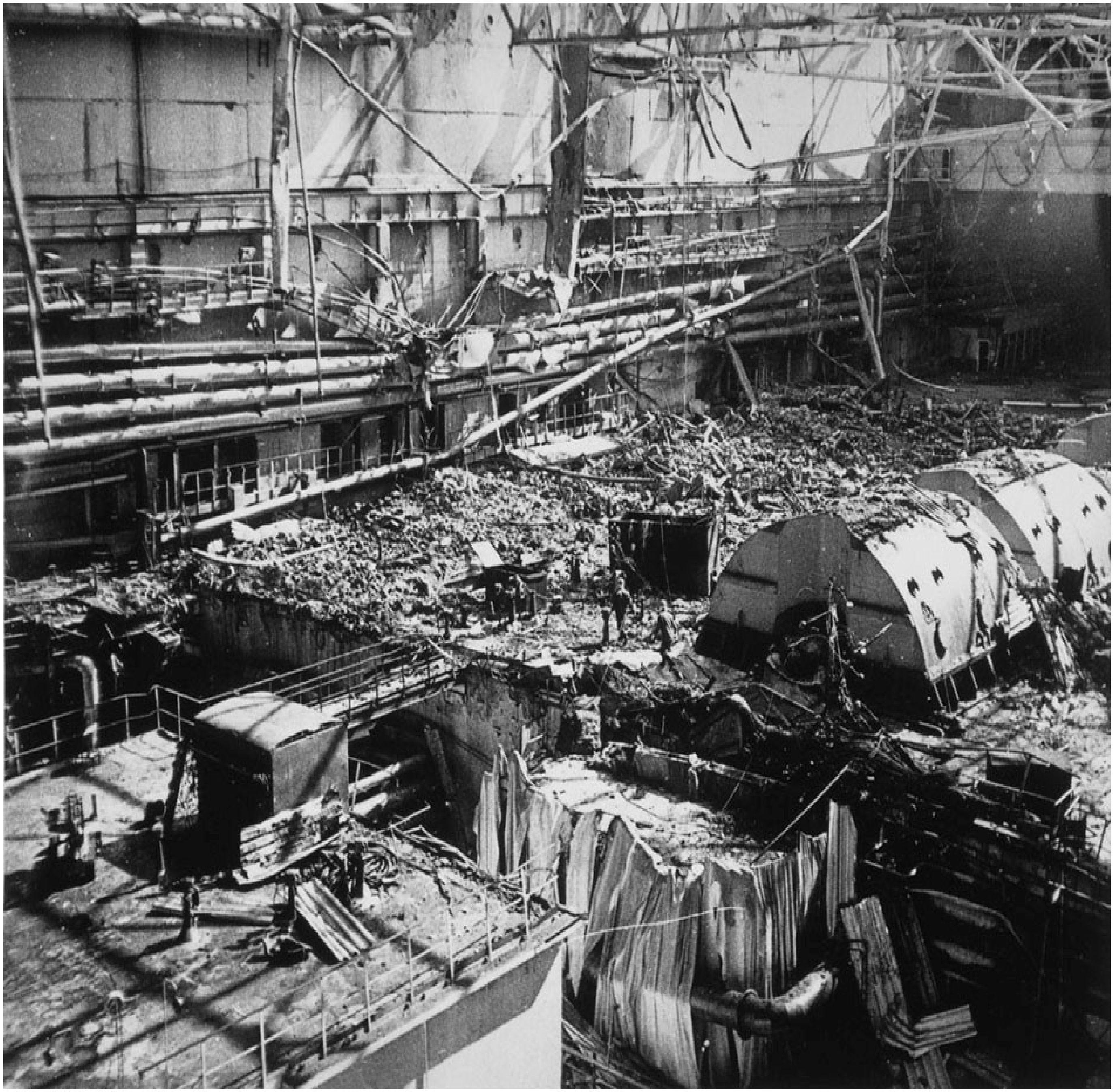


Fig. 15-19, p. 389

Remains of a nuclear reactor at the Chernobyl nuclear power plant in Ukraine 3 days after it blew up and released massive amounts of dangerous radiation into the environment. Workers and volunteers put out the fires and hastily built a concrete tomb around the reactor to contain its high-level radiation, and many of these workers died from radiation exposure.



MELTDOWN

MELTDOWN 2

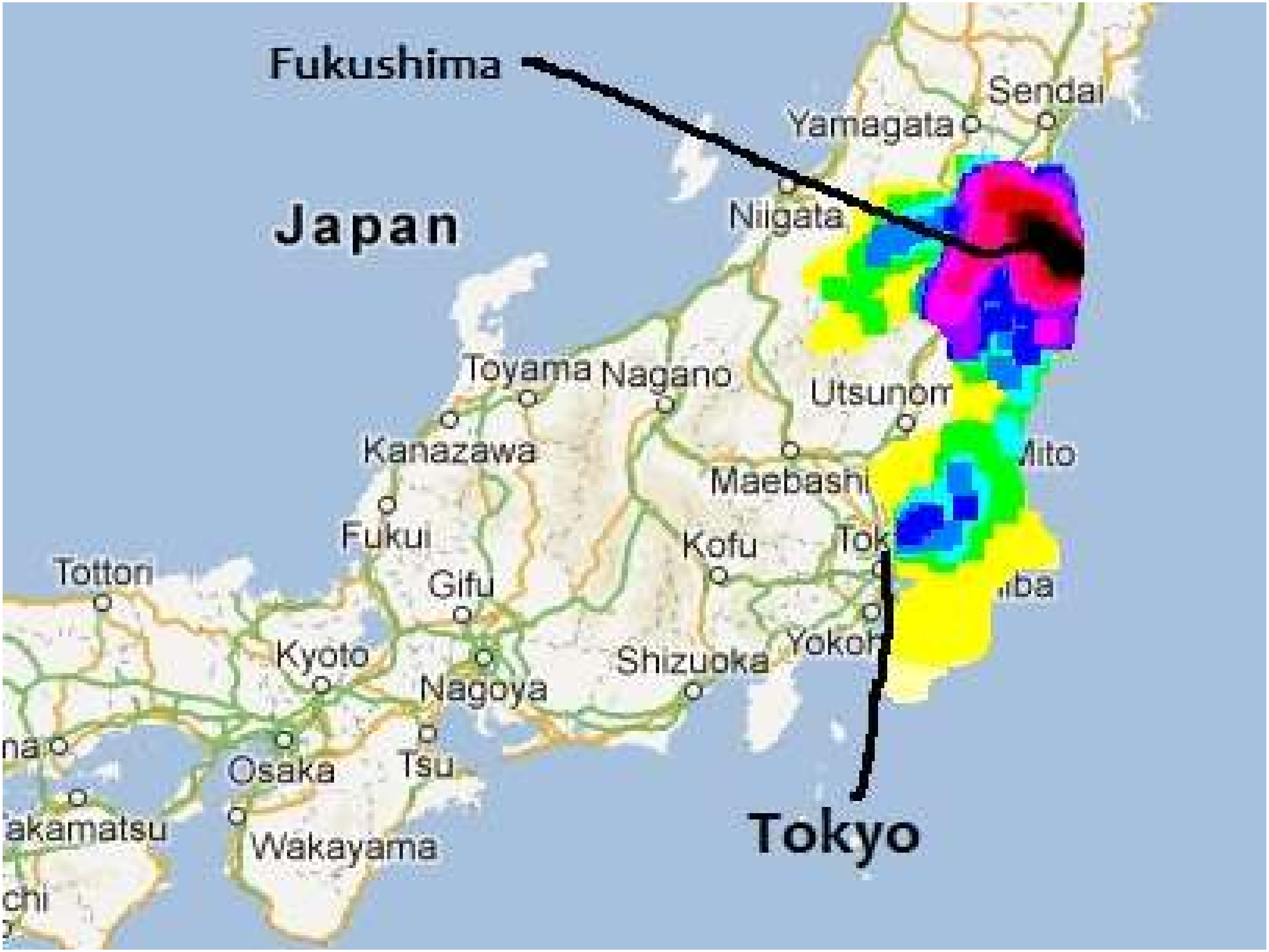
Fig. 15-20, p. 391

The Fukushima Daiichi nuclear was a series of equipment failures, nuclear meltdowns and releases of radioactive materials at the Fukushima I Nuclear Power Plant, following an earthquake and subsequent tsunami in March 2011. It is the largest nuclear disaster since the Chernobyl disaster of 1986 .
As the water boiled away in the reactors and the water levels in the fuel rod pools dropped, the reactor fuel rods began to overheat severely and melt down. In the hours and days that followed, Reactors 1, 2 and 3 experienced full meltdown.

MELTDOWN 3

Measuring radiation on the streets of Fukushima

Fukushima Now



Fukushima
Japan
Sendai
Yamagata
Niigata
Toyama
Nagano
Utsunom
Kanazawa
Mito
Maebashi
Fukui
Kofu
Totton
Gifu
Kyoto
Shizuoka
Nagoya
Osaka
Tsu
Wakayama
Tokyo

TRADE-OFFS

Conventional Nuclear Fuel Cycle

Advantages

Large fuel supply

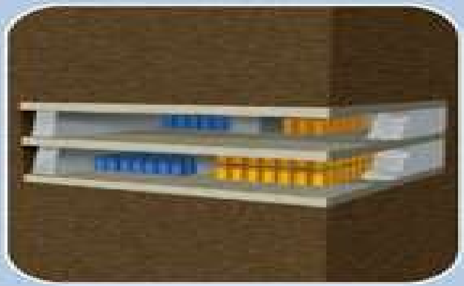
Low environmental impact (without accidents)

Emits 1/6 as much CO_2 as coal

Moderate land disruption and water pollution (without accidents)

Moderate land use

Low risk of accidents because of multiple safety systems (except for Chernobyl-type reactors)



Disadvantages

Cannot compete economically without huge government subsidies

Low net energy yield

High environmental impact (with major accidents)

Environmental costs not included in market price

Risk of catastrophic accidents

No widely acceptable solution for long-term storage of radioactive wastes

Subject to terrorist attacks

Spreads knowledge and technology for building nuclear weapons

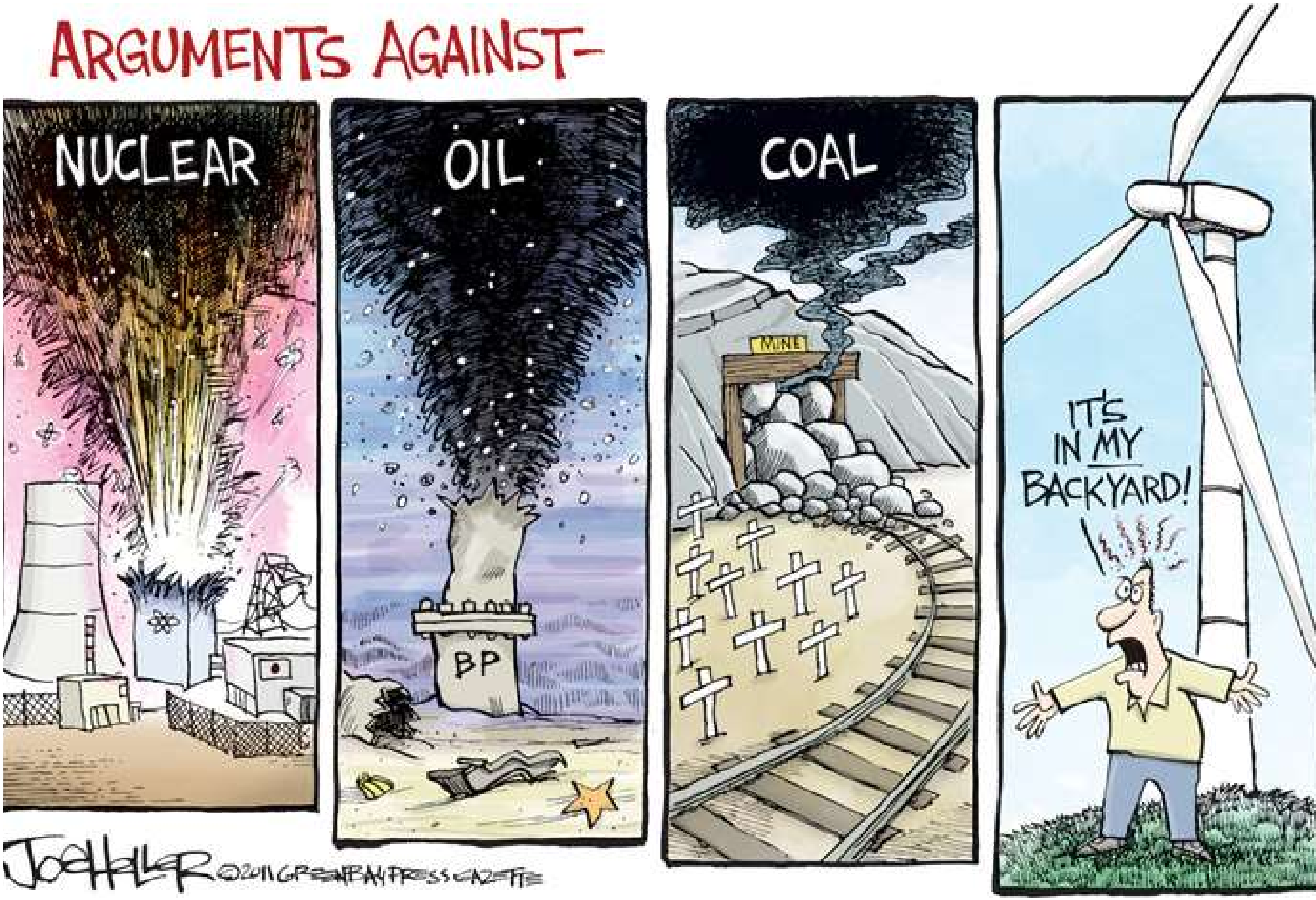
Fig. 15-21, p. 391

TRADE-OFFS

Coal vs. Nuclear

Coal	Nuclear
Ample supply	Ample supply of uranium
High net energy yield	Low net energy yield
Very high air pollution	Low air pollution
High CO_2 emissions	Low CO_2 emissions
High land disruption from surface mining	Much lower land disruption from surface mining
High land use	Moderate land use
Low cost (with huge subsidies)	High cost (even with huge subsidies)

Fig. 15-22, p. 392


ARGUMENTS AGAINST-
NUCLEAR
OIL
BP
COAL
MINE
IT'S IN MY BACKYARD!
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