Energy

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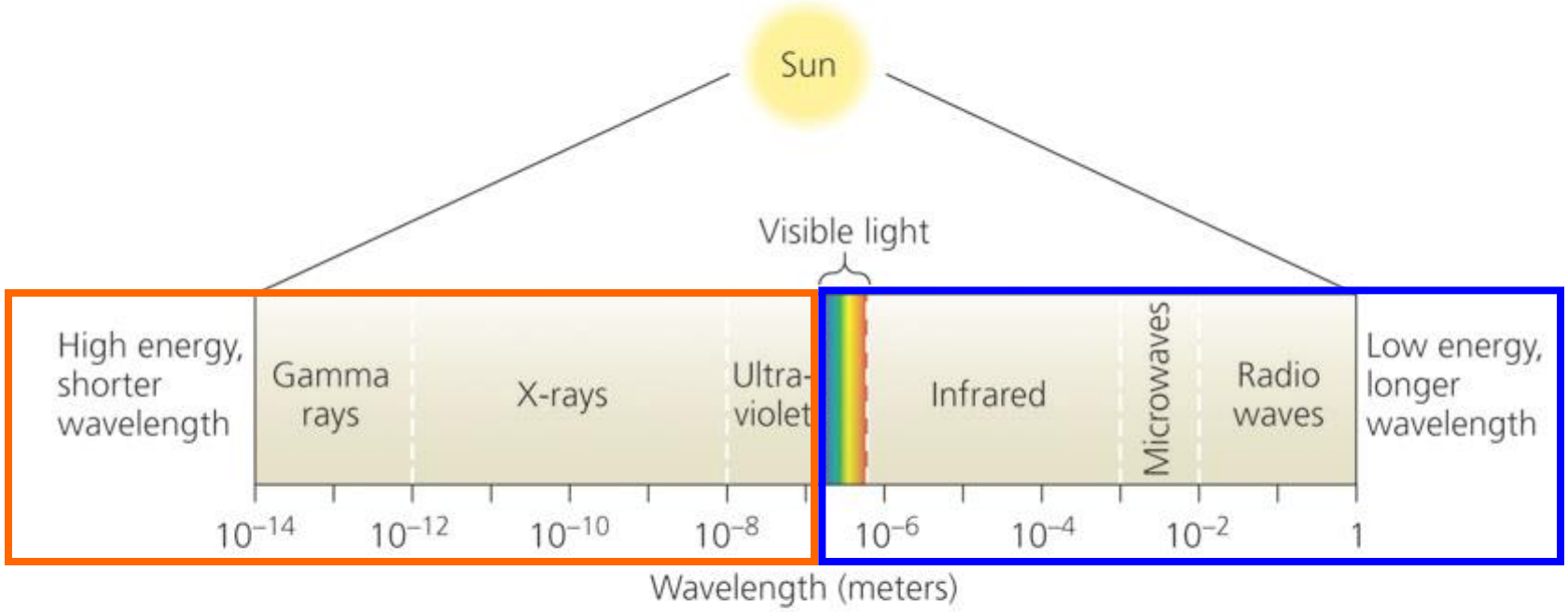
Energy

- The capacity to do work or transfer heat

Solar Capital

- Almost all the energy that heats the earth and our buildings comes from the sun at no cost to us.
- Without this perpetual, inexhaustible source of energy, the Earth's average temperature would be -240°C!!
- Life would not exist!!

Solar Capital



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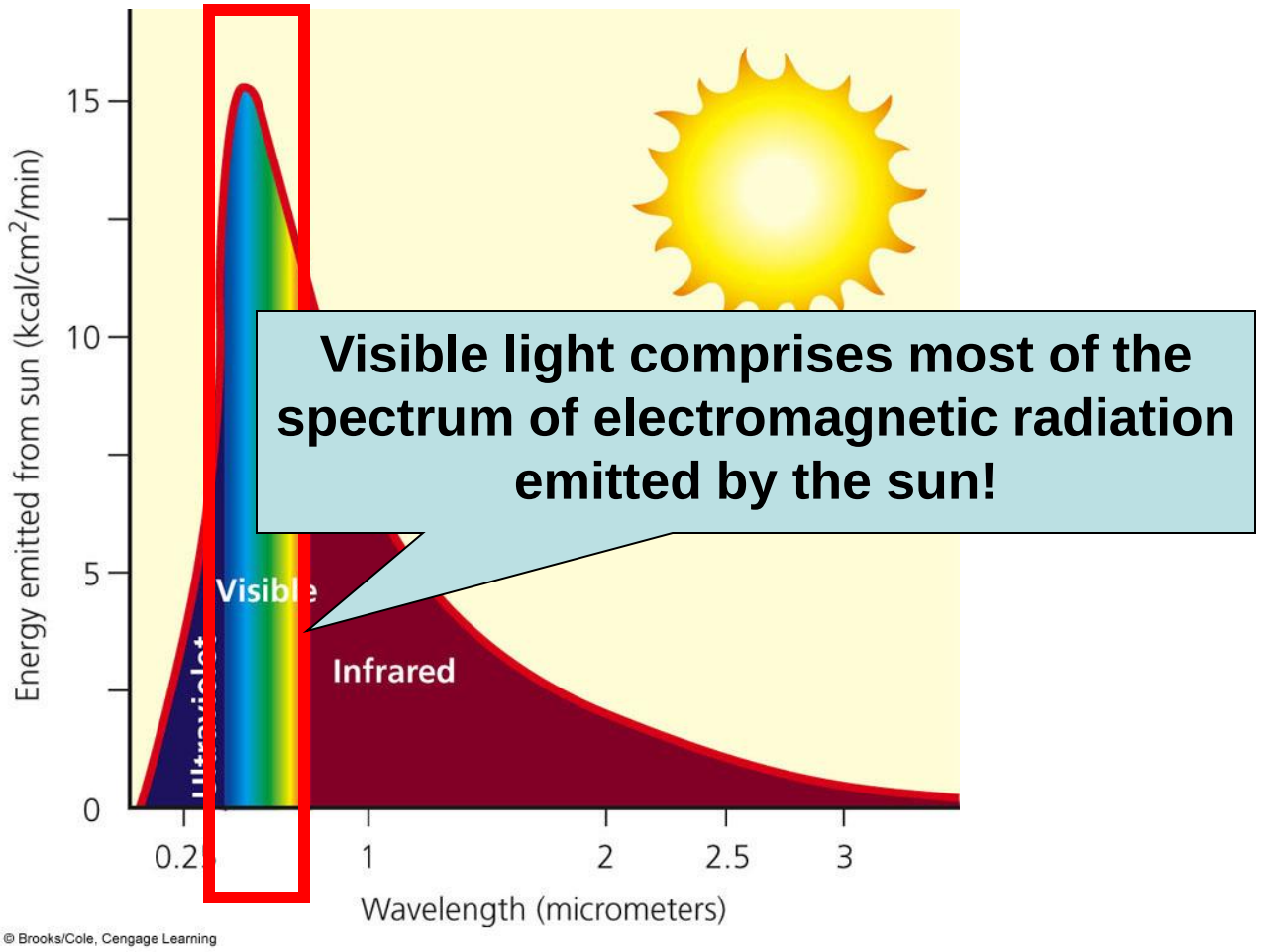
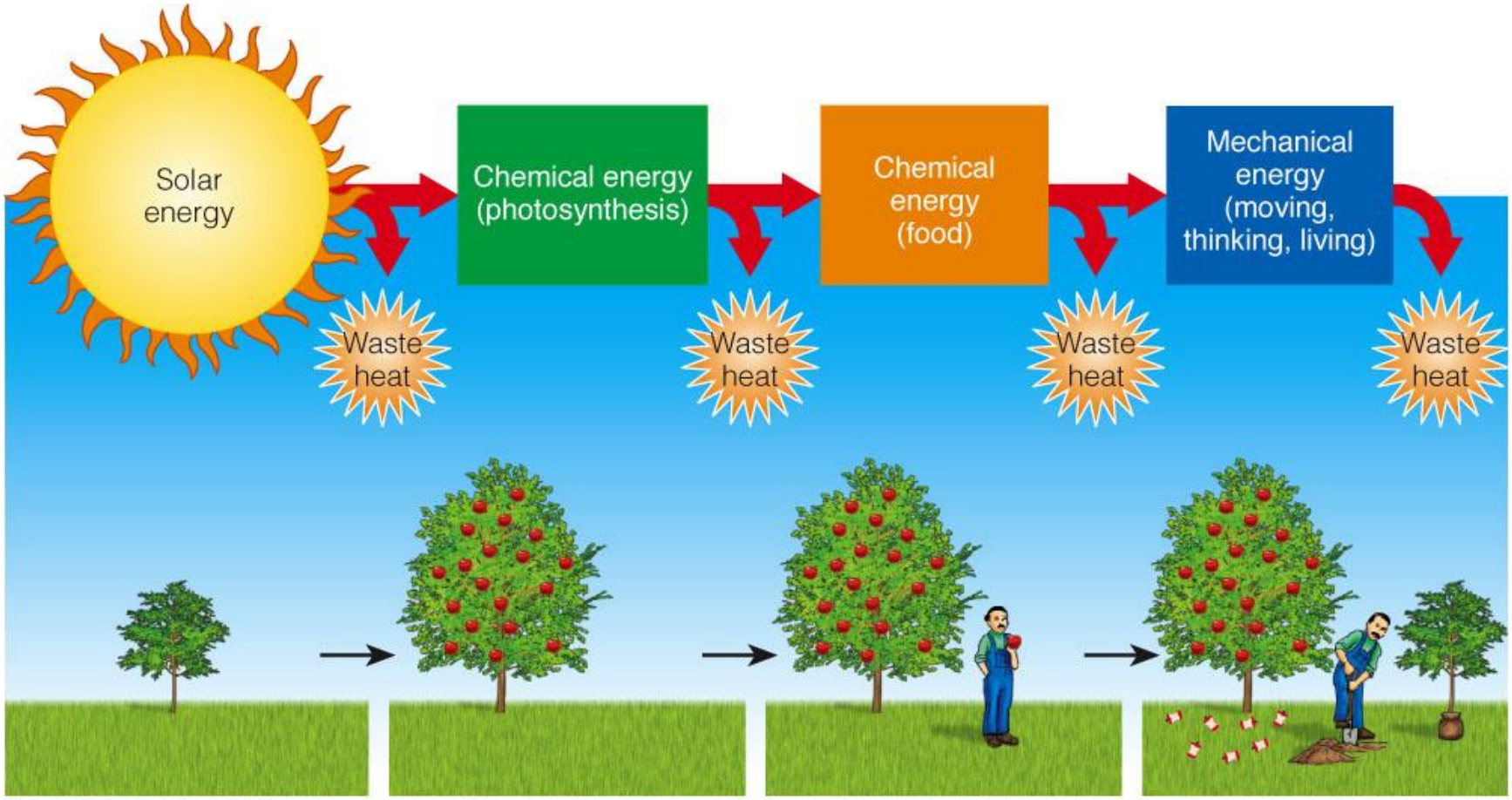
Solar Capital



Visible light comprises most of the spectrum of electromagnetic radiation emitted by the sun!

Energy Transformation



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Energy Transformation

- When driving your car, only 6% of the high quality energy available in its gasoline fuel actually moves the car.
- 94% of the high quality energy is released as low quality heat!
- 94% of the money you spent on gasoline is wasted!!

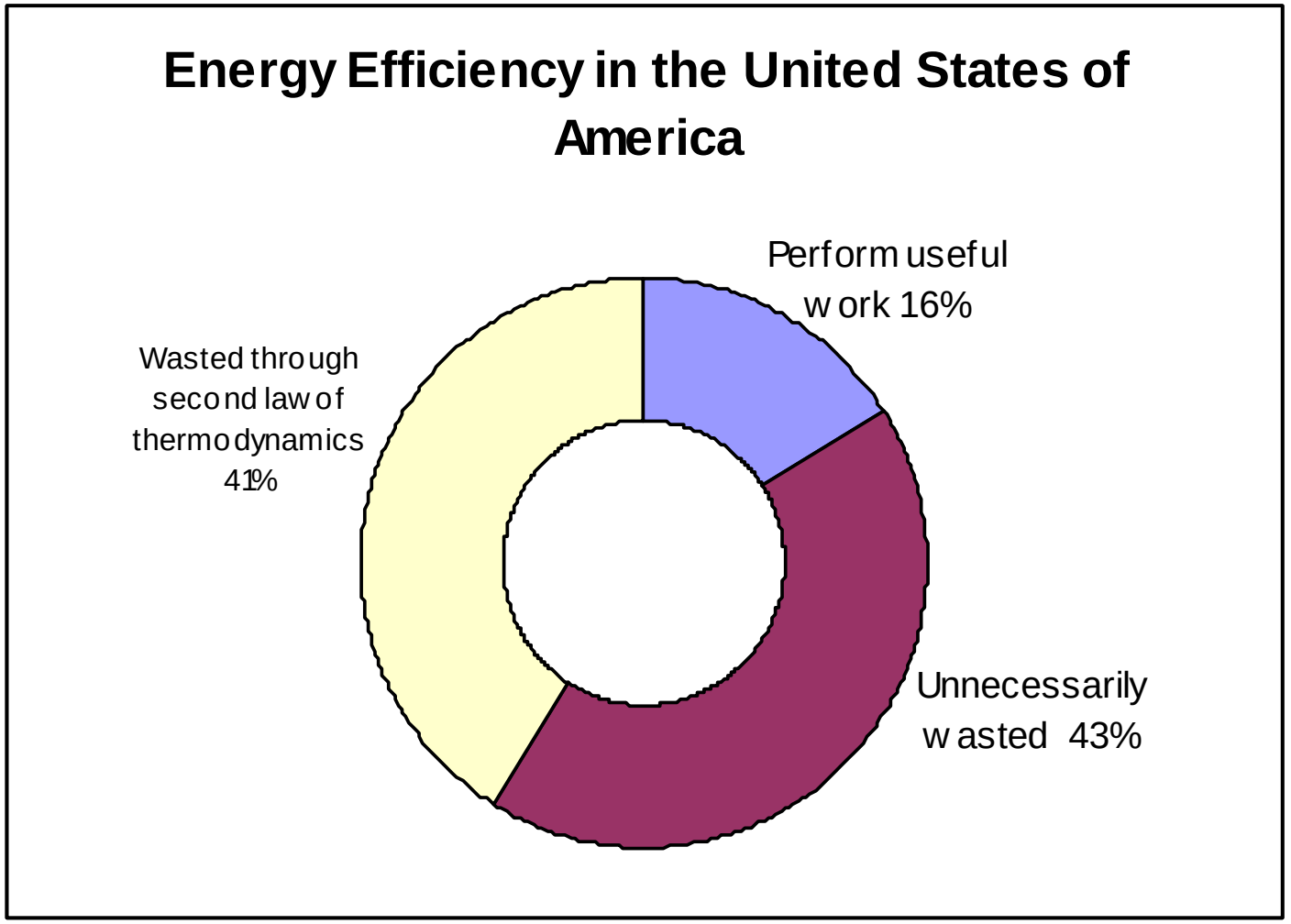
Energy Efficiency

- Also known as energy productivity
- A measure of how much useful work is accomplished by a particular input of energy into a system

Energy Efficiency

Plenty of room for improvement!!

Stop wasting energy!!



Energy Quality

- A measure of an energy source's capacity to do useful work; The amount of energy available that can perform useful work
  - **High-quality energy:** concentrated; has a high capacity to do useful work
    - Examples: Very high-temperature heat, concentrated sunlight, high velocity wind, energy from burning fossil fuels
  - **Low-quality energy:** dispersed; has little capacity to do useful work
    - Examples: Amount of heat stored in a large amount of matter (The Atlantic for example)

Energy

In terms of renewability:

- **Perpetual**

  Solar, wind, hydroelectric

- **Renewable**
- **Renewable, but not on human timescales**

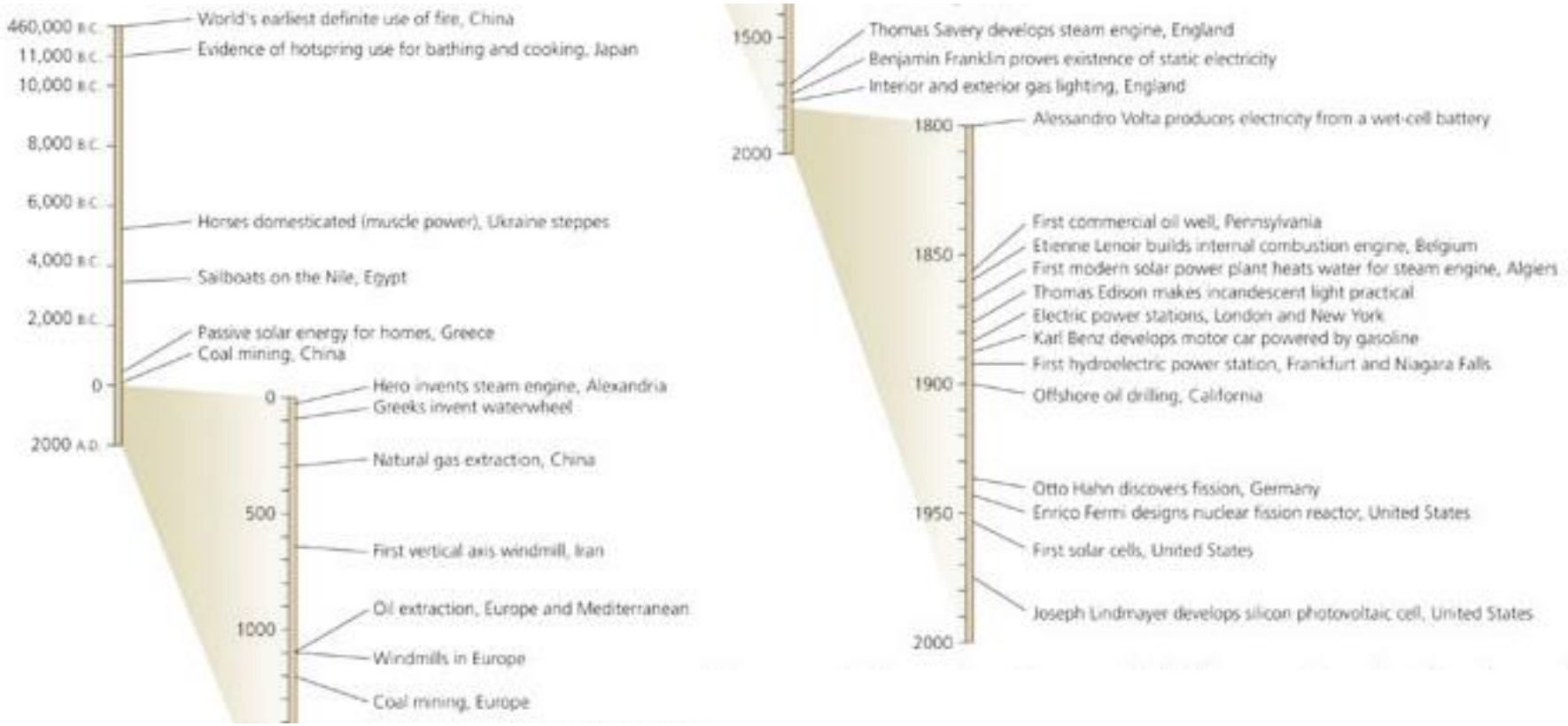
  Fossil fuels, nuclear

  Considered **non-renewable for practical purposes**

Solar Energy

- Direct and Indirect
- Direct solar energy produces several forms of renewable energy (Indirect solar energy):
  - Wind (Moving air masses heated by the sun)
  - Hydropower (Flowing water kept fluid by the sun)
  - Biomass (Solar energy converted to chemical energy and stored in plants)

History of Human Energy Use



History of Human Energy Use

- Muscle power
- Fire as first step along the energy path
- Muscle power; domesticated wild animals
- Wind and flowing water
- Steam engine operated on wood; deplete forests
- Coal, then oil
- Nuclear energy
- Energy crisis

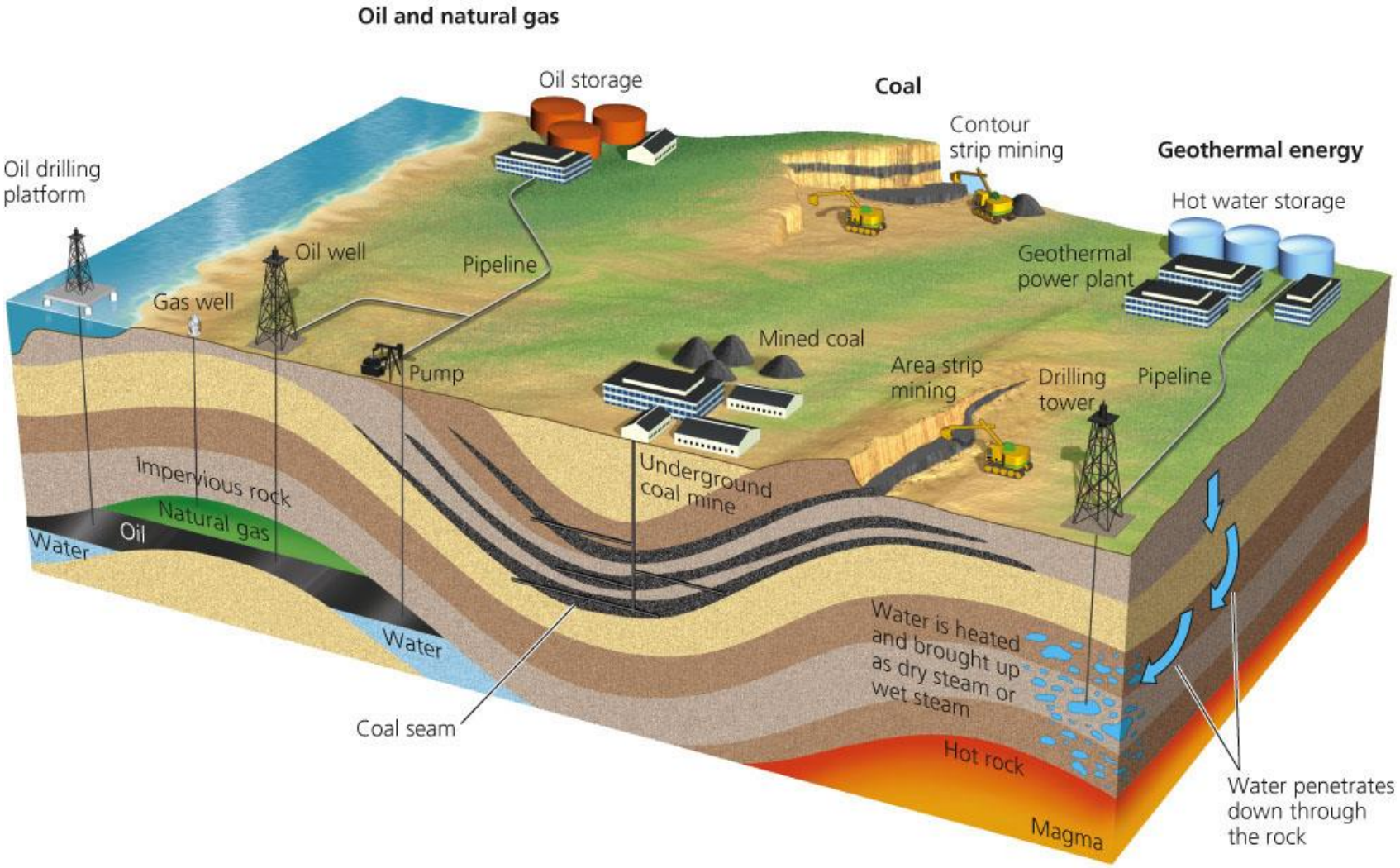
History of Human Energy Use

- 2000 kilocalories per person per day for hunters and gatherers
- Additional 600,000 kilocalories per person per day for modern humans; mainly used by machines and systems that maintain our complex lifestyle

Sources of Energy

- Commercial energy: energy sold on the market
  - Non-renewable sources: mainly carbon-containing fossil fuels (oil, coal, natural gas) – We live in a fossil fuel era!!
  - Renewable sources: wind, hydropower, biomass, geothermal

Sources of Energy



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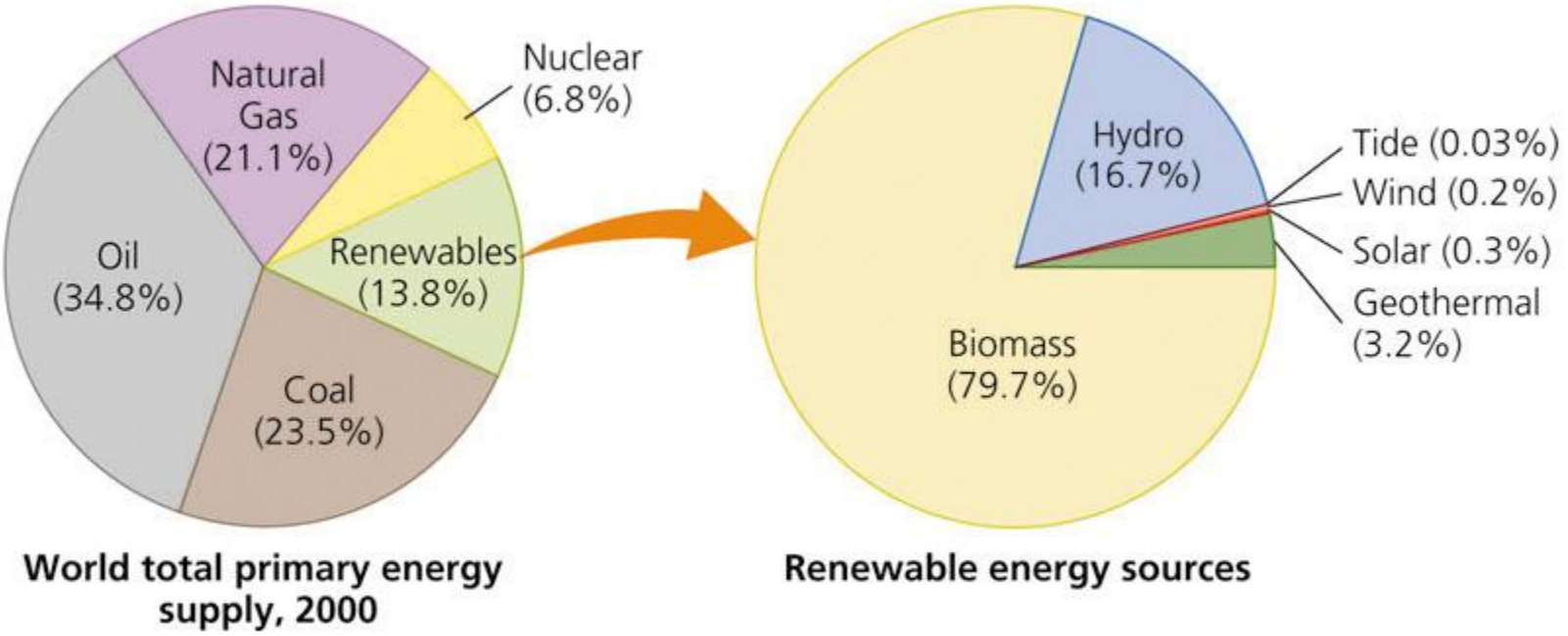
Sources of Energy

Table 17.1 Energy Sources We Use Today

Energy source	Description	Type of energy
Crude oil	Fossil fuel extracted from ground	Nonrenewable
Natural gas	Fossil fuel extracted from ground	Nonrenewable
Coal	Fossil fuel extracted from ground	Nonrenewable
Nuclear energy	Energy from atomic nuclei of processed uranium mined from ground	Nonrenewable
Hydropower	Energy from running water	Renewable
Solar energy	Energy from sunlight directly	Renewable
Wind energy	Energy from the power of wind	Renewable
Geothermal energy	Earth's internal heat rising from core	Renewable
Biomass energy	Chemical energy stored in plant matter from photosynthesis	Renewable
Tidal and wave energy	Energy from tidal forces and ocean waves	Renewable

Sources of Energy



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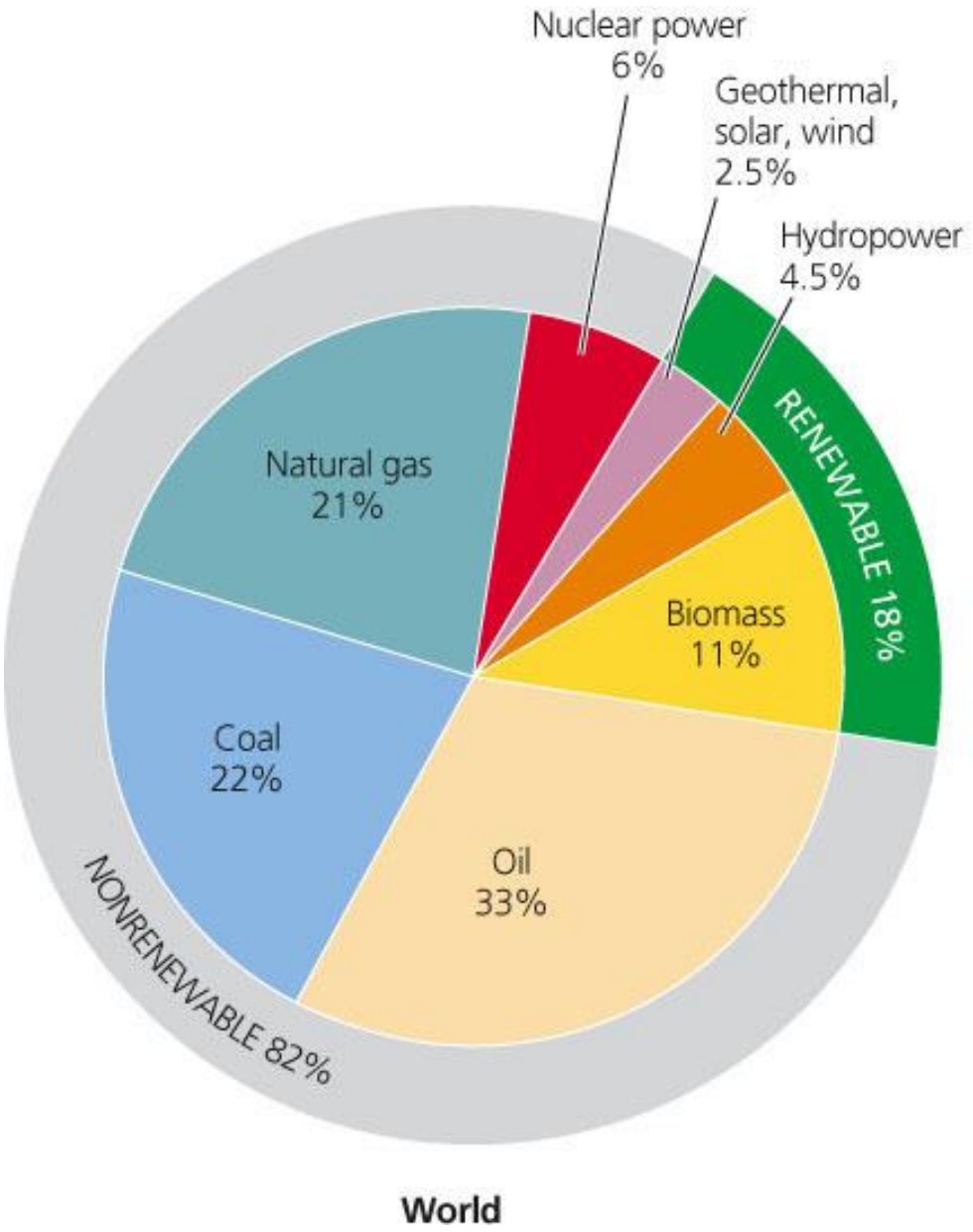
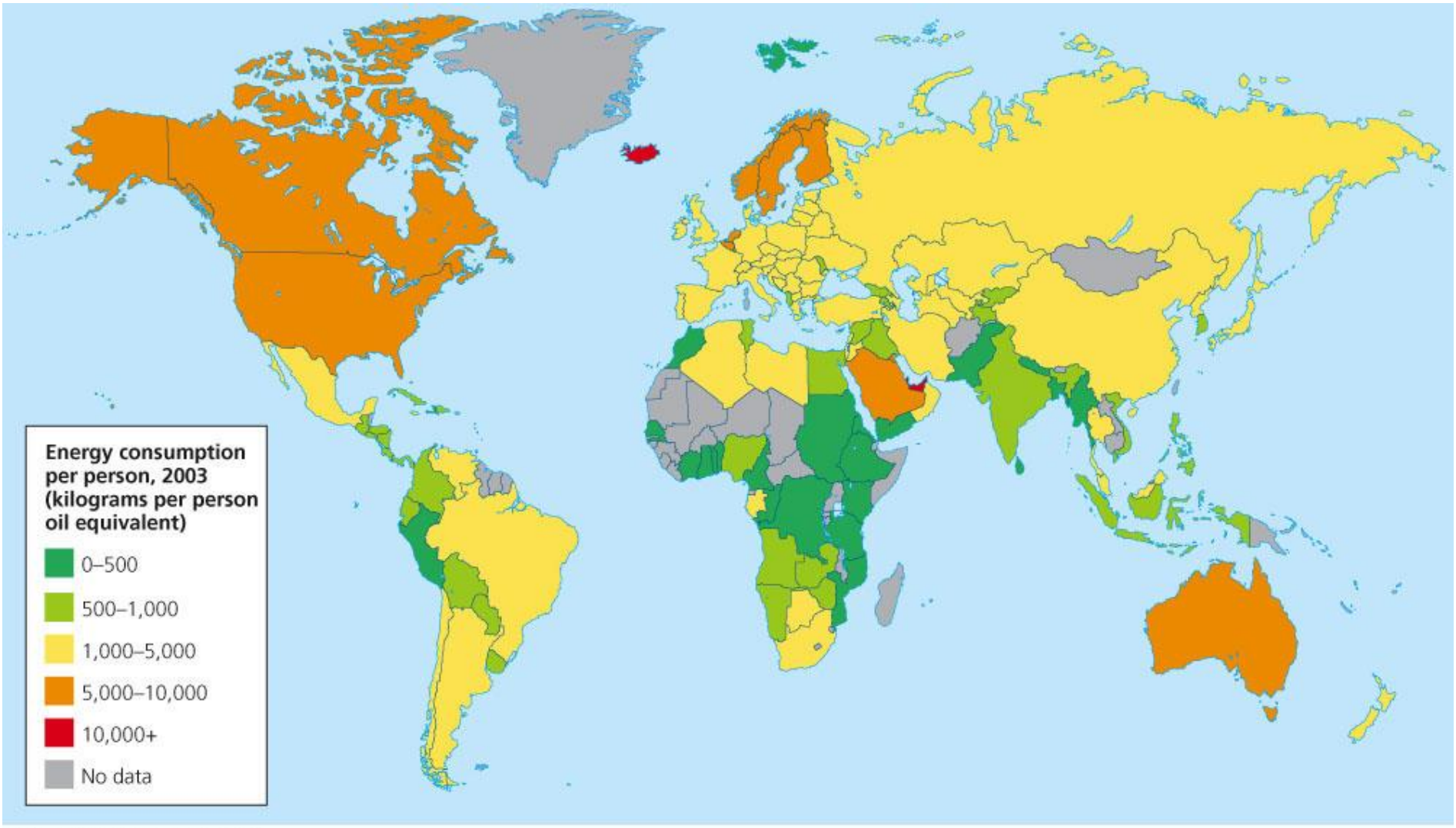
Sources of Energy



Energy Consumption



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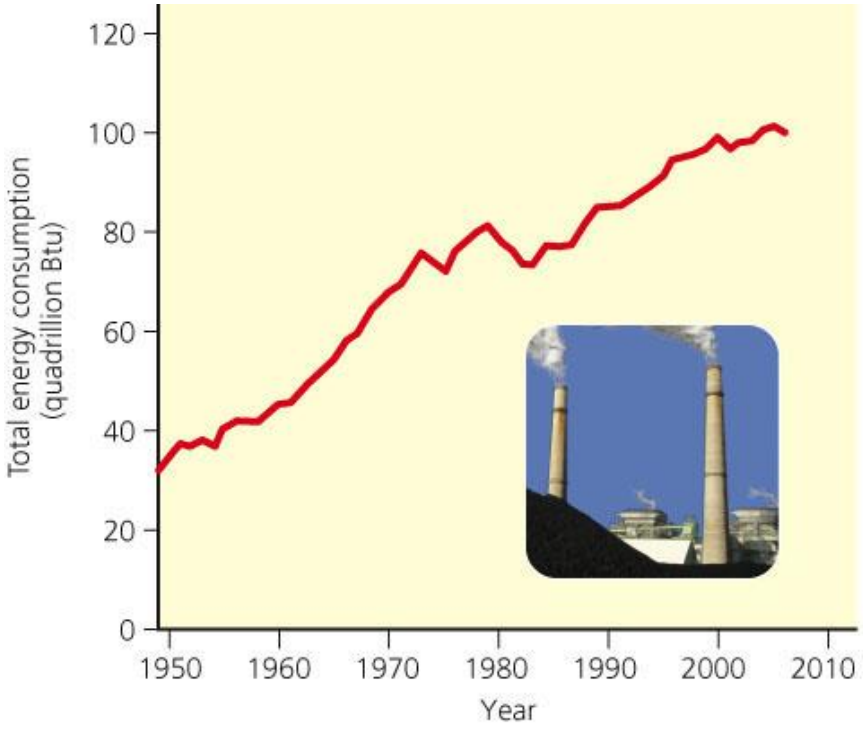
Energy Consumption



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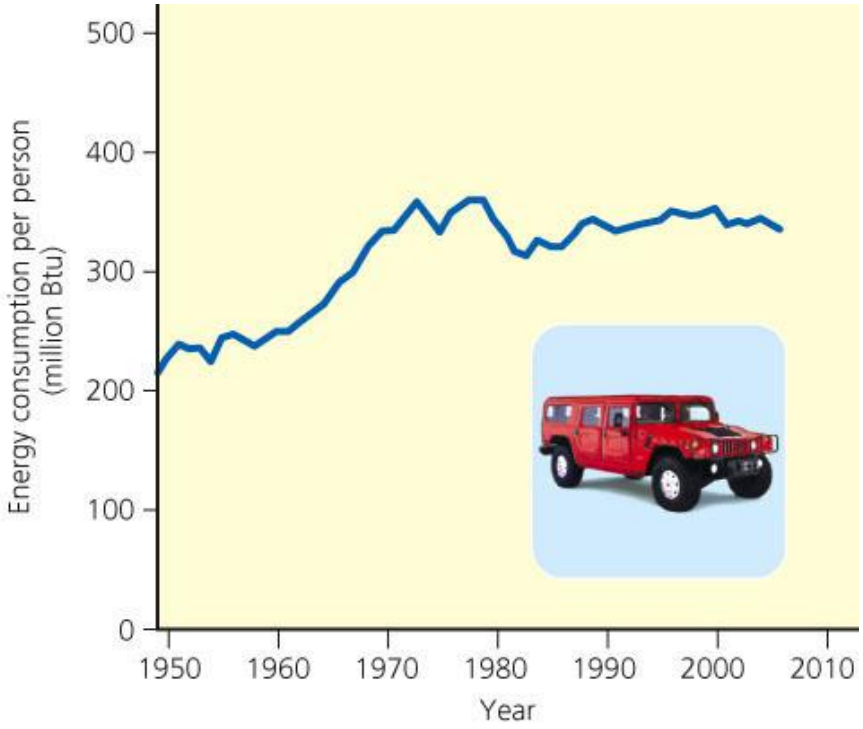
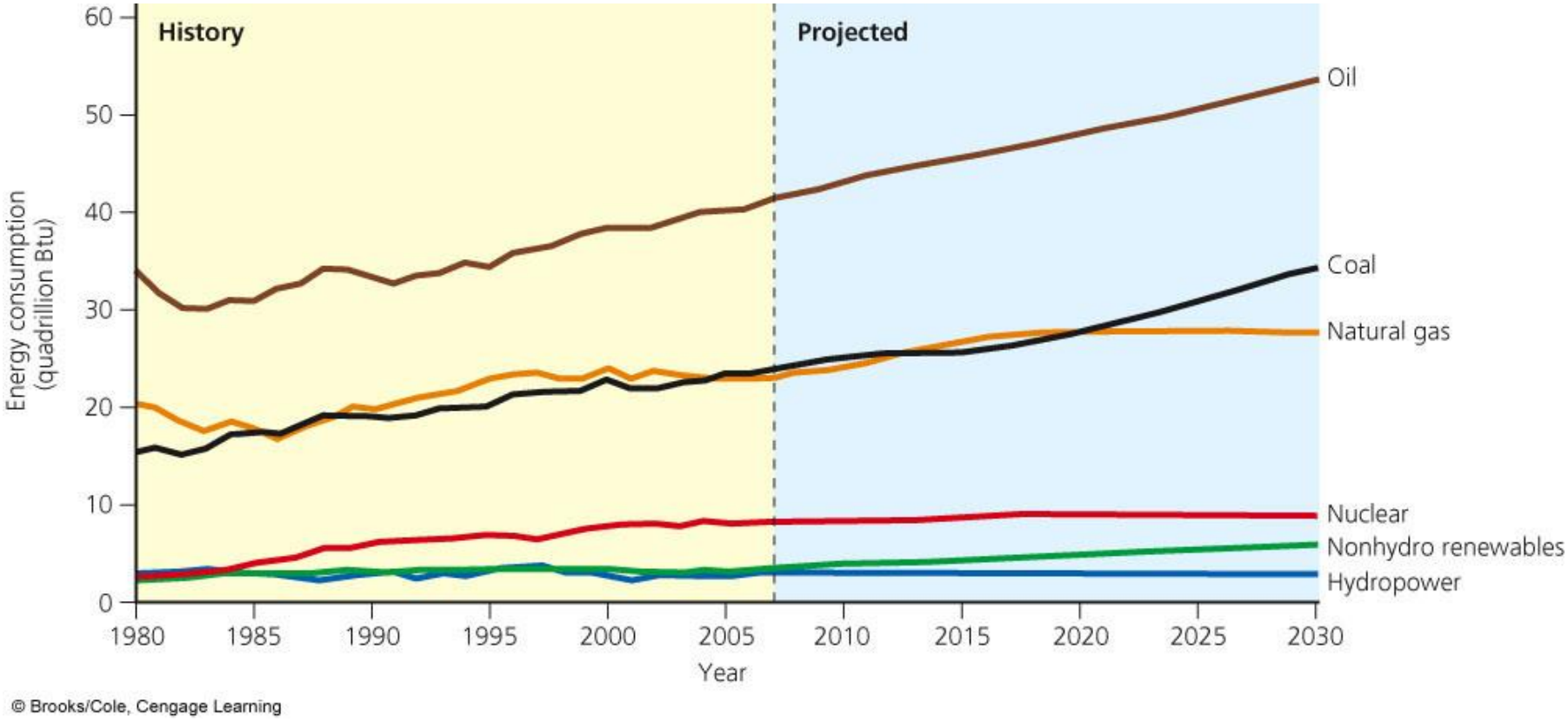


Energy Consumption



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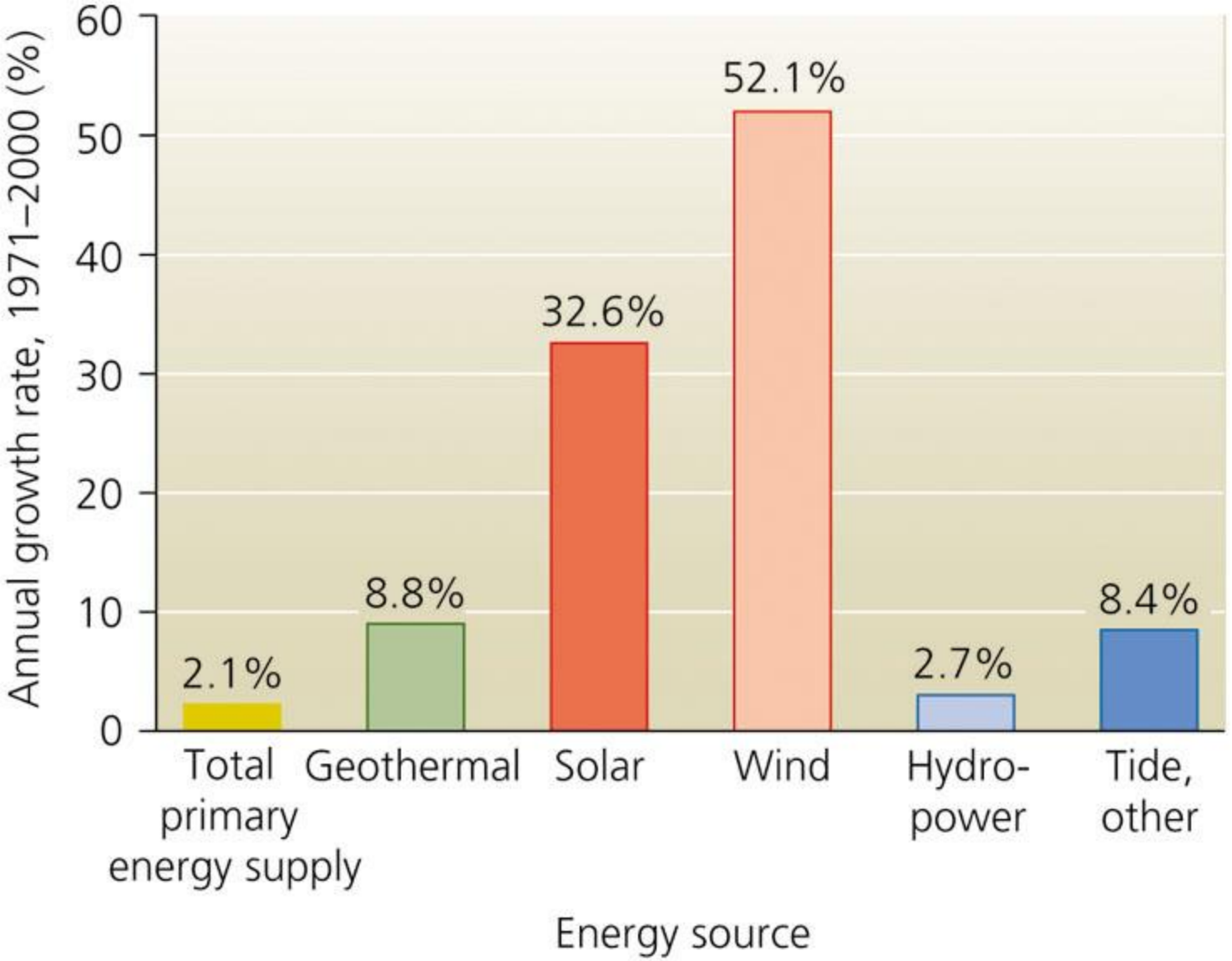
Energy Consumption



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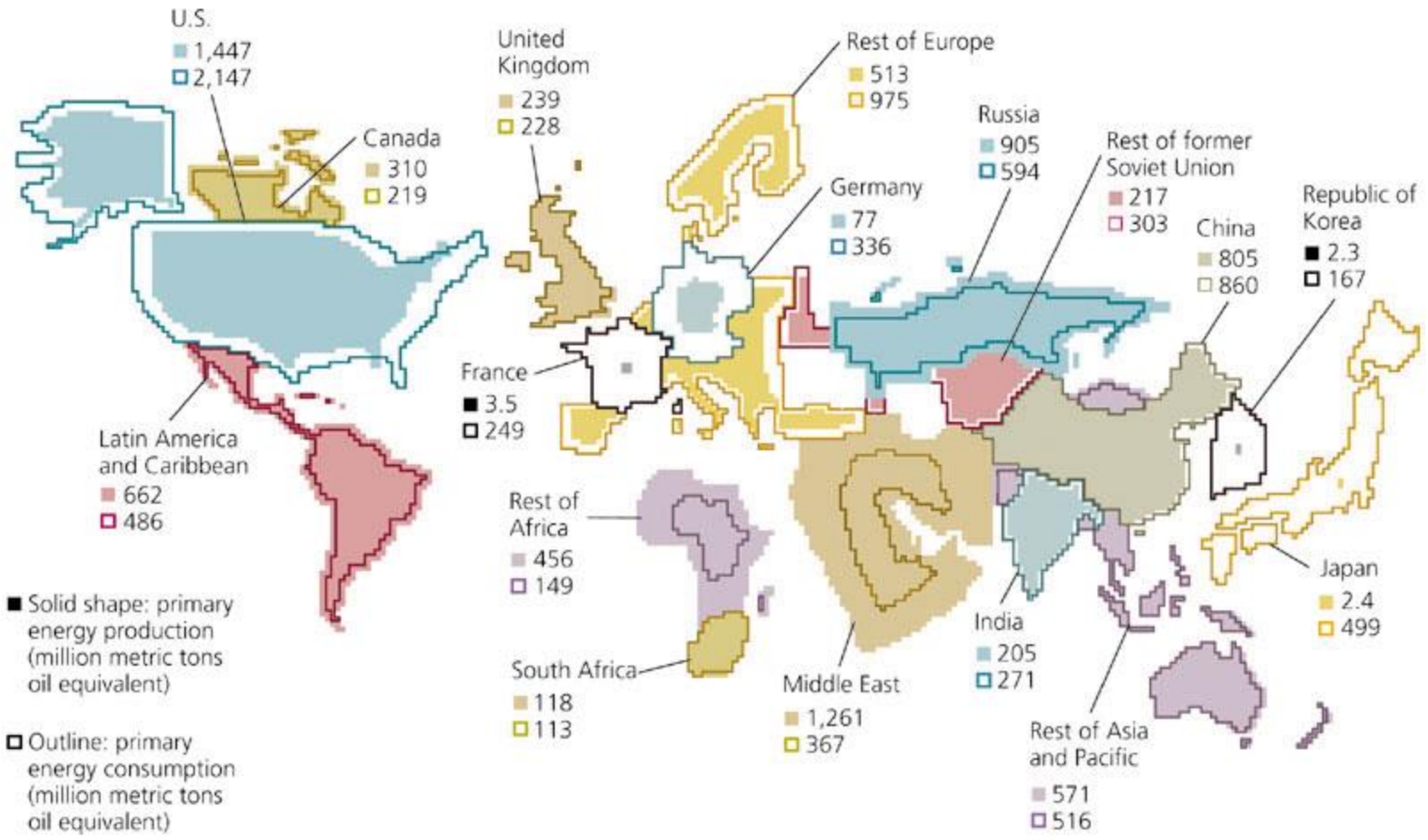
Energy Consumption



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Evaluating Energy Resources

- Supplies
- Environmental impact
- Amount of useful energy provided

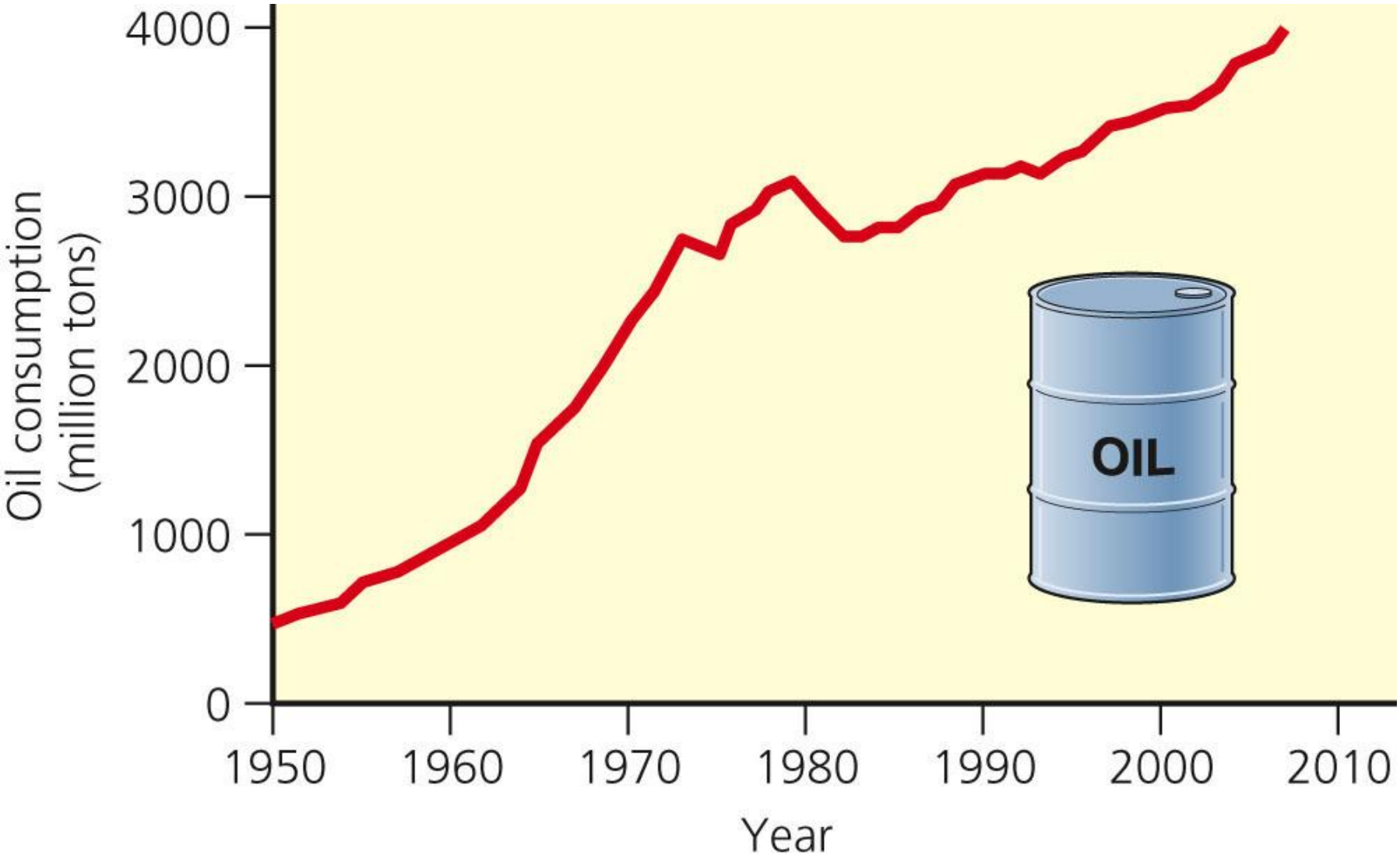
Evaluating Energy Resources

- Any energy resource with a low net energy will need government subsidies to compete in the marketplace with high net energy resources.

Fossil Fuels

- Dominant source of power!!
- High energy content
- Efficient to burn, ship and store

Fossil Fuels



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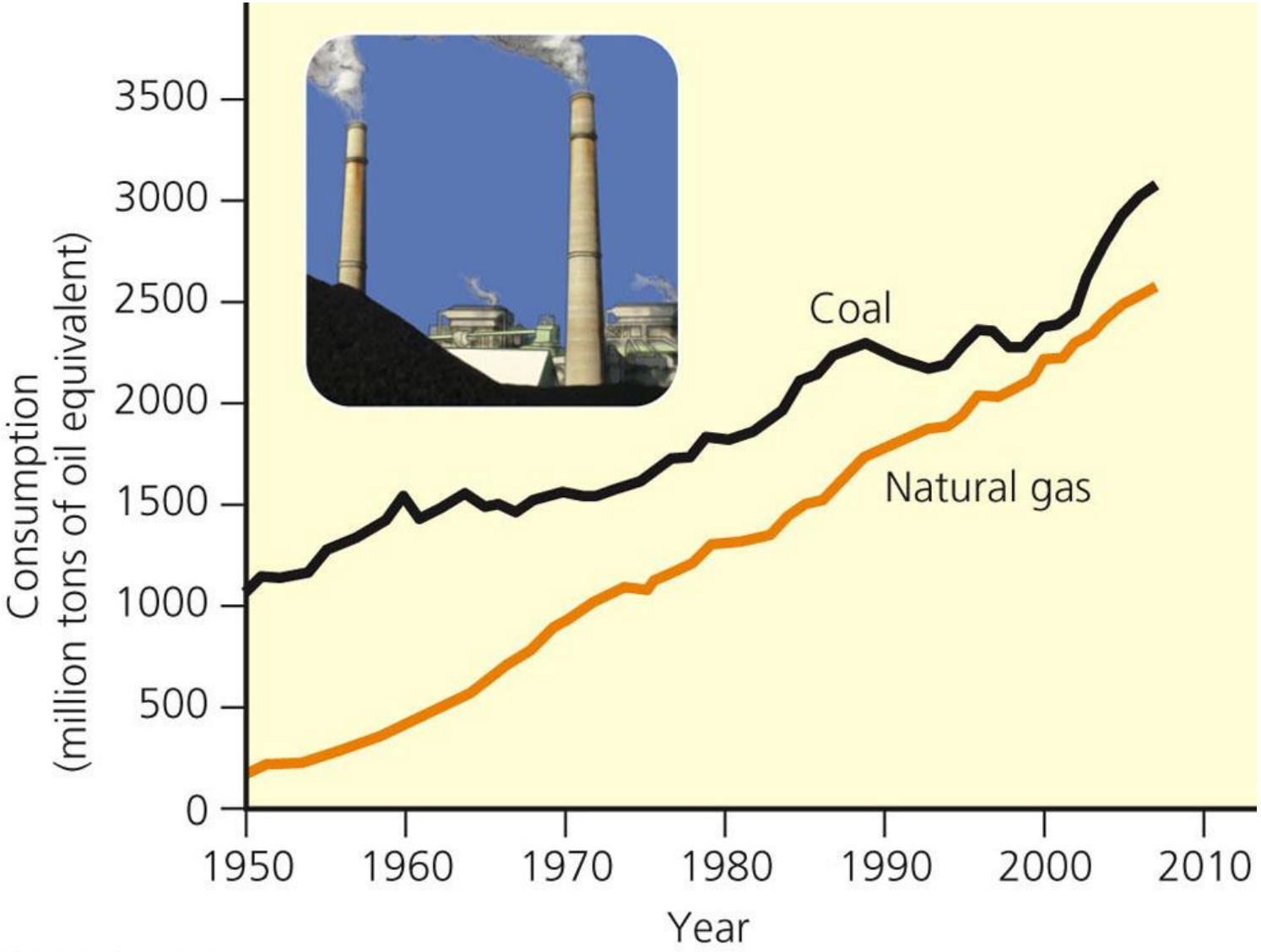
Fossil Fuels



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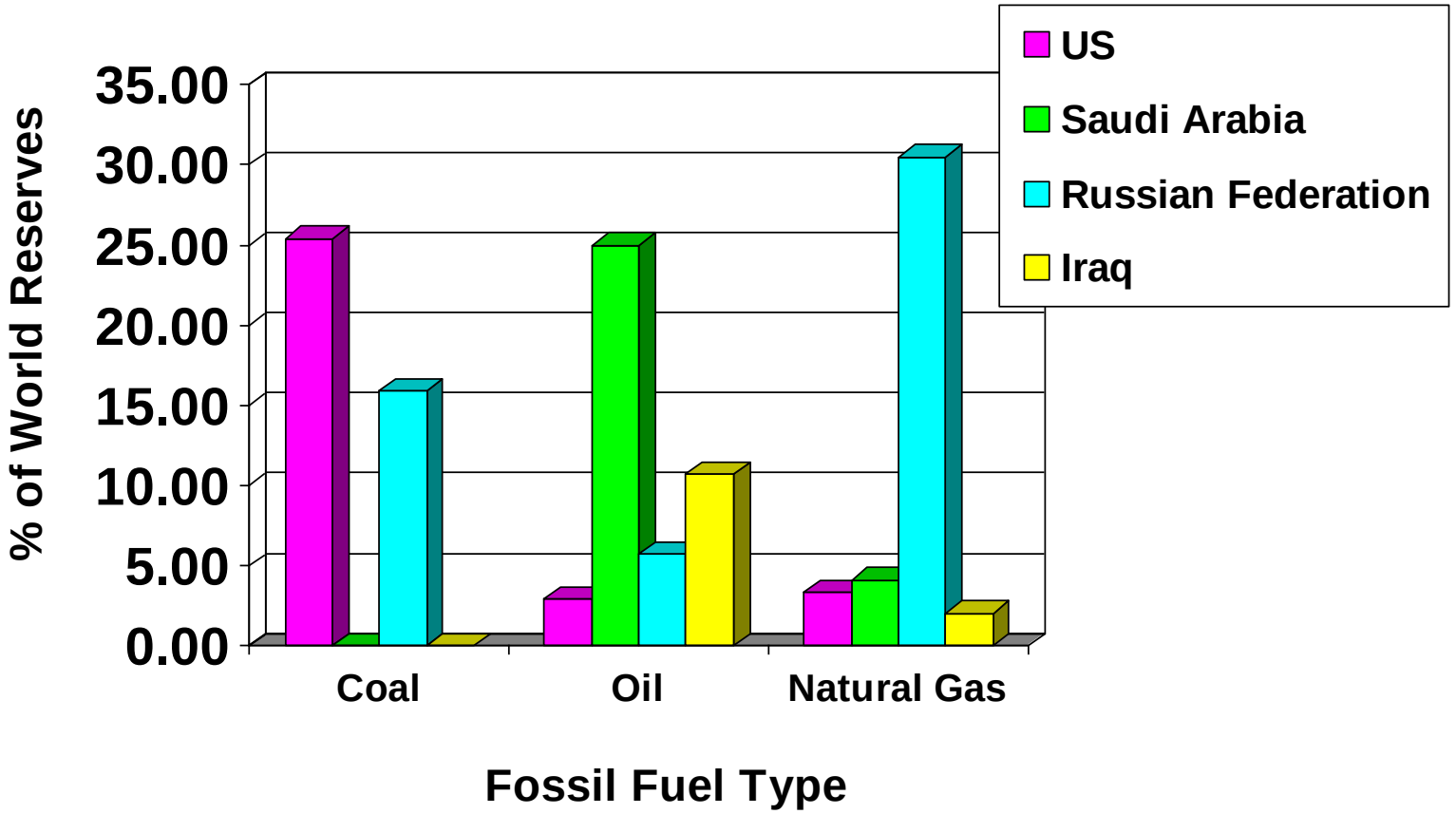
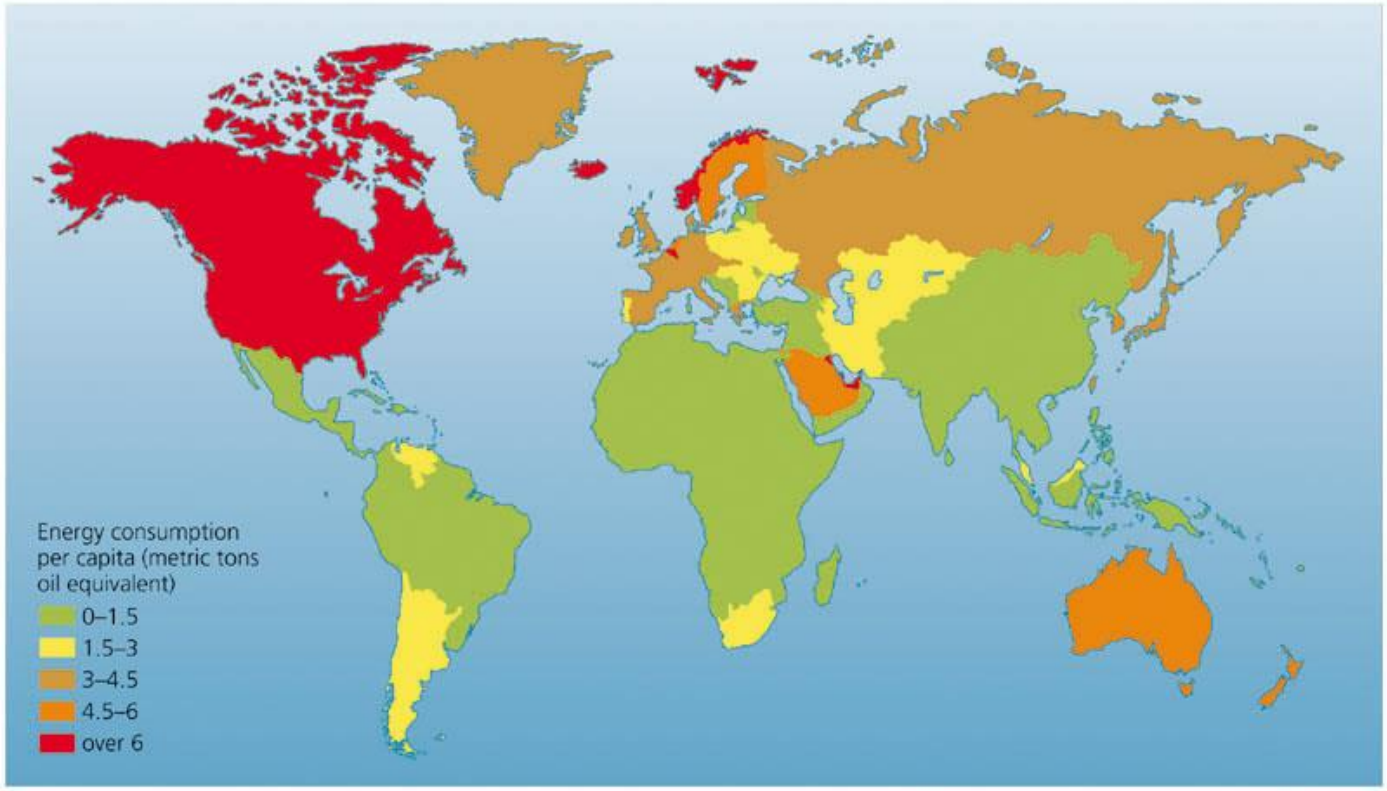
Fossil Fuels
Unevenly Distributed!!



Fossil Fuels

Per capita consumption varies!!

Developed countries use more than developing countries!!



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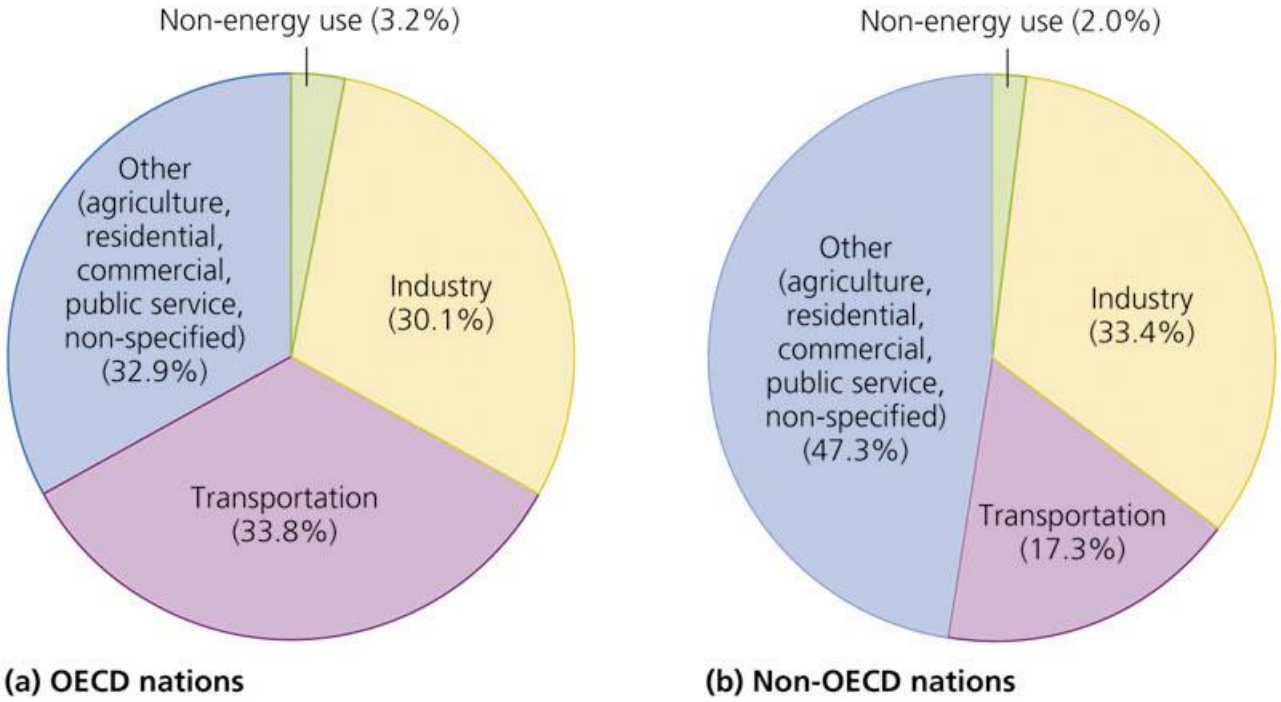
Fossil Fuels

Different profiles of energy use!!



Mainly Developed Nations

Mainly Developing Nations

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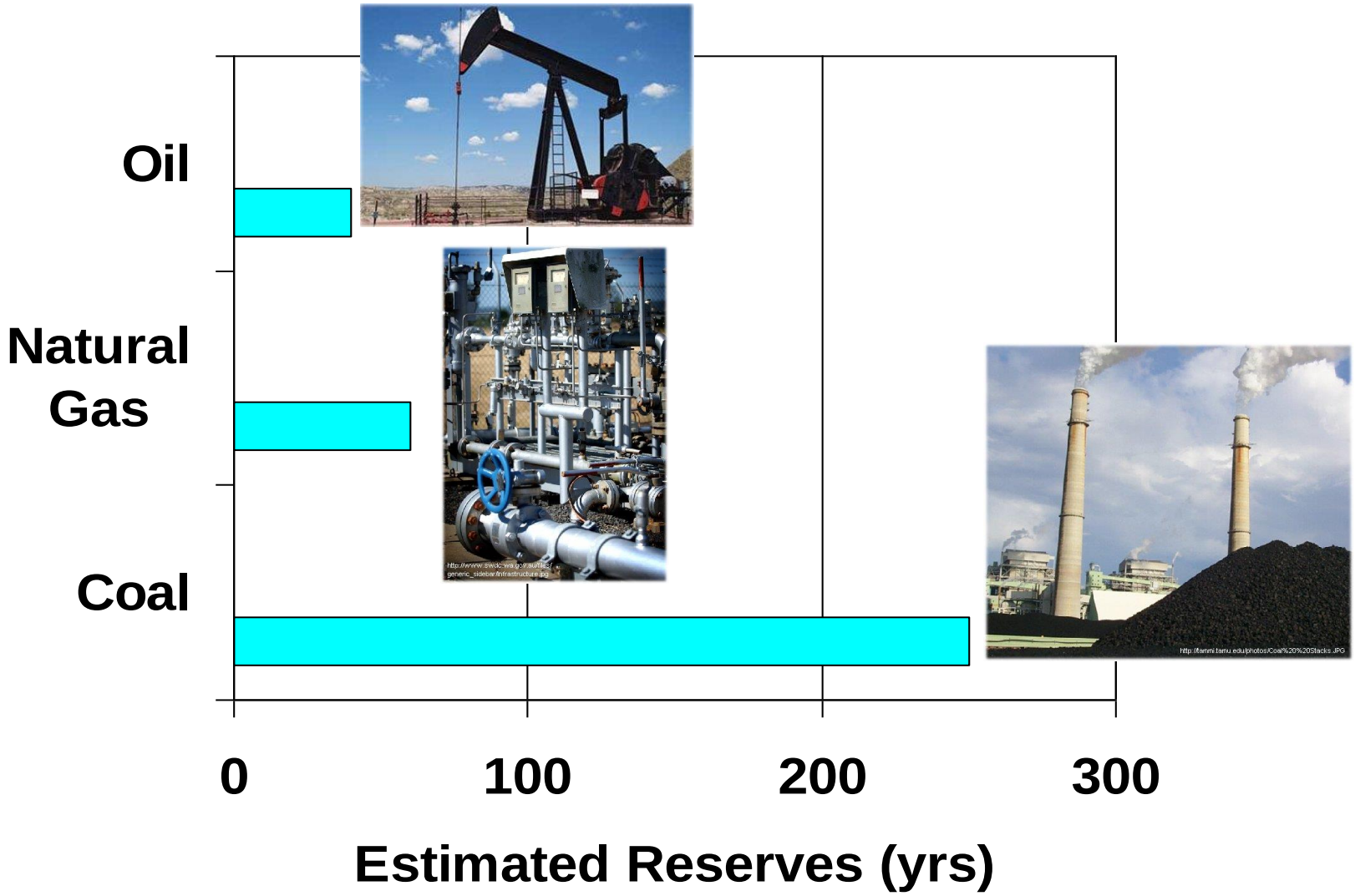
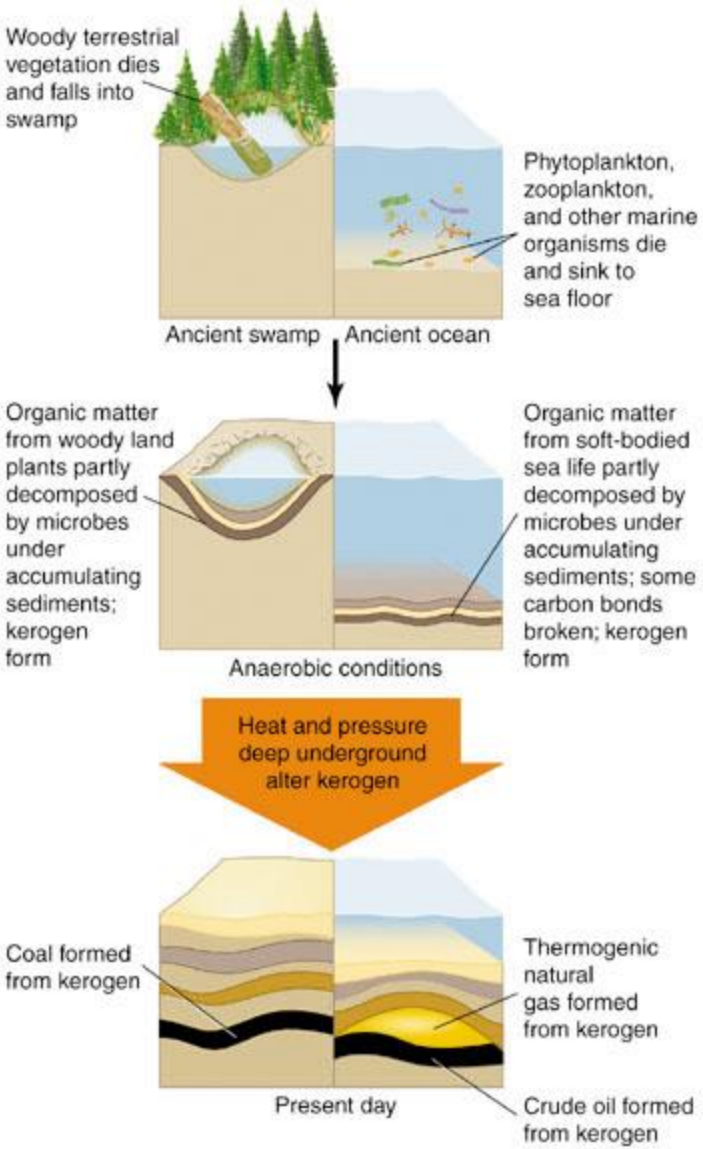
OECD = Organization for Economic Cooperation and Development

Fossil Fuels

Decreasingly available!!



Fossil Fuel Formation



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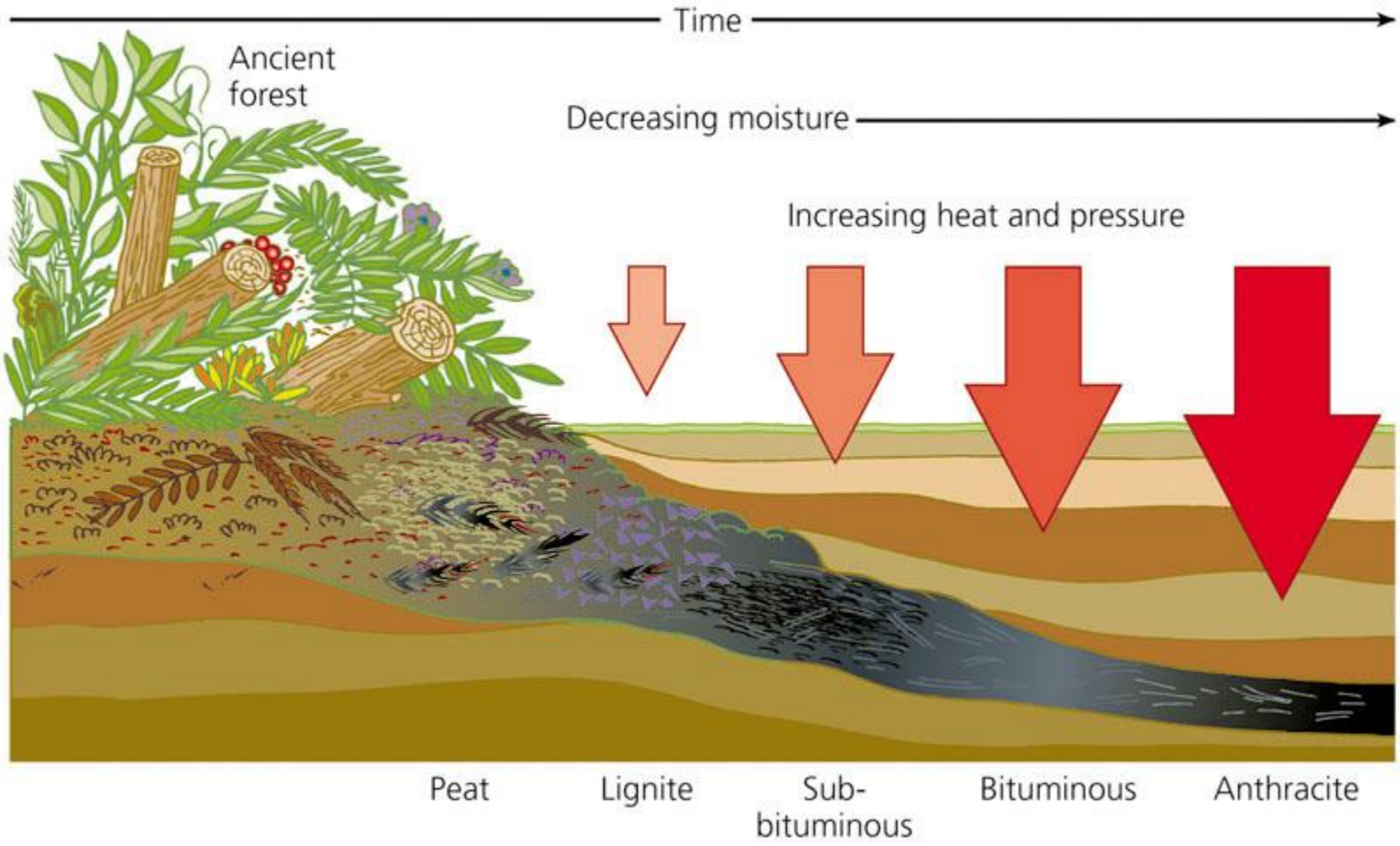
Coal

- Most abundant fossil fuel
- Organic matter (generally woody plant material) compressed under very high pressure to form dense, solid carbon structures
- Burned in 2100 power plants, generates 40% of the world's electricity

Coal



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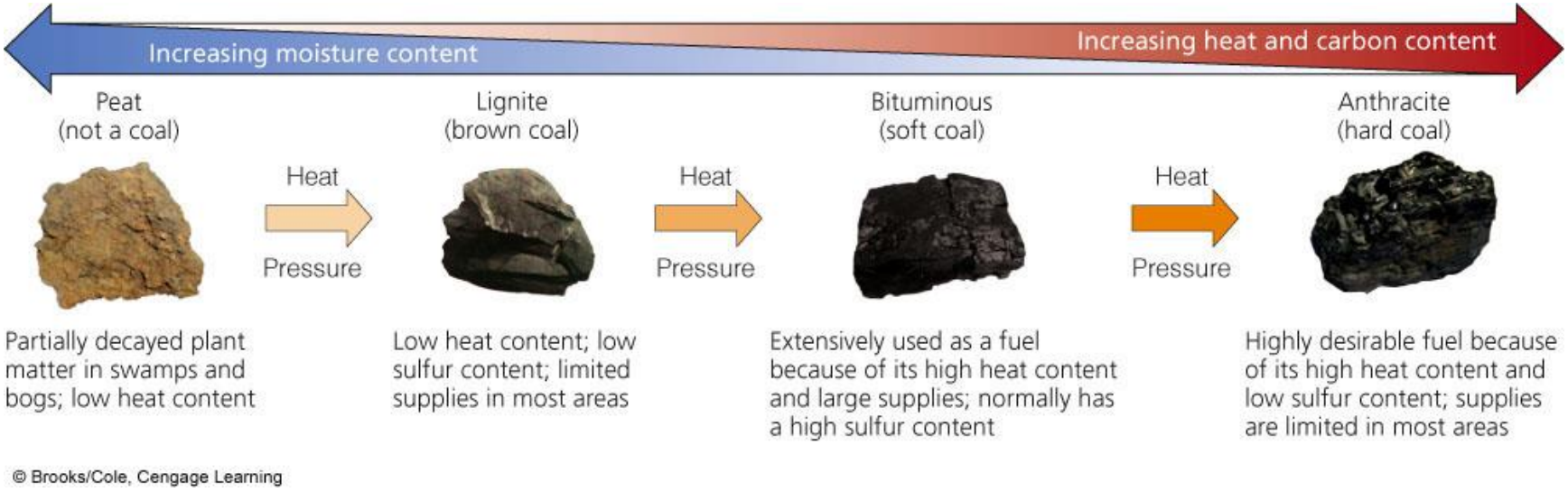
Coal



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Coal

Table 17.4 Top Producers and Consumers of Coal

Production (% world production)	Consumption (% world consumption)
China, 29.5	China, 27.7
United States, 24.0	United States, 23.1
Australia, 7.7	India, 7.5
India, 7.1	Japan, 4.4
South Africa, 5.3	Russian Federation, 4.1
Russian Federation, 4.8	Germany, 3.5
Poland, 3.0	Poland, 2.4
Indonesia, 2.7	Australia, 2.1
Germany, 2.3	South Korea, 2.0
Ukraine, 1.8	Ukraine, 1.6

Data from British Petroleum, Statistical review of world energy, 2003.

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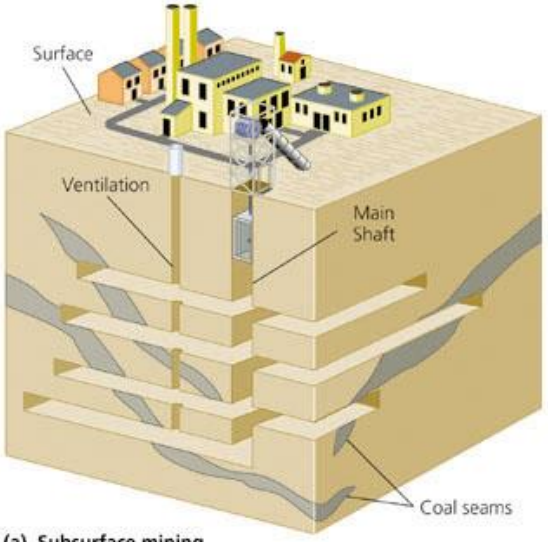
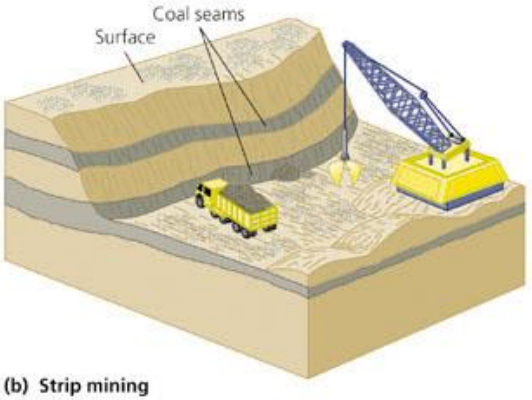
Coal

- Three largest coal-burning countries
  - China
  - United States
  - Canada

Coal



(a) Subsurface mining



(b) Strip mining

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Coal
Strip Mining

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Coal

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Coal

Severe air pollution!!

- Sulfur released as SO_2
- Large amount of soot
- CO_2
- Trace amounts of Hg and radioactive materials


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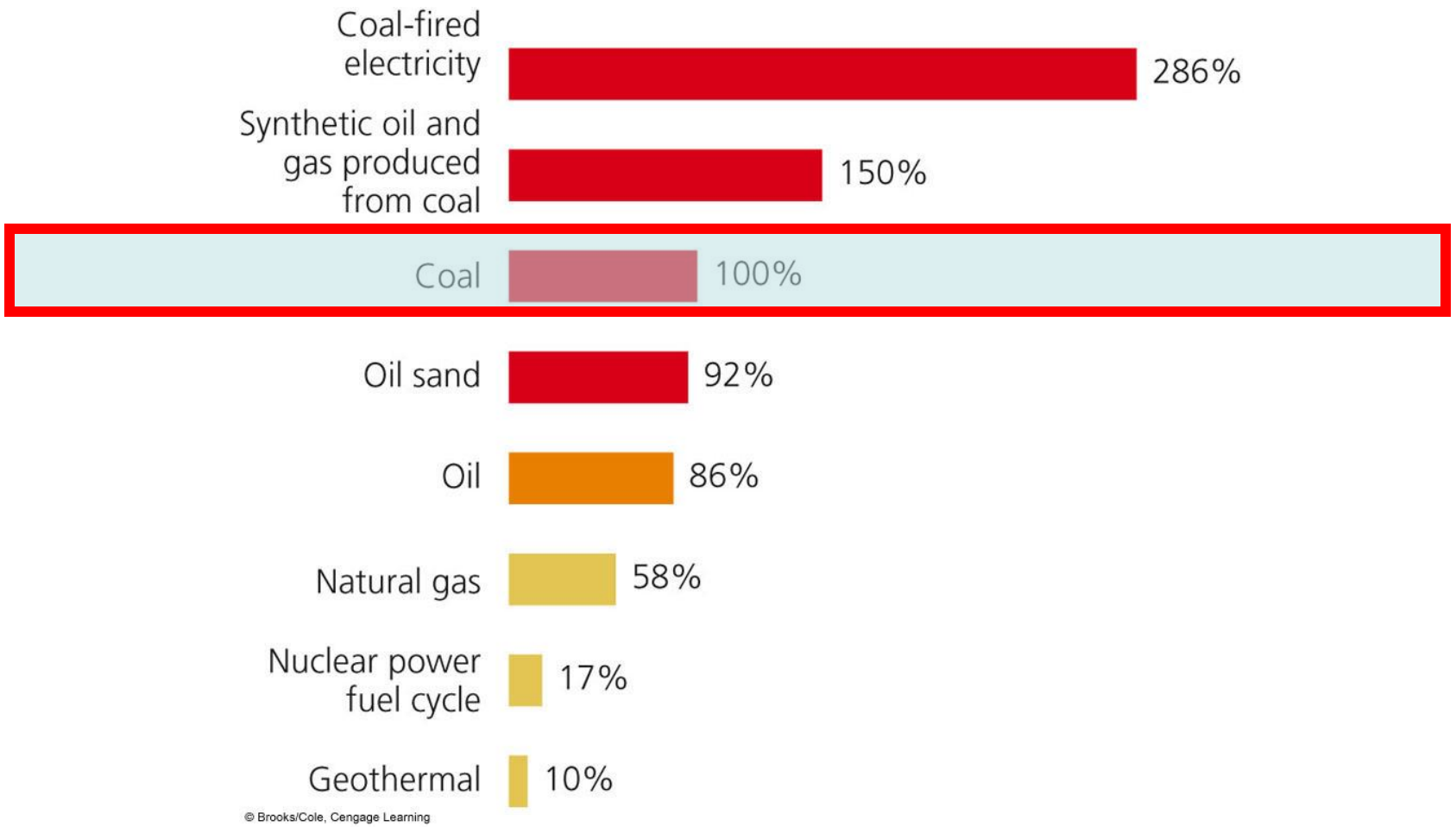
Coal

- Single biggest air polluter in coal-burning countries
- One-fourth of the annual CO_2 emissions
- Many opposed to new coal-burning power plants!!
- Environmentalists call for
  - Taxation on carbon dioxide production by power plants.
  - Cleaner coal-burning plants.

CO_2 Emissions Per Unit of Electrical Energy Produced for Energy Sources, expressed as % of emissions released by burning coal directly



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

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Coal

- **Conversion of solid coal to**
  - **Synthetic natural gas (SNG)** by **coal gasification**
  - Methanol or synthetic gasoline by **coal liquefaction**
- Are there benefits to using these synthetic fuels?

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

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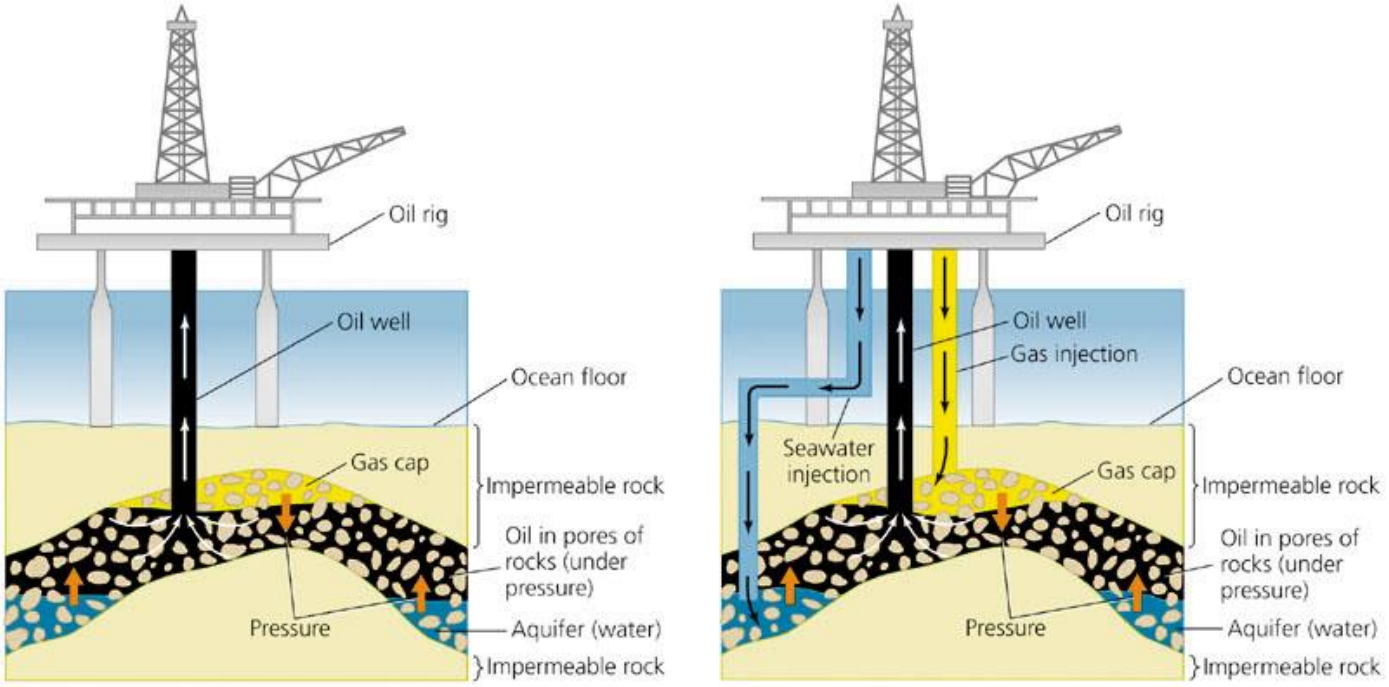
Oil

- Also known as crude oil, conventional oil, light oil or petroleum
- Most used fuel since the 1960s
- Accounts for ca. 40% of the world’s commercial energy consumption

Oil



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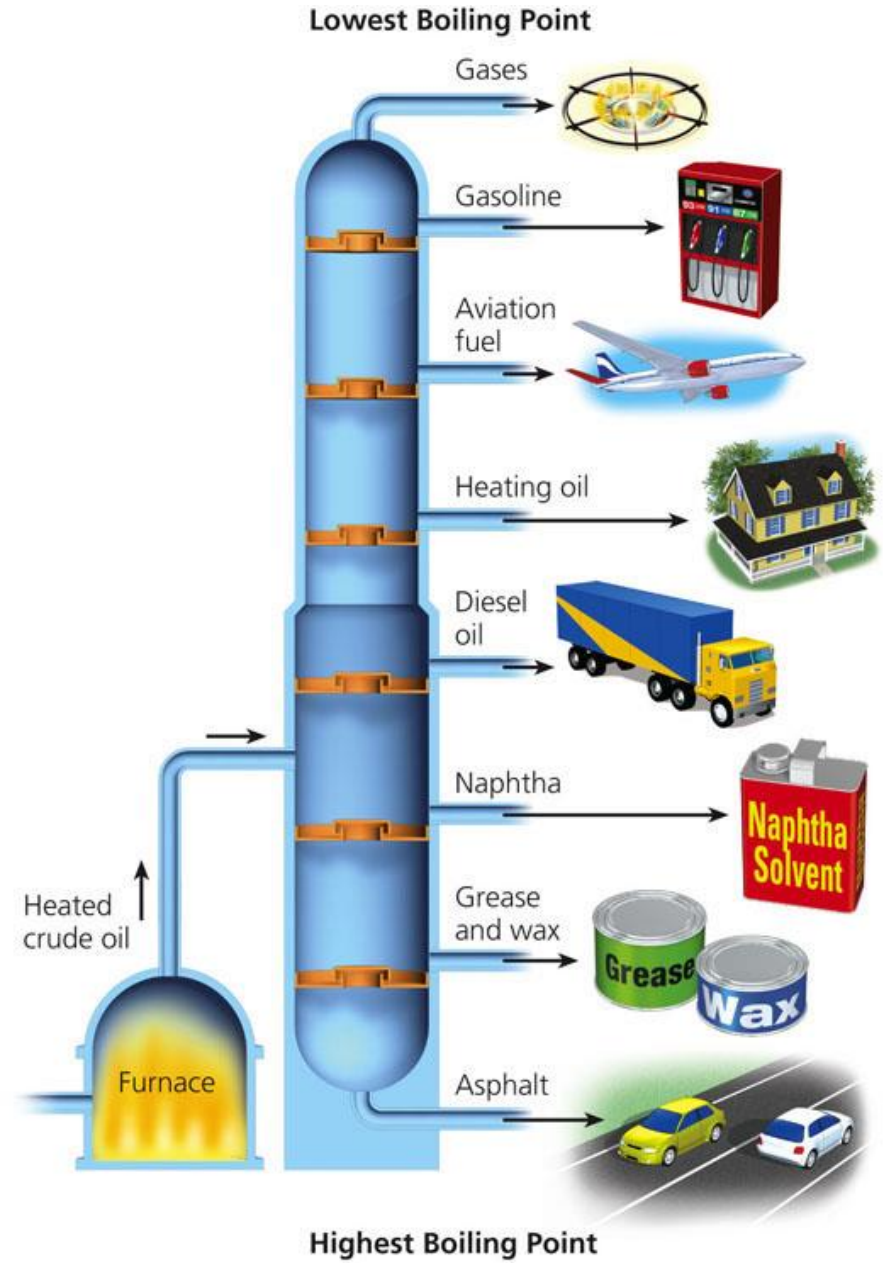

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Petrochemicals: products of oil distillation

Oil

Saudi Arabia 13.1

Russia 11.9

USA 8.5

Iran 5.2

Mexico 4.9

China 4.5

Venezuela 4.0

Canada 3.8

Norway 3.9

UAE 3.3

Table 17.3 Top Producers and Consumers of Oil

Production (% world production)	Consumption (% world consumption)
Saudi Arabia, 11.8	United States, 25.4
Russian Federation, 10.7	China, 7.0
United States, 9.9	Japan, 6.9
Mexico, 5.0	Germany, 3.6
China, 4.8	Russian Federation, 3.5
Iran, 4.7	South Korea, 3.0
Norway, 4.4	India, 2.8
Venezuela, 4.3	France, 2.6
Canada, 3.8	Italy, 2.6
Great Britain, 3.3	Canada, 2.5

Data from British Petroleum, Statistical review of world energy, 2003.

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USA 24.9

China 8.6

Japan 6.4

Russia 3.4

Germany 3.3

India 3.2

S. Korea 2.8

Canada 2.6

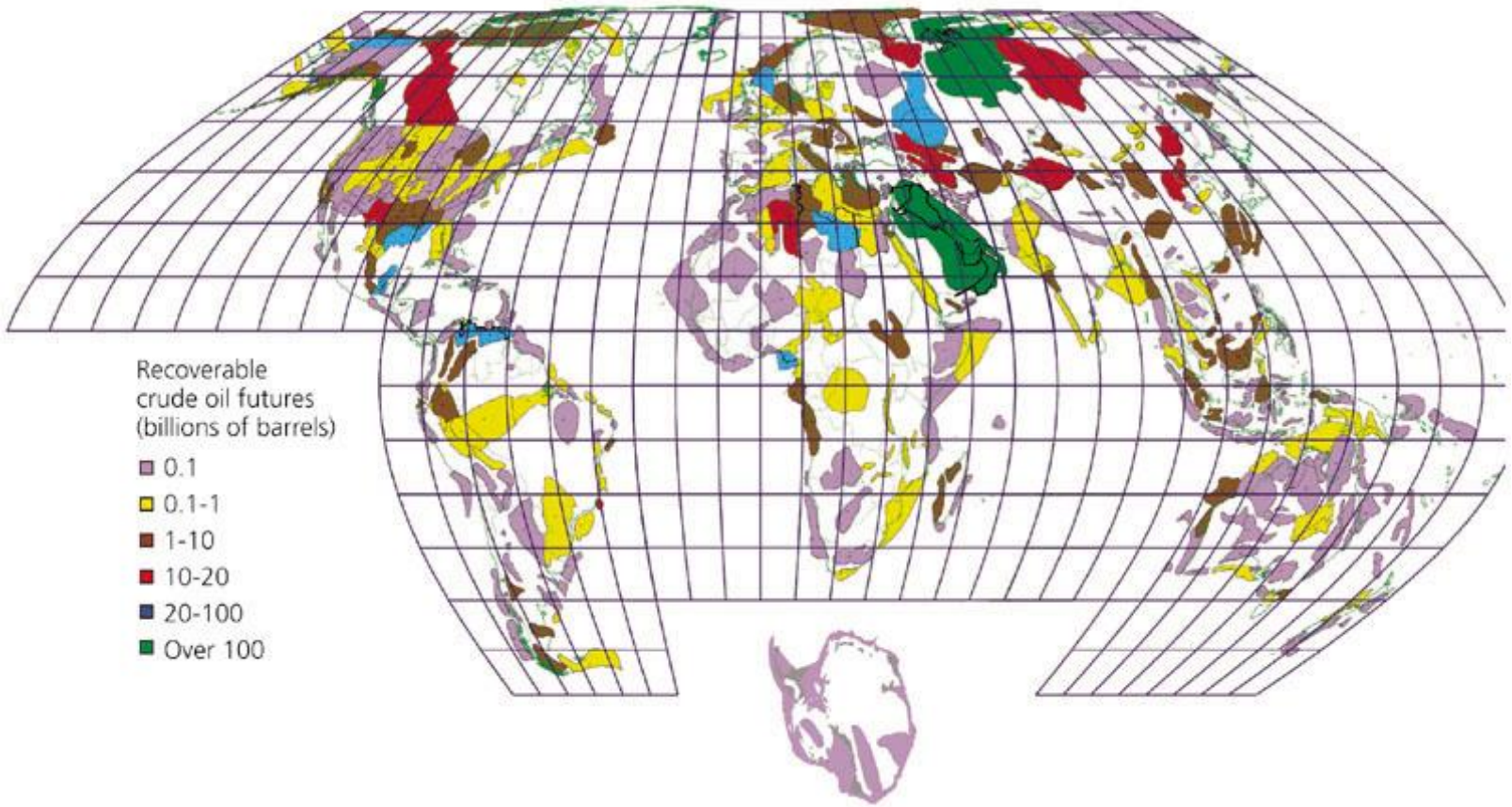
France 2.5

Italy 2.4

Oil

- 13 countries have at least 60% of the world's crude oil reserves
  - Saudi Arabia: 25%
  - Canada: 15%

Oil



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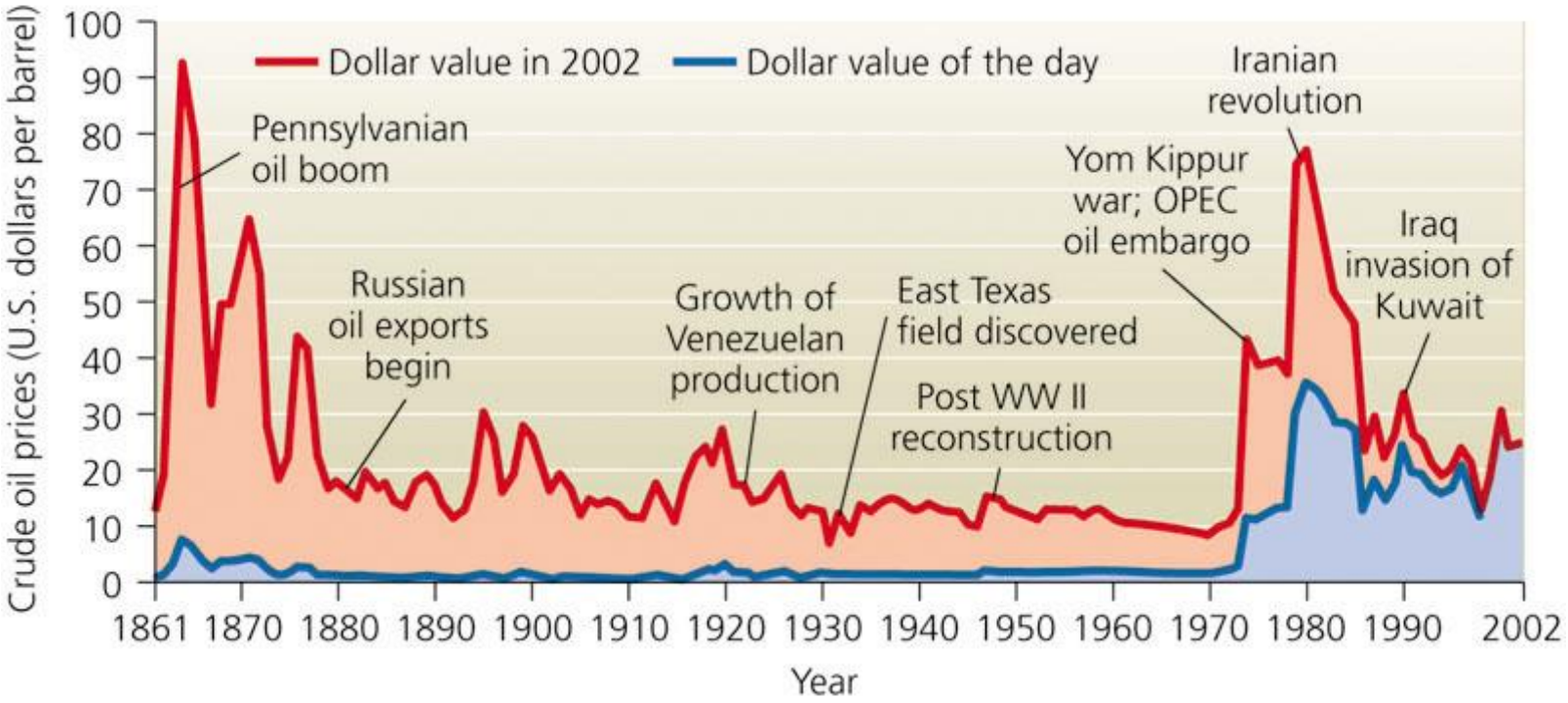
Oil

- Organization of Petroleum Exporting Countries (OPEC) controls oil prices!

Oil



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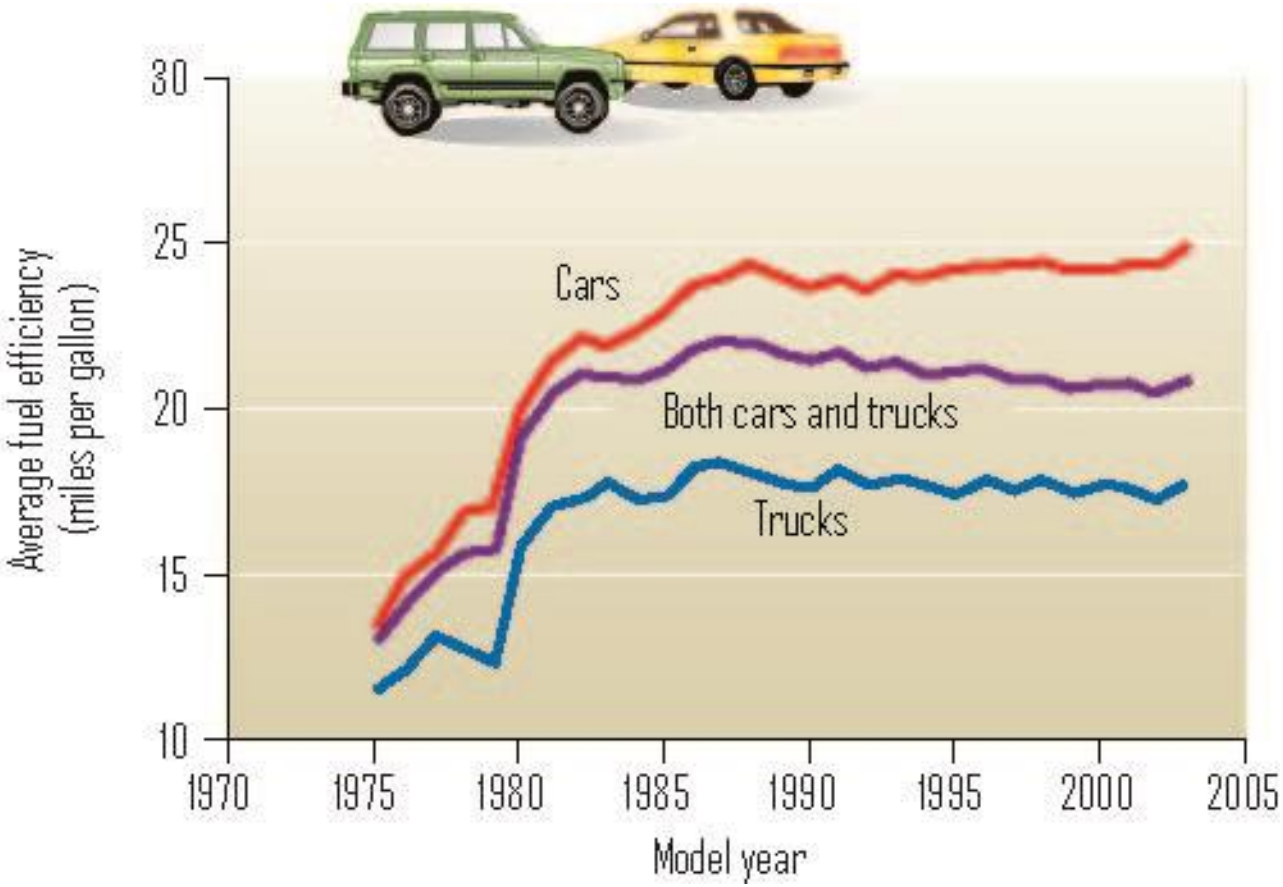
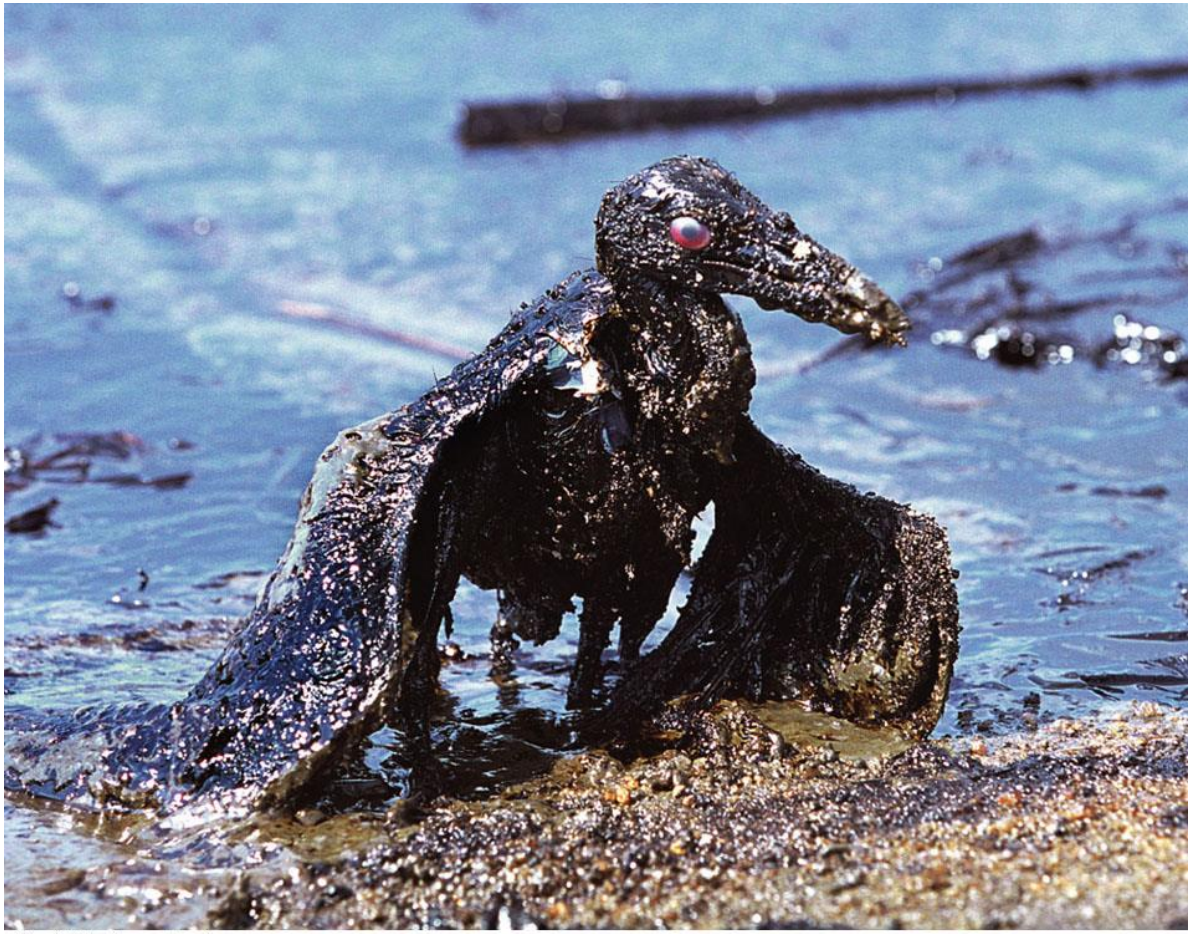
Oil

- Possible effects of steeply rising oil prices
  - Reduce energy waste
  - Shift to non-carbon energy sources
  - Higher prices for products made with petrochemicals
  - Higher food prices; buy locally-produced food
  - Airfares higher
  - Smaller more fuel-efficient vehicles
  - Upgrade of public transportation

Oil


30
25
20
15
10
Average fuel efficiency (miles per gallon)
Cars
Both cars and trucks
Trucks
1970
1975
1980
1985
1990
1995
2000
2005
Model year

Oil Spills



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Oil Spills

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

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Oil Sand or Tar Sand

Alberta Tar Sands

© Garth Lenz

Oil Sand or Tar Sand

- A mixture of clay, sand, water and a combustible organic material called **bitumen** – thick sticky heavy oil with high sulfur content
- The oil sands of Canada and Venezuela have more oil than in Saudi Arabia!!
- Extraction
  - Serious environmental impact: boreal forest clear cut; extraction requires large amount of water; air and water pollution
  - Low net energy yield: Is it cost effective?

Oil Shale
Becomes shale oil after distillation!

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Oil Shale

- Contain a solid combustible mixture of hydrocarbons called **kerogen**
- 72% of the world's reserve is in arid areas of western United States; there is a catch!
  - Locked up in rock
  - Lack of water needed for extraction and processing
  - Low net energy yield

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

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Natural Gas

- A mixture of gases; more than half is methane
- Lies above most reservoirs of crude oil
- The fastest-growing fossil fuel in use today
- One quarter of global commercial energy consumption
- Supplies projected to last for around 60 years

Natural Gas

Russia 21.9

USA 20.2

Canada 6.8

UK 3.6

Iran 3.2

Algeria 3.0

Norway 2.9

Indonesia 2.7

Netherlands 2.6

Saudi Arabia 2.4

Table 17.5 Top Producers and Consumers of Natural Gas

Production (% world production)	Consumption (% world consumption)
Russian Federation, 22.0	United States, 26.3
United States, 21.7	Russian Federation, 15.3
Canada, 7.3	Great Britain, 3.7
Great Britain, 4.1	Germany, 3.3
Algeria, 3.2	Canada, 3.2
Indonesia, 2.8	Japan, 3.1
Norway, 2.6	Ukraine, 2.8
Iran, 2.6	Iran, 2.7
Netherlands, 2.4	Italy, 2.5
Saudi Arabia, 2.2	Saudi Arabia, 2.2

Data from British Petroleum, Statistical review of world energy, 2003.

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USA 24.0

Russia 15.0

UK 3.6

Canada 3.3

Iran 3.2

Germany 3.2

Italy 2.7

Japan 2.7

Ukraine 2.6

Saudi Arabia 2.4

Natural Gas

- **Conventional natural gas**
  - **Liquefied petroleum gas (LPG):** mainly propane and butane
  - **Liquefied natural gas (LNG)** – Liquefied under very low temperature and high pressure; low net energy yield
- **Unconventional natural gas**
  - **Coal bed methane gas:** Found in coal beds near the earth's surface
  - **Methane hydrate:** methane trapped in ice in tundra (Alaska and Siberia)

TRADE-OFFS

Conventional Natural Gas

Advantages

Ample supplies

High net energy yield

Low cost

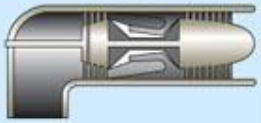
Less air pollution than other fossil fuels

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

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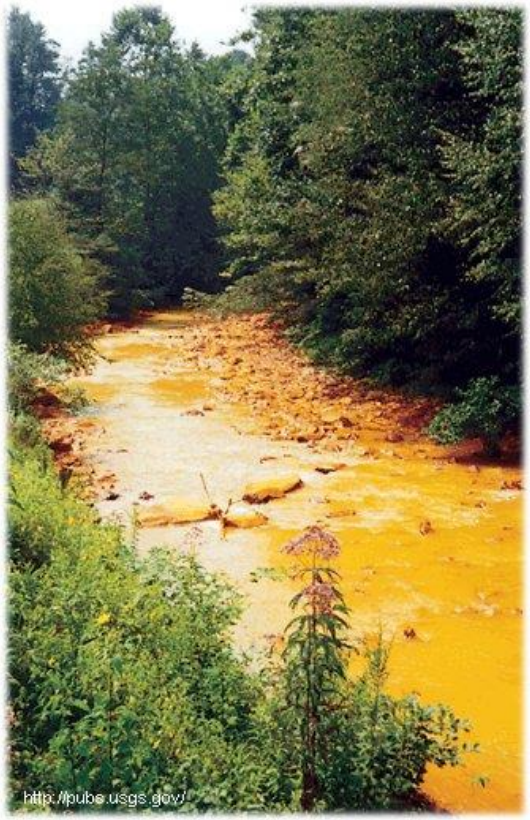
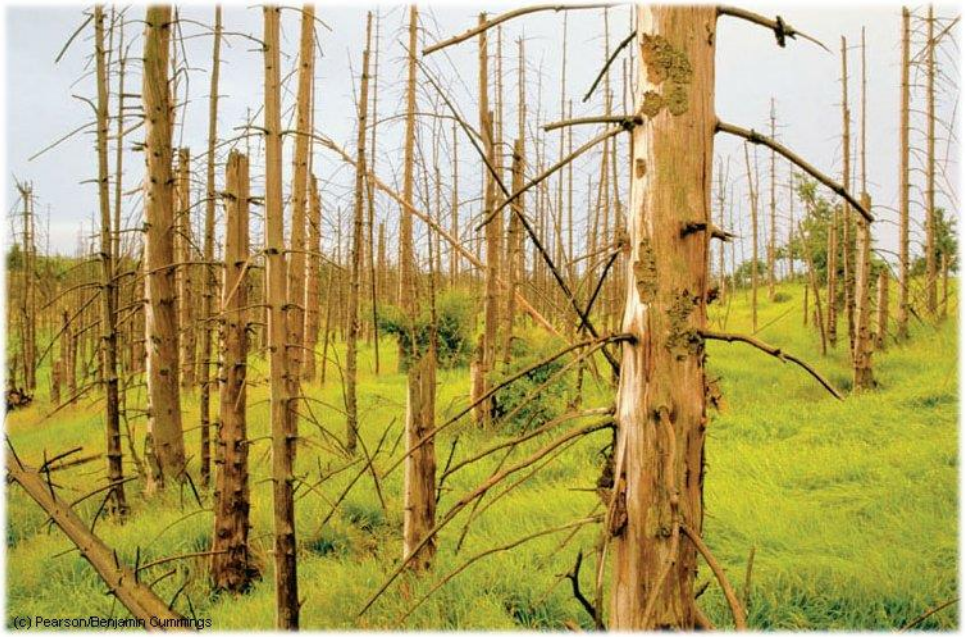
Fossil fuel use harms the environment.



Air & Water Pollution

Fossil fuel use harms the environment.

Acid rain causes soil degradation.



Fossil fuel use harms the environment.

Habitat Loss/Degradation