Ειδικά κεφάλαια παραγωγής ενέργειας

Ενότητα 1: Εισαγωγή

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Τμήμα Μηχανολόγων Μηχανικών

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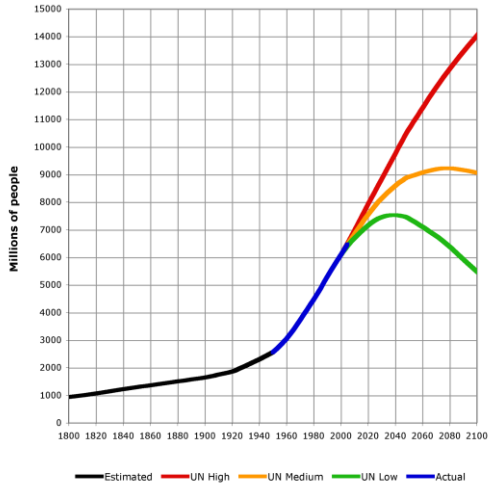
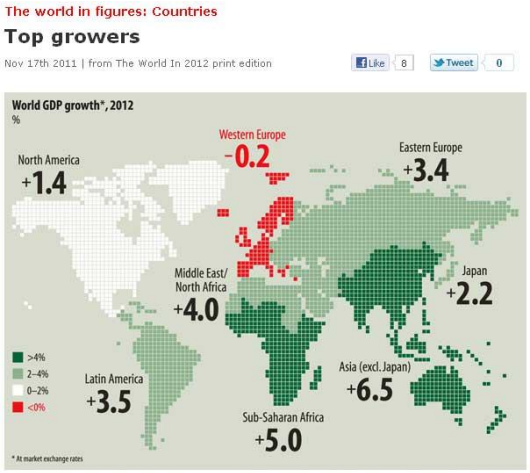
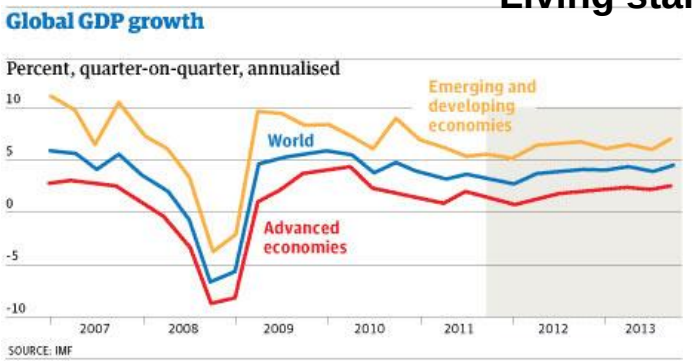
- Το έργο «**Ανοικτά Ψηφιακά Μαθήματα στο Πανεπιστήμιο Δυτικής Μακεδονίας**» έχει χρηματοδοτήσει μόνο τη αναδιαμόρφωση του εκπαιδευτικού υλικού.
- Το έργο υλοποιείται στο πλαίσιο του Επιχειρησιακού Προγράμματος «Εκπαίδευση και Δια Βίου Μάθηση» και συγχρηματοδοτείται από την Ευρωπαϊκή Ένωση (Ευρωπαϊκό Κοινωνικό Ταμείο) και από εθνικούς πόρους.

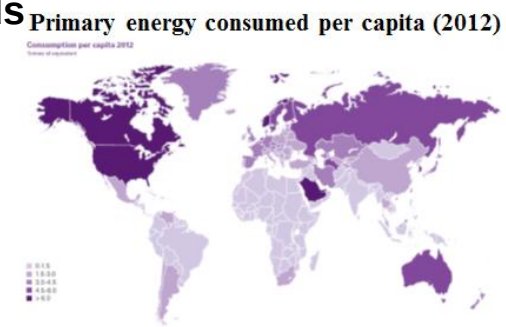
World Energy Demands are Increasing



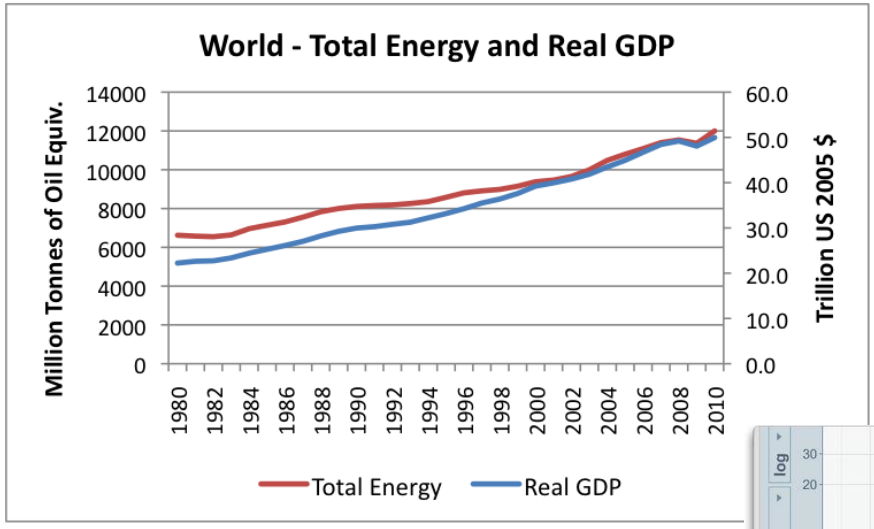


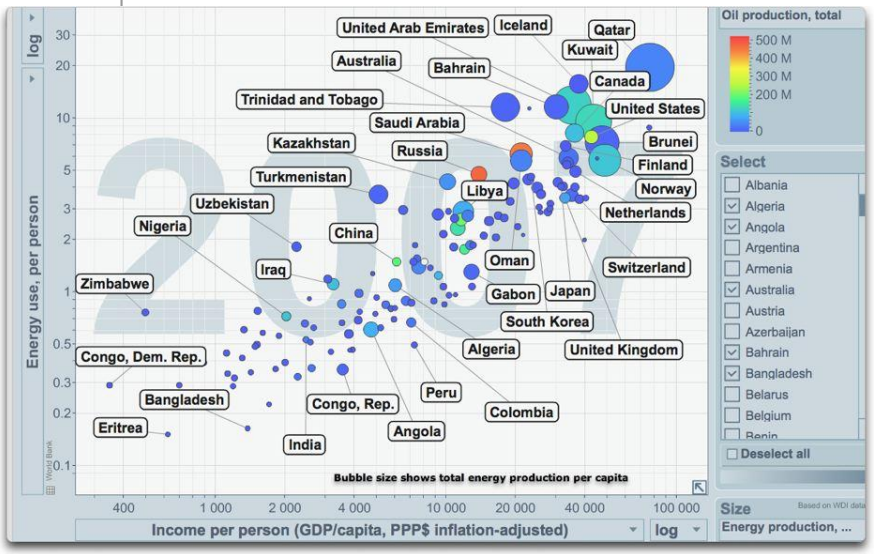
- **Increase of population**
- **Technological development**
- **Living standards**





Correlation GDP & Energy Consumption





Significance of Energy

- Energy has always played an important role in human and economic development and in society's well-being.
- Without energy, economic activity would be limited and restrained.
- Modern society uses more and more energy for industry, services, homes and transport.
- The effects of growing demand and depleting resources calls for a close monitoring of the energy situation.
- Energy dependency, security.
- Environmental concerns (e.g. climate change, acid rain, ozone depletion, photochemical smog).

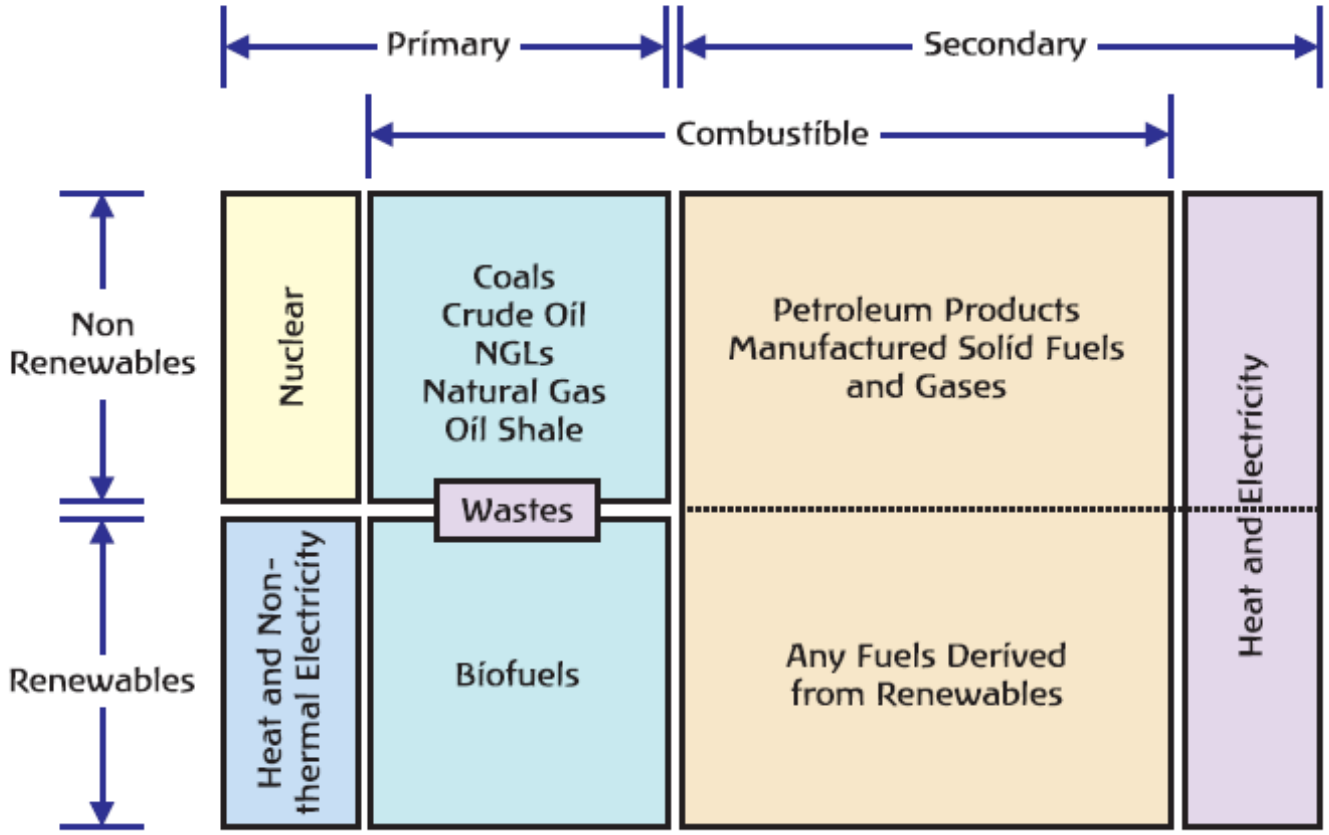
EU Energy Policy

"The energy challenge is one of the greatest tests faced by Europe today. Rising energy prices and increasing dependence on energy imports jeopardise our security and competitiveness. Key decisions have to be taken to slash our emissions and mitigate climate change."

Competitive, sustainable and secure energy.

Categorization of Energy forms

Figure 1.1 • Terminology for Energy Commodities

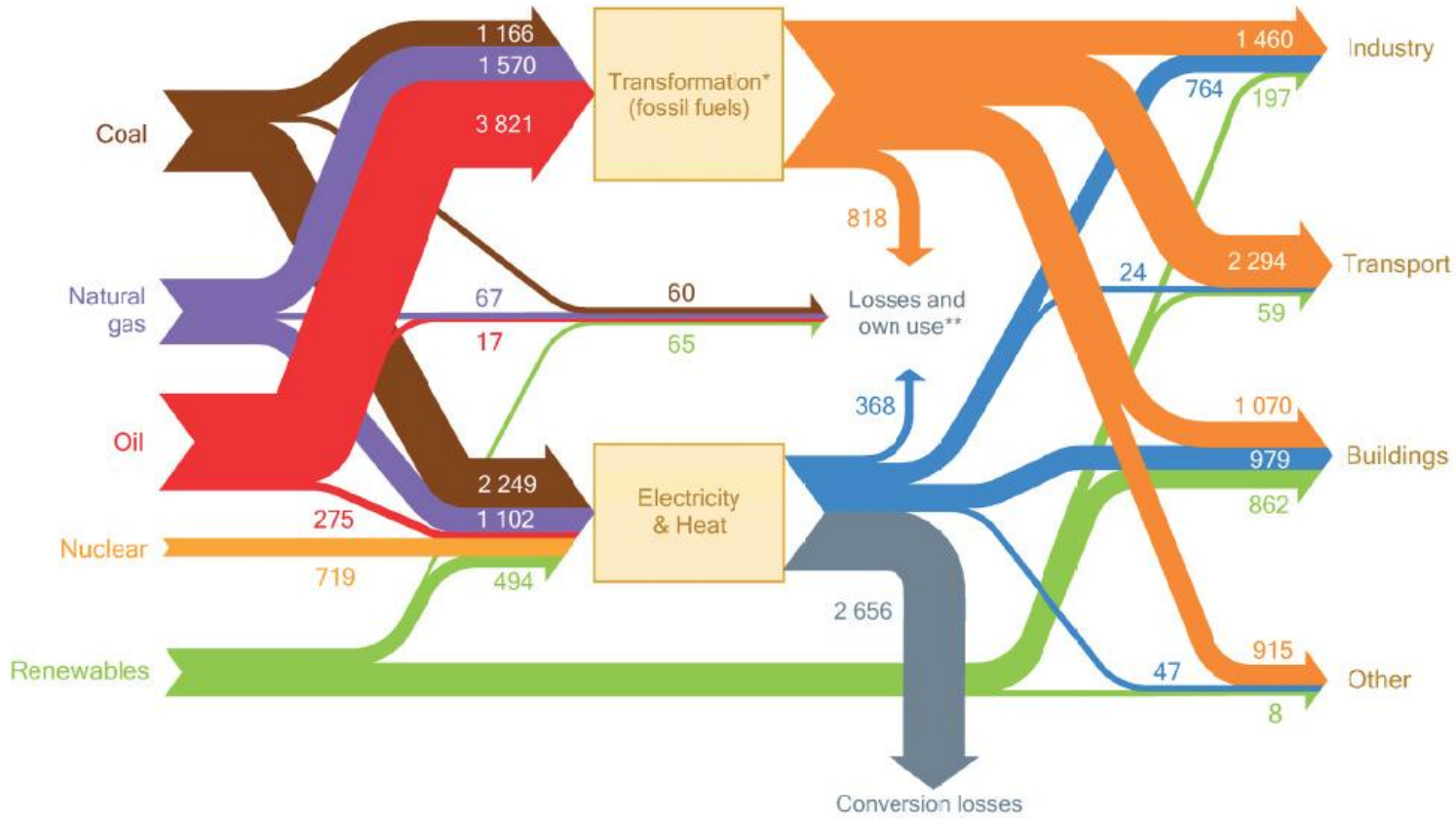


Energy Consumption Sectors

- Industry (chemicals, iron and steel manufacture).
- Transport (Road, Air, Pipelines, etc).
- Agriculture (pumps for irrigation).
- Residential (heating, lighting).
- Non-energy uses of fuels, e.g. as raw materials on non-fuel products, as lubricants due to their unique properties and as solvents.

Primary World Energy Consumption

Figure 2.8 ▷ **The global energy system, 2010** (Mtoe)



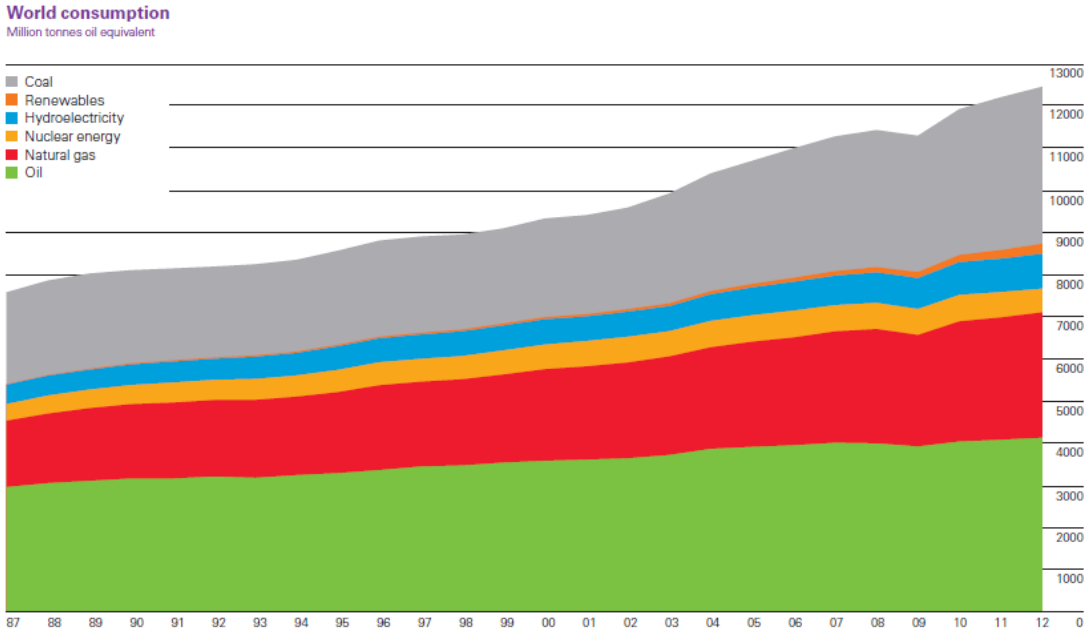
Energy Overview (1/6)

- The **"Arab Spring"** (energy supply and security) and the **earthquake/tsunami** in Japan (nuclear power) were the main events that affected the global energy in 2011.
- **Oil prices** hit an all-time record high in 2011.
- All of the net growth in 2012 took place in emerging economies, with **China-India** alone accounting for **nearly 90%** of the net increase in global energy consumption.
- OECD consumption declined for the 4th time in the past 5 years, led by a large decline in the US.

Energy Overview (2/6)

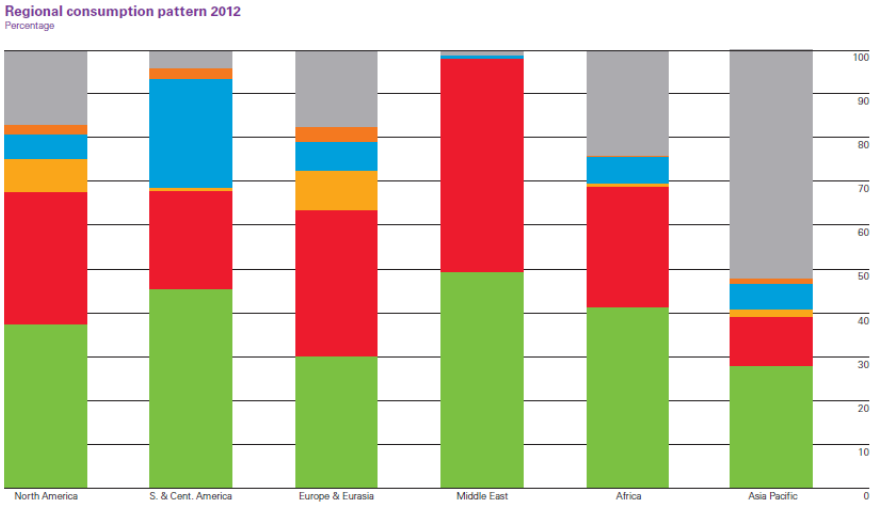
- Despite the slowdown, consumption/production reached record levels except for nuclear power and biofuels.
- Global energy consumption grew by **1.8% in 2012,** well below the 10-year average of **2.6%.**
- Consumption in OECD countries fell by 1.2%, led by a decline of 2.8% in the US.
- **Non-OECD consumption grew by 4.2%, below the 10-year average of 5.3%.**

2012 – World Consumption



- World primary energy consumption grew by a below –average 1.8% in 2012. Growth was below average in all regions except Africa.
- Oil remains the world's leading fuel, accounting for 33.1% of global energy consumption. Oil has lost market share for 13 years in a row.
- Hyrdoelectricity (6.7%) and other RES (1.9%) reached record shares.

Regional Consumption Pattern 2012



- The Asia Pacific region accounted for a record 40% of global energy consumption and 69.9% of global coal consumption in 2012; the region also leads in oil and hydroelectricity generation.
- Europe & Eurasia is the leading region for consumption of natural gas, nuclear power and renewables.
- Pacific region, the only region dependent on a single fuel for more than 50% of total primary energy consumption.

Energy Overview (3/6)

- Global oil consumption grew by a below-average 0.9%.
- Oil had the weakest global growth rate among fossil fuels for the 3rd consecutive year.
- Global oil production, in contrast, increased by 1.9 mb/d or 2.2%.

-1.3%

Decline in OECD oil consumption, the sixth decrease in the past seven years.

+1 million b/d

Growth of US oil production, the largest in the world.

Energy Overview (4/6)

- World natural gas consumption grew by 2.2%. Growth was below average (2.7%).
- Consumption growth was above average in S&C America, Africa and N. America, where the US (+4.1%) recorded the largest increment in the world. China (9.9%) and Japan (10.3%) were responsible for the next-largest growth increments.
- EU faced a large decline (-9.9%) in 2011 and this was also the case for 2012 (-2.3%). Due to the weak economy, high gas prices, warm weather and continued growth in RES power generation.
- Global natural gas production grew by 1.9%.

-0.9%

The first decline on record for global LNG trade.

23.9%

Natural gas's share of global primary energy consumption.

Energy Overview (5/6)

- Coal consumption grew by 2.5% in 2012, well below the 10-year average of 4.4% but still the fastest-growing fossil fuel.
- Consumption outside the OECD rose by a below-average 5.4%. China still accounts for all of the net growth in global coal consumption.
- Global coal production grew by 2%, with growth in China (3.5%) and Indonesia (9%) offsetting a decline in the US (-7.5%)
- Coal reached the highest share of global primary energy consumption (29.9%) since 1970.

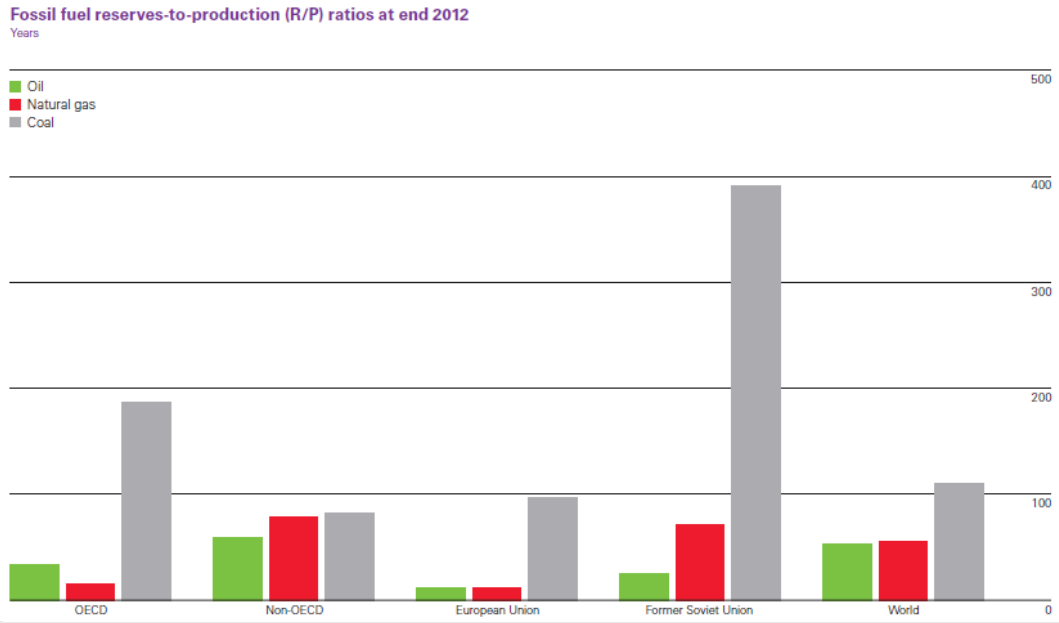
50.2%

China's share of global coal consumption.

Energy Overview (6/6)

- Global nuclear output fell by 6.9%, the largest decline on record for a 2nd consecutive year. **Japanese output fell by 89%, accounting for 82% of the global decline.**
- Nuclear output accounted for 4.5% of global energy consumption, the **smallest share since 1984.**
- **Hydroelectric output** grew by above average 4.3% reaching **the highest share on record (6.7%)** of the global energy consumption.
- RES saw mixed results in 2012. Global biofuels production recorded the 1st decline since 2000 (mainly to US).
- Renewable energy used in power generation grew by 15.2%, slower year-on-year growth for the 1st time since 2008.
- Wind energy (+18.1%) accounted for more than half of RES power generation. Solar power grew more rapidly (+58%).

Fossil Fuel Reserves to Production (2012)

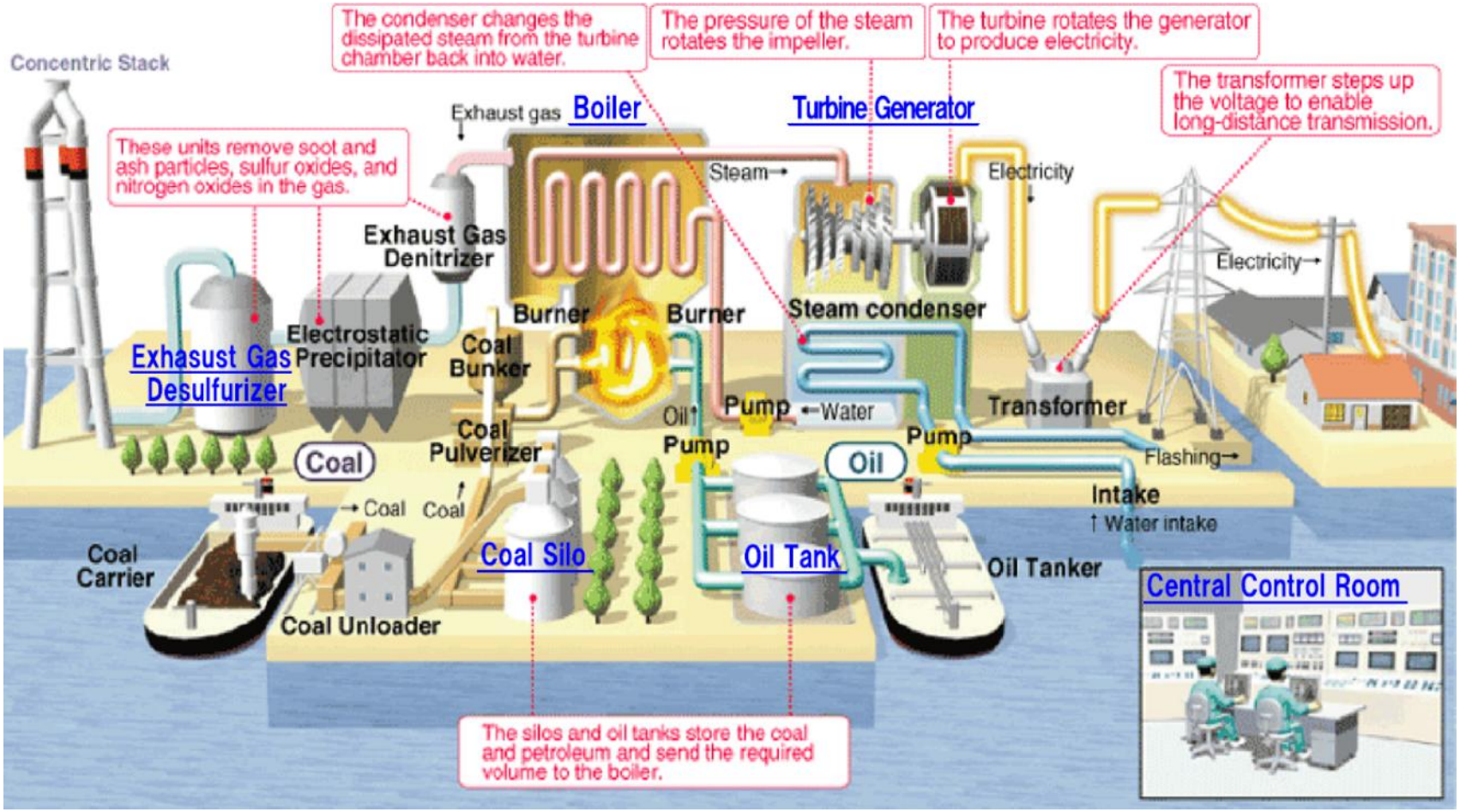


- Coal remains the most abundant fossil fuel by global R/P ratio, although global oil and natural gas reserves have increased significantly over time.
- Non-OECD countries possess the majority of proved reserves for all fossil fuels, and have a higher R/P ratio than the OECD countries for oil and natural gas.

Electricity & heat

- Electricity is an energy carrier with a very wide range of applications (industrial production, household use, lighting, heating, etc).
- Primary electricity is obtained from natural sources such as hydro, wind, solar, tide and wave power.
- Secondary electricity is produced from the heat of nuclear fission of nuclear fuels, from the geothermal and solar thermal heat, and by burning primary combustible fuels (coal, natural gas, oil, renewables and wastes).
- Heat, as electricity, is an energy carrier primarily used for warming spaces and industrial processes.

Electricity Generation



Electricity and Heat Flows

Figure 2.1 • Simplified Flow Chart for Electricity

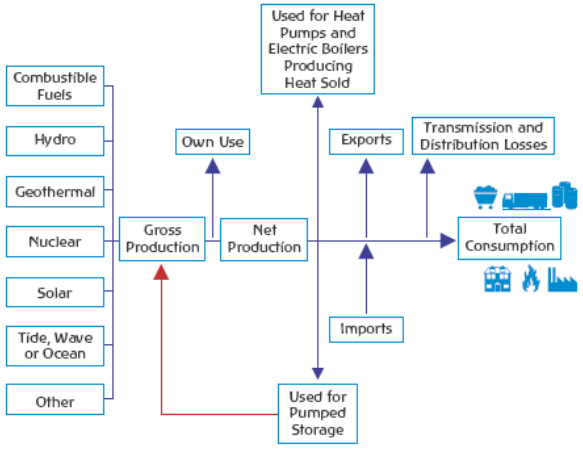
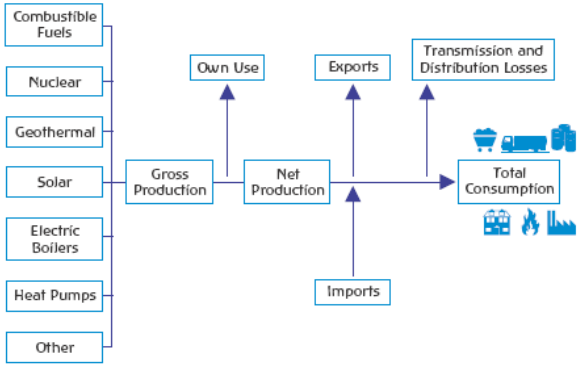


Figure 2.2 • Simplified Flow Chart for Heat



Electricity & Heat Supply

- Electricity and heat are produced from several sources in two basic types of plants, by two types of producers.
- The sources, include coal, petroleum products, Natural Gas, renewables, etc.
- Type of plants: electricity only, heat only, CHP.
- Types of producers: public and private producers.
- The major sources for production of electricity and heat are coal (39%), followed by NG, nuclear, hydro (each 17%) and oil (8%).
- During the past 30 years, the share of oil decreased from 25 to 8%, while the nuclear increased from 3 to 17%.

Electricity & Heat – Imports & Exports

- With increasing globalization and opening of countries' economies, trade of electricity has been growing.
- On all continents, countries are connecting their grids in order to improve security of electricity supply and take advantage of generating cost differentials.
- Electricity is transported using high-voltage national transmission grids, which are interconnected at borders.
- Since it is impossible to store electricity, supply must always equal to demand in order to keep the grid in balance (cross-border flows).

Electricity & Heat Consumption (1/2)

The consumption of electricity and heat occurs in several sectors:

- In the transformation sector, and by the energy industry within the energy sector.
- In the transmission and distribution of electricity and heat.
- In the various sectors and branches of final consumption (industry, transport, residential, services, etc.).

- The transformation and energy sectors consume around 10% of global electricity supply and around 9% of global heat supply.
- For electricity, the distribution losses account for anywhere from 7 to 15% of electric supply.
- The amount of losses depend on the size of the country (grid length), voltage of transmission and distribution, quality of network.
- For heat, distribution losses account for about 15%. The heat is usually distributed over short distances, otherwise it becomes inefficient.

Electricity & Heat Consumption (2/2)

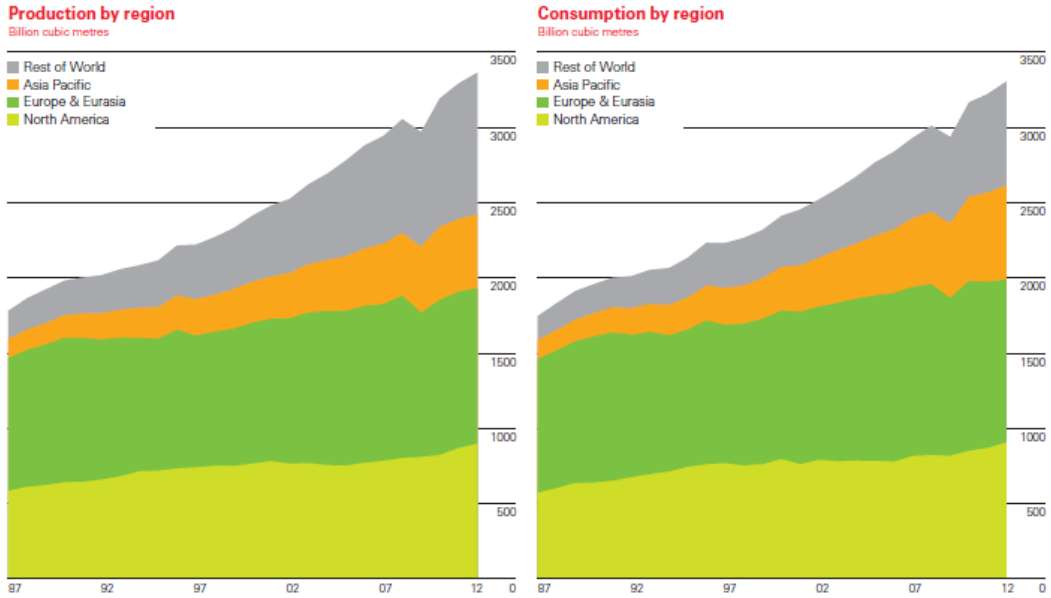
- The final consumption is a major part of the electricity and heat consumption accounting for about 80% of total consumption.
- The share of the residential and commercial/public service sectors combined increased from about 38 to 52% over the last 30 years.
- The industry sector has constantly increased at a lower rate compared to residential and commercial/public sectors. The share of industry has decreased from 51% in 1973 to around 42%.

Natural Gas Overview

Natural Gas

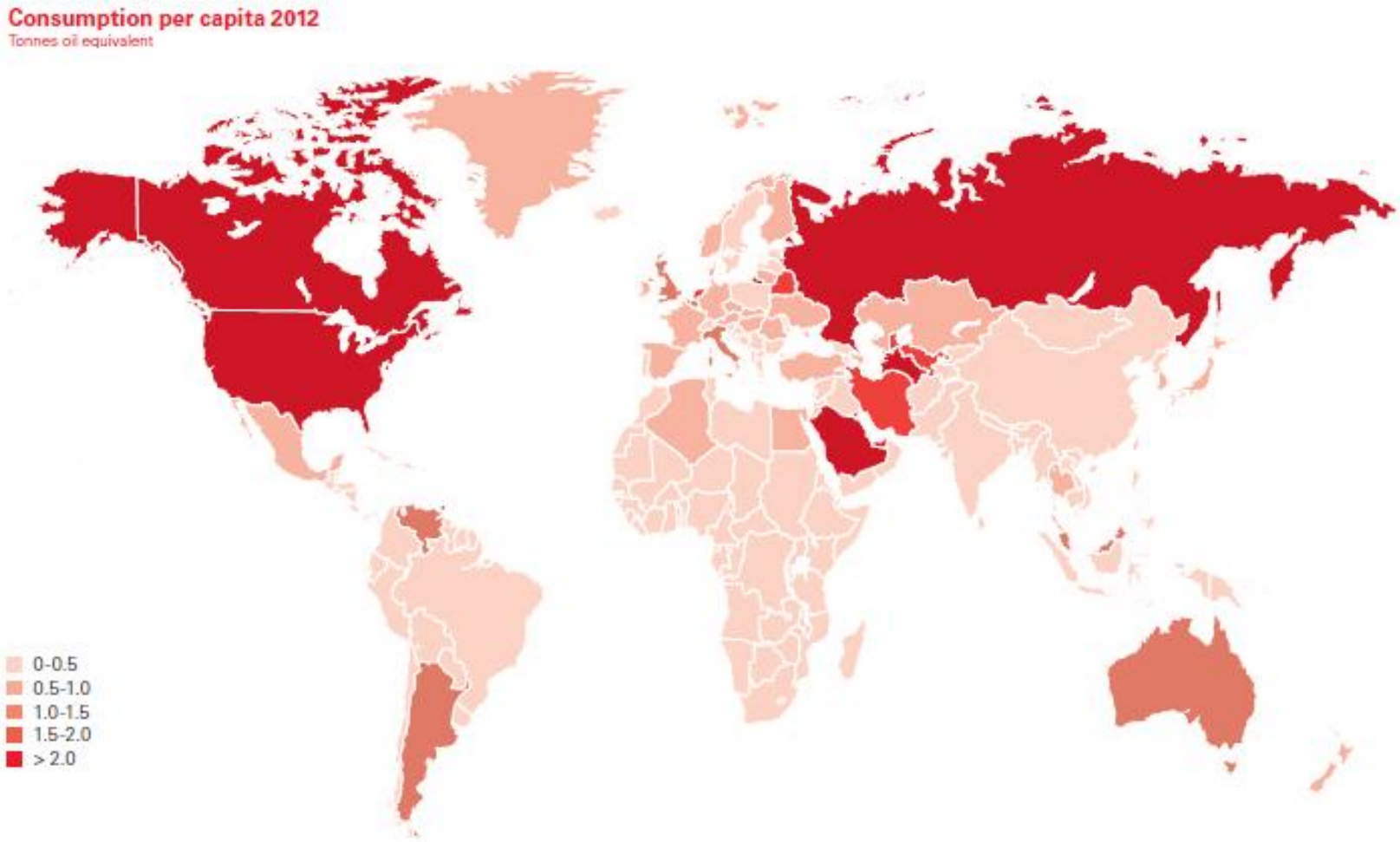
- Natural gas comprises several gases, but consists mainly of methane (85%).
- Natural Gas is taken from natural underground reserves and is not a chemically unique product.
- When NG is produced in association with oil is called **associated gas** while when is deriving from a gas reservoir is **non-associated gas.**
- The gas that is produced when coal is mining from underground mines is called **colliery gas.**
- When a gas contains appreciable amounts of butane and heavier hydrocarbons is termed as **wet gas.**
- Dry gas consists mainly of CH_4 with relatively small amounts of C_2H_6, C_3H_8.
- When gas is liquified is called **Liquified Natural Gas** (LNG).
- NG now accounts for more than 21% of global total primary energy supply compared to 16.2% in 1973.

2012 – Natural Gas Production/Consumption

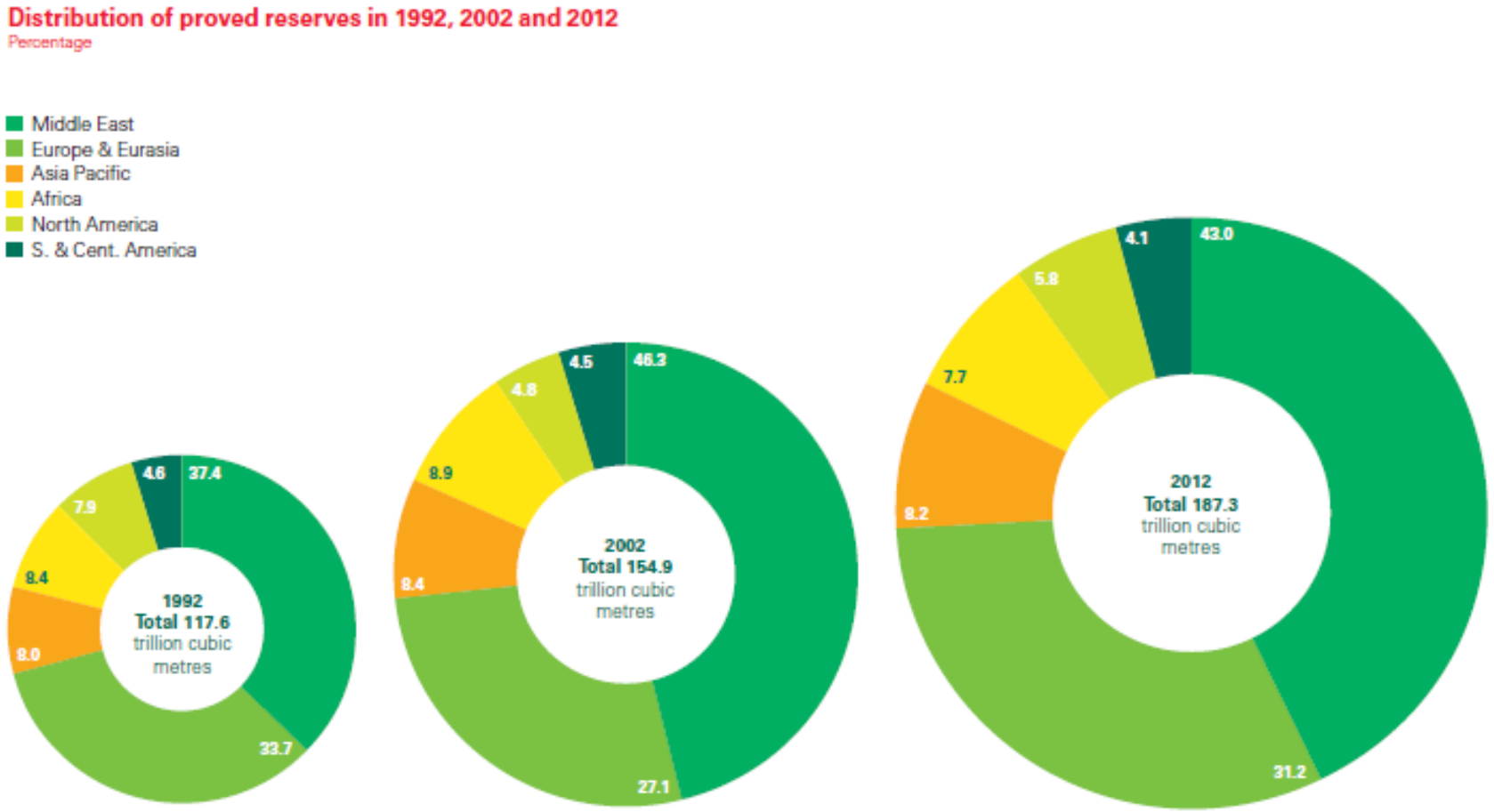


- World NG production increased by 1.9% in 2012, while consumption increased by a below average 2.2%.
- Production grew in every region except Europe (lowest level since 2000) and Eurasia, where declines in Russia and the UK offset a gain in Norway.

2012 – Natural Gas Consumption per capita



2012 – Natural Gas PROVED RESERVES

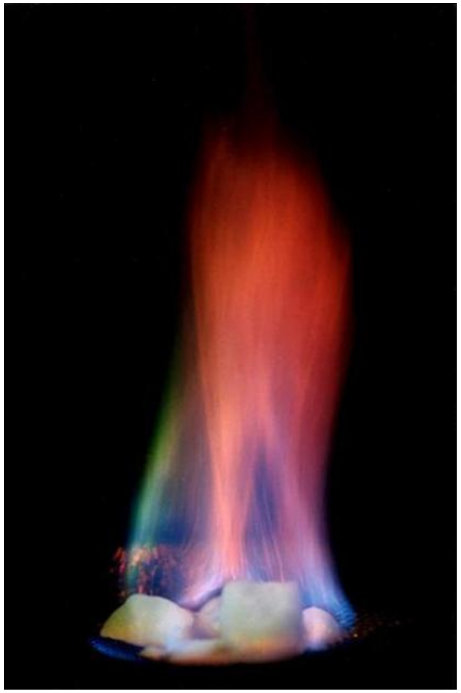


2012 – Natural Gas Reserves to Production

- World proved NG reserves are sufficient to meet 55.7 years of global production.
- Proved reserves declined by 0.3% relative to end 2011.

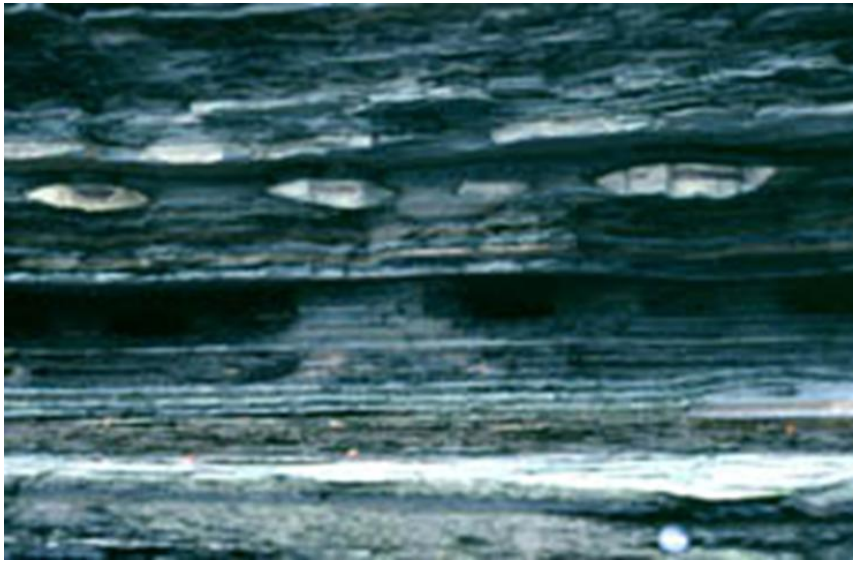
Natural gas formation

- Natural gas forms mainly from the remains of plankton, or a type of small water organisms including algae.



Formation of Petroleum and Natural Gas (1/3)

- Accumulation of organic material – typically marine sludge.
- Burial and preservation of organic material – reducing conditions.
- Reducing conditions in deep sea or on continental shelves during times of unusual oceanic circulation.



Formation of Petroleum and Natural Gas (2/3)

- Black, organic-rich sludge is buried deeper and converted to rock – shale.
- With burial, the organic matter is heated.
- When heat is sufficient (but not too great) – in the range of 100-300 ^{o}C – the organic matter is “cooked” and oil forms.
- Process is called **thermal maturation.**

Formation of Petroleum and Natural Gas (3/3)

- If heat is greater than 300 ^{o}C, the liquid petroleum is further broken down to form **natural gas.**

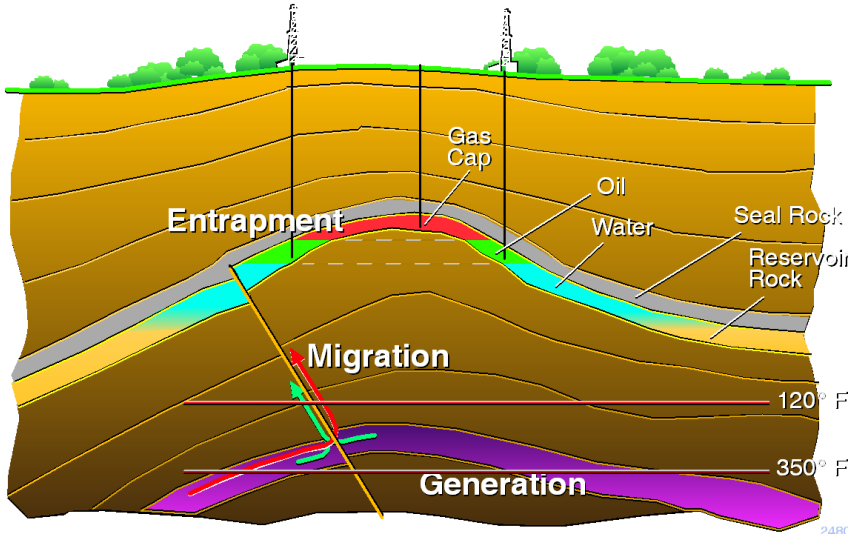
- If heat is too great, even the natural gas is broken down to form **carbon dioxide**, which has no value as a fuel.

How NG is created

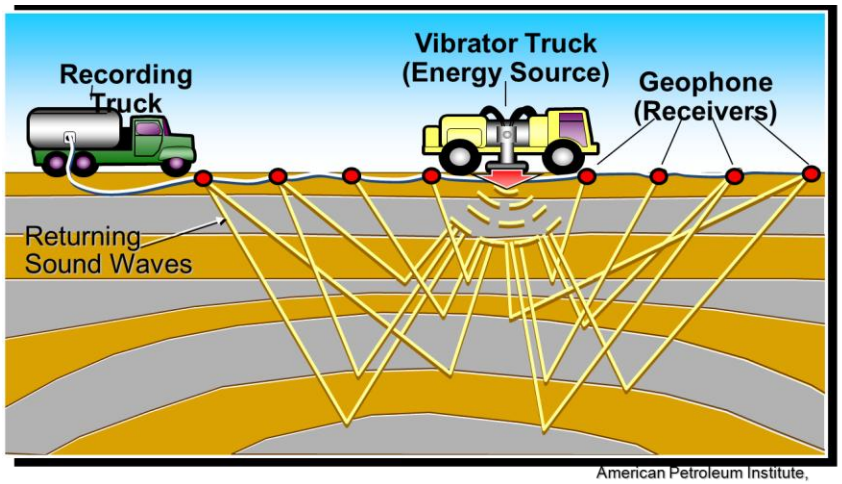
Natural gas is formed underground though heat and pressure acting on organic matter.

The light gas “travels” through porous earth until it gets trapped under rock formations.

Oil and water are also found in these reservoirs.



Locating Natural Gas Reserves



American Petroleum Institute, 1986

The technologies used to locate and extract gas have improved significantly.

Seismography measures the travel time of shock waves from the surface, refracted,

and reflected back by underground rock formations.

This provides a picture of underground structures and probable locations for gas and oil.

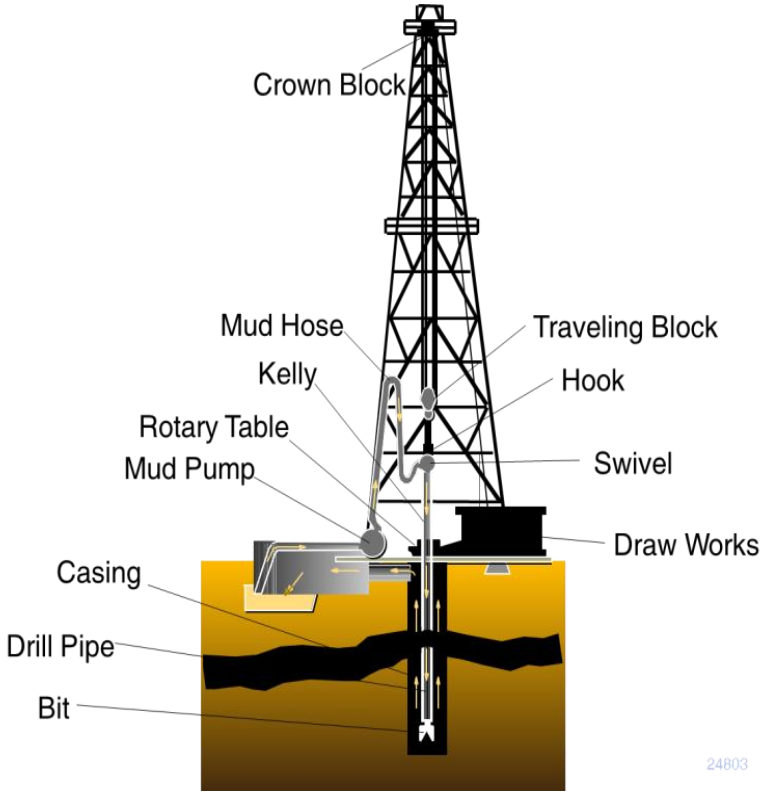
Drilling Rig

A well is dug by a drilling rig.

In a rotary drilling rig, a rotating bit is mounted on the bottom of a drill pipe.

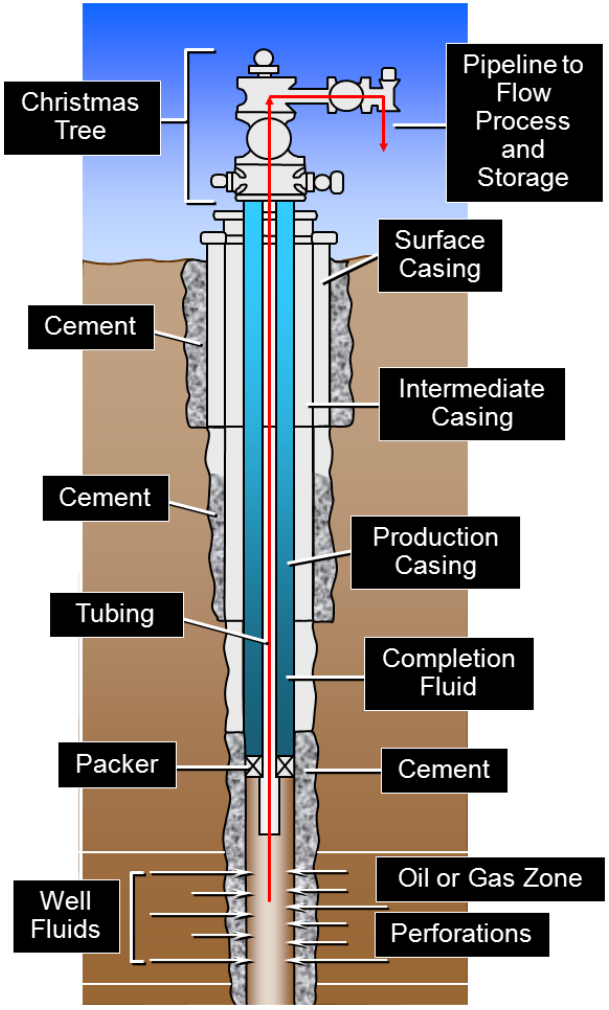
Drilling mud lubricates and cleans the rotating bit, which is propelled by the Sludge Pump through the Sludge tube.

Casing lines the hole preventing collapse.

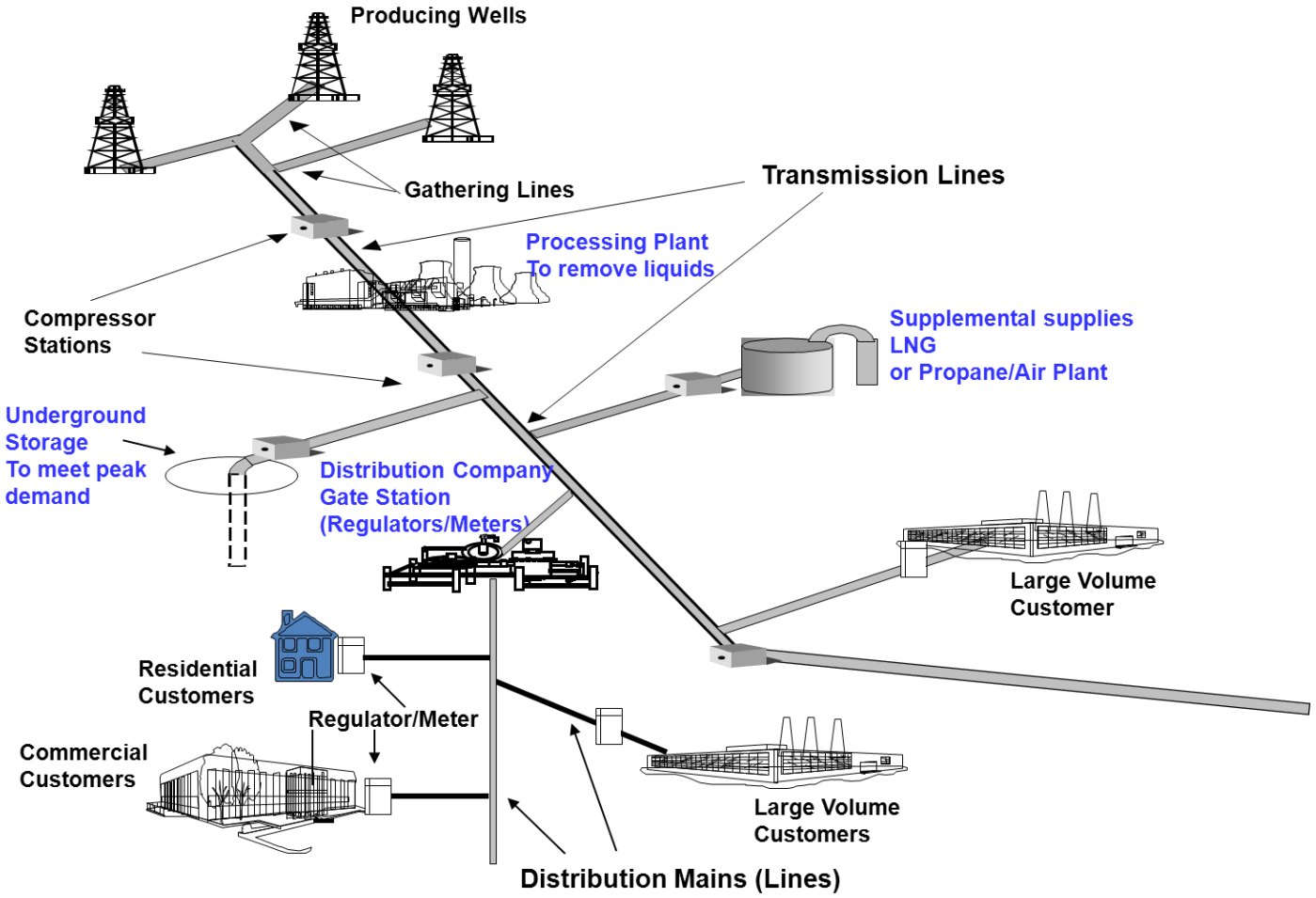


Completed Well

- Once the hole is drilled, cement is poured outside the casing to stabilize the ground.
- Gas is forced by underground pressure to travel to the surface where flow is controlled and directed by a series of pipes and instruments.
- The gas then flows into the gathering systems lines.

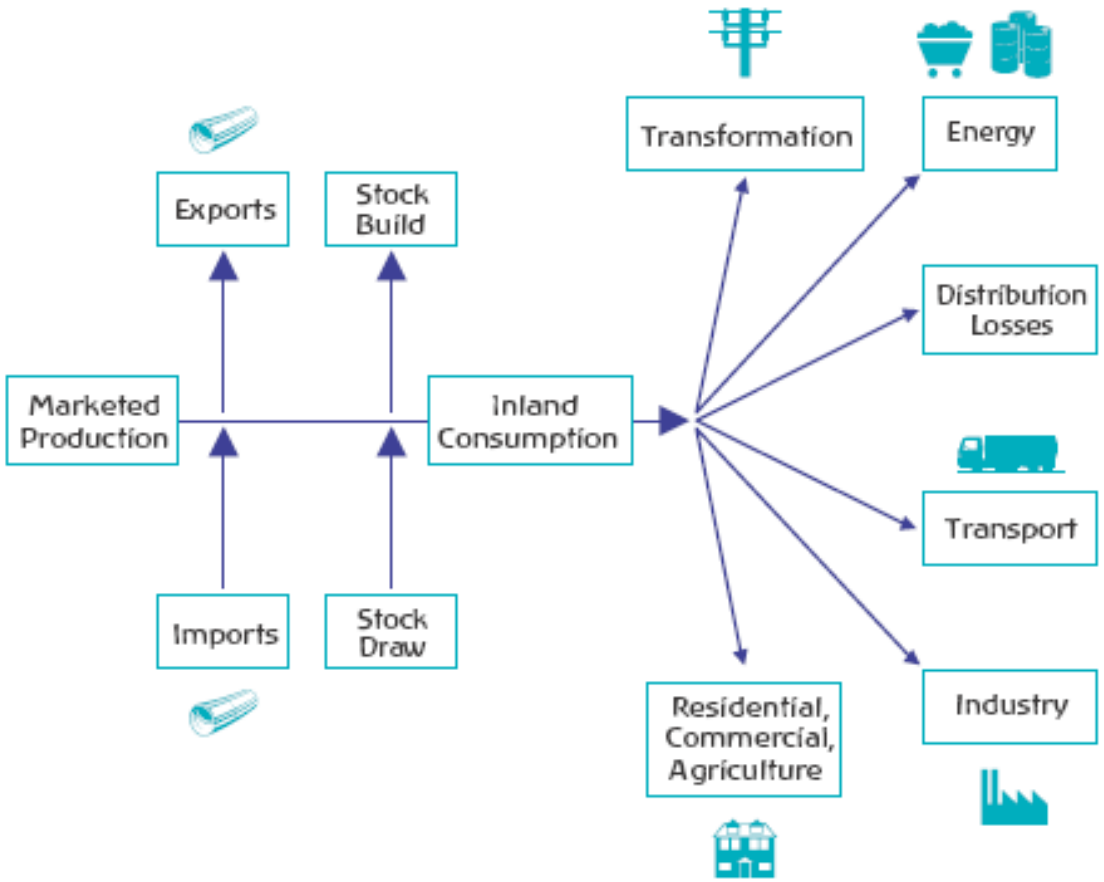


Natural Gas Transportation System



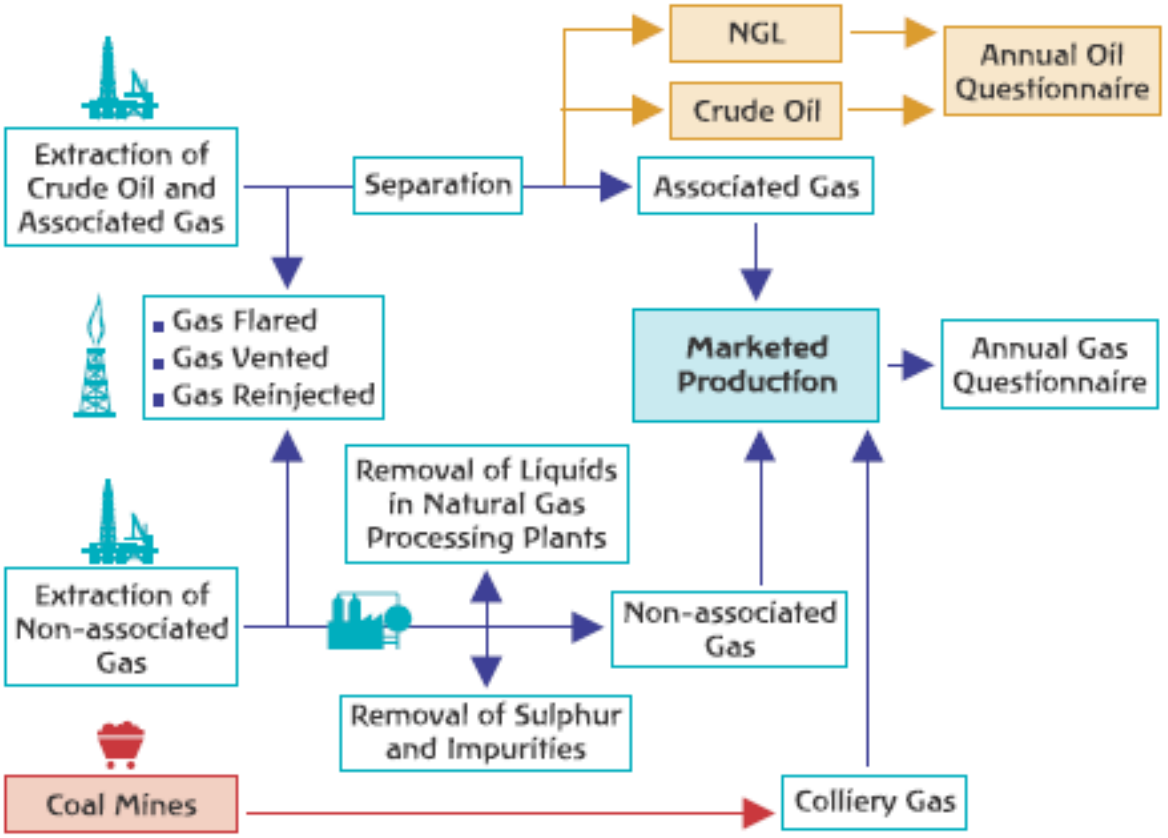
Natural Gas flows

Figure 3.1 • Simplified Flow Chart for Natural Gas



Natural Gas supply

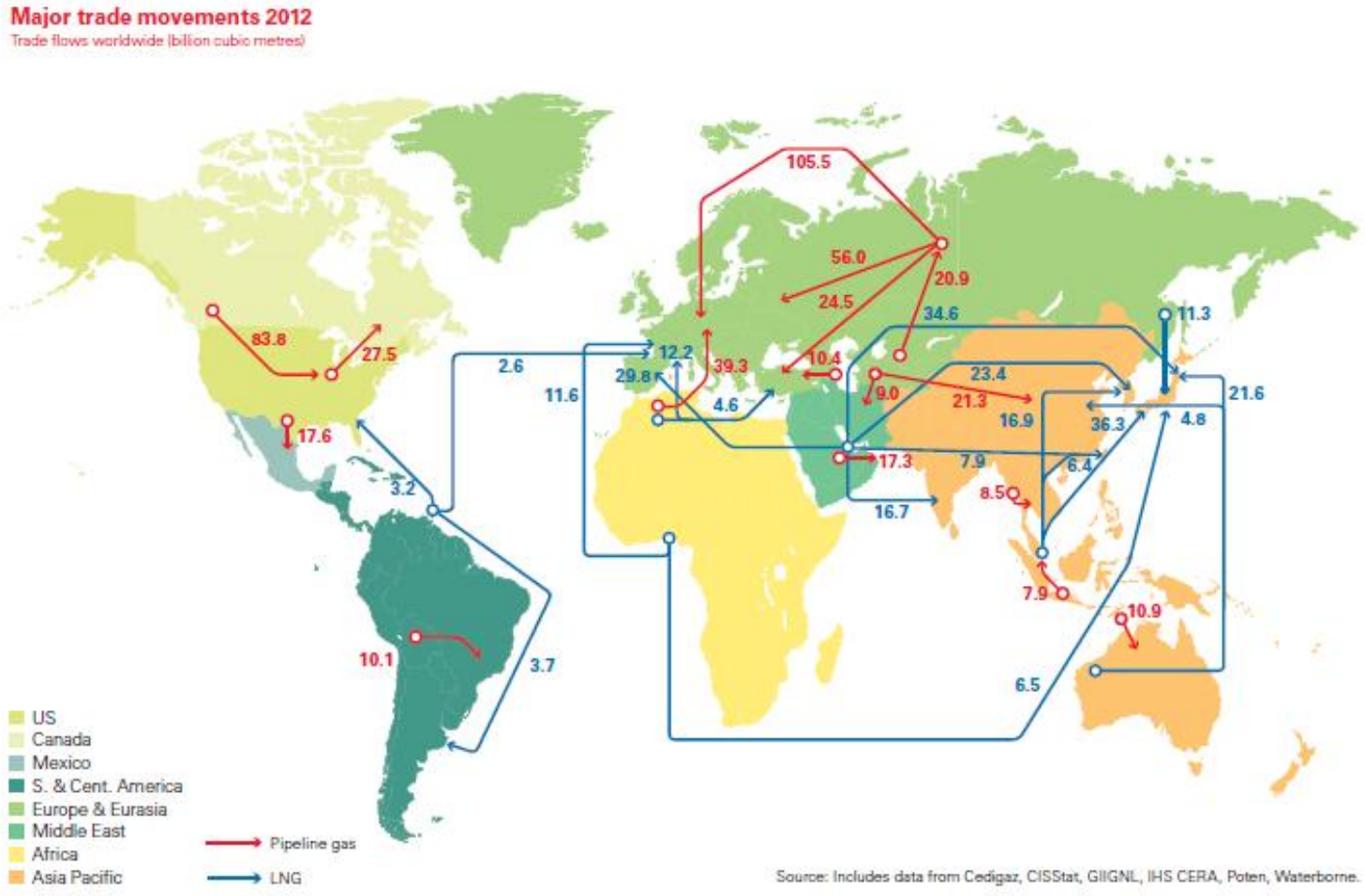
Figure 3.3 • Simplified Flow Chart for Natural Gas Production



Natural Gas – Imports & Exports

- There are two main means of transport of NG: in a gaseous from by gas pipeline, and in a liquid form by LNG carriers.
- Because of the relative difficulty and high cost for transporting NG, trade of gas remained limited until recently.
- In 1971, the gas traded accounted for 5.5% of total NG consumed. However, in the last decade, NG trade increased fast and is now representing more than ¼ of oil gas consumed.
- In the past the trade was local, however with the development of more efficient pipelines the market became more regional.

2012 – Natural Gas Trade Movements



Natural Gas – Stocks levels and Changes

- NG demand is very seasonal in most countries.
- To limit the need for long-distance transport and to improve the security of gas supplies, countries have started to build gas storage facilities.
- Gas storage facilities are divided to seasonal and peak.
- Seasonal storage sites must be able to store huge volumes of gas built up during low demand times for slow release during periods of high demand.
- Peak facilities store smaller quantities but must be able to inject gas quickly into the transmission network to meet surges in demand.
- The storage facilities can be classified according to physical type: aquifers, salt caverns, LNG peak-shaving units, mined caverns, etc.

2012 – Natural Gas Prices

Natural Gas consumption

The consumption of natural gas occurs in several sectors:

- In the transformation sector.
- By the energy-producing industry within the energy sector.
- In the transport and distribution of gas.
- In the various sectors and branches of final consumption (industry, transport, residential, services, etc.). This includes both energy and non-energy uses of natural gas.

- In the past, NG was perceived as a noble fuel, reserved for premium uses. Due to its high efficiency, low capital costs and cleanliness, it is used in a variety of applications.
- In recent years, NG consumed for electricity has accounted for almost 20% of global electricity production (up from 13% in 1973), and accounts half of the world heat generation in CHP and heat plants.

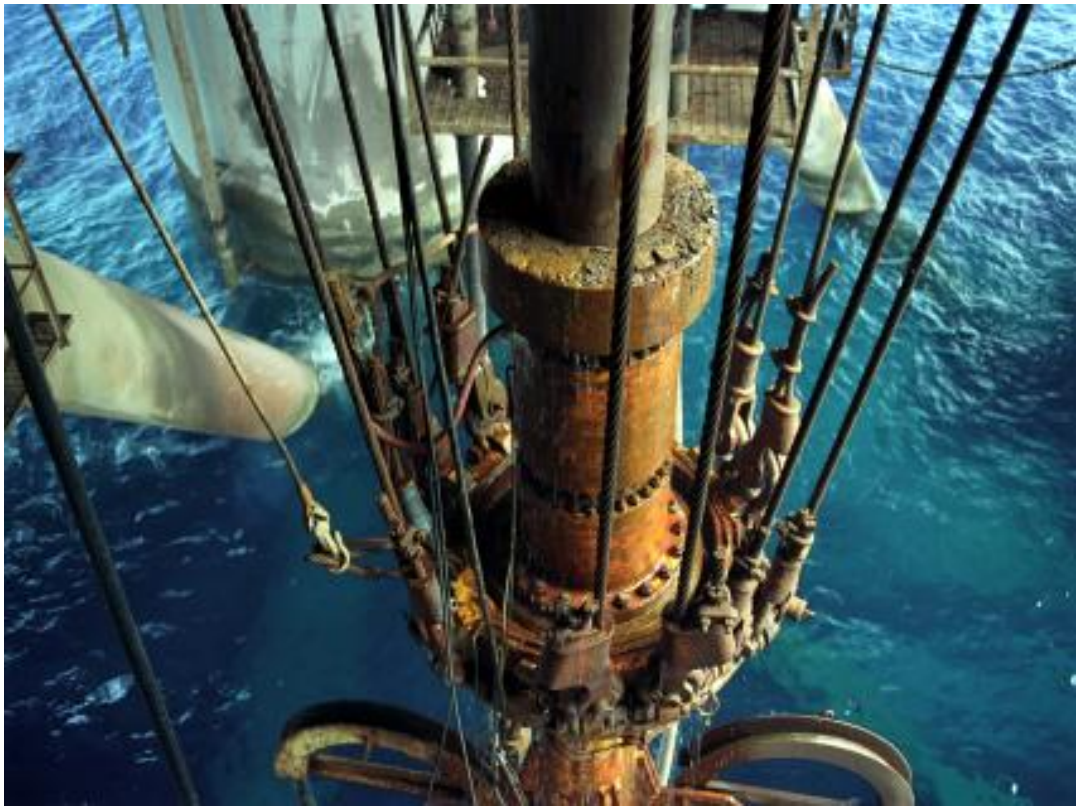
Natural Gas – Transport & Distribution losses

- As NG is often piped over long distances, some losses may occur.
- Transport losses are those that occur during the transmission of gas over a long distance.
- Distribution losses are those that happen in the gas supply chain through the local distribution network.
- These losses are due to differences in measurement of flows (flows calibrations, different ambient conditions).
- These losses account for less than 1% in global gas supply.

Natural Gas – Final Consumption

- In the transport sector, NG is used in a compressed (CNG) or in liquified form (LNG).
- CNG is used due to its clean burning properties, in light duty vehicles and is stored in high-pressure cylinders.
- LNG is favoured for heavy duty vehicles.
- Non-energy uses concern the petrochemical industry (NG is used for ammonia and methanol syntheses).
- NG represents 16% of global final energy consumption.

Oil Overview



BP website (http://www.BP.com

Oil

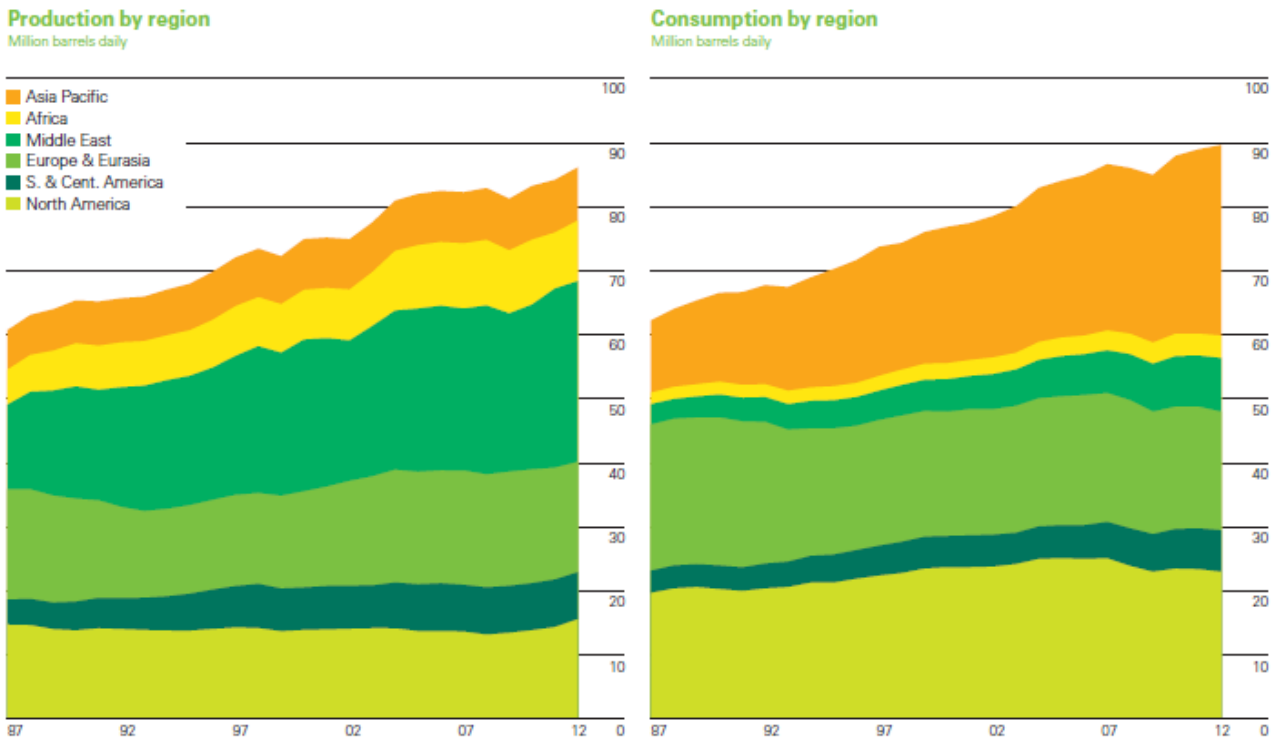
- Petroleum is a complex mixture of liquid hydrocarbons, chemical compounds containing hydrogen and carbon, occurring naturally in underground reservoirs in sedimentary rock.
- Crude oil is the most important oil from which petroleum products are manufactured.
- A whole range of petroleum products are derived from crude oil, varying from light products such as liquified petroleum gas (LPG) and motor gasoline to heavier ones such as fuel oil.
- Oil is the largest traded commodity worldwide, either through crude oil or refined products.
- Although oil supply grows in absolute values, its share in global total energy supply has been decreasing, from over 45% in 1973 to 35%.

Oil Products

Table 4.1 • Primary versus Secondary Oil

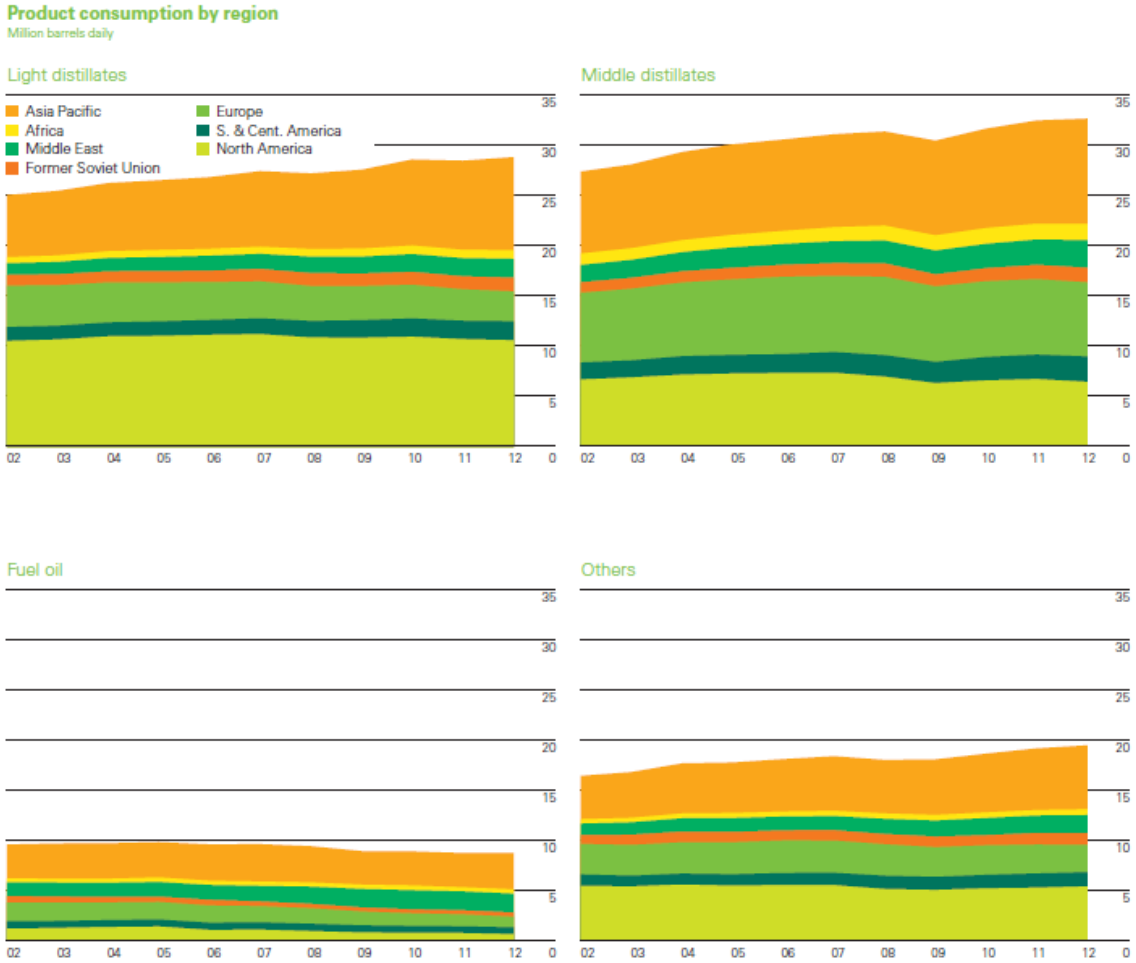
PRIMARY OIL PRODUCTS	Crude oil	
	Natural gas liquids	
	Other hydrocarbons	
SECONDARY PRODUCTS	Additives/blending components	
INPUTS TO REFINERY	Refinery feedstocks	
SECONDARY OIL PRODUCTS	Refinery gas	Transport diesel
	Ethane	Heating and other gasoil
	Liquefied petroleum gases	Res. fuel: low-sulphur content
	Naphtha	Res. fuel: high-sulphur content
	Aviation gasoline	White spirit + SBP
	Gasoline type jet fuel	Lubricants
	Unleaded gasoline	Bitumen
	Leaded gasoline	Paraffin waxes
	Kerosene type jet fuel	Petroleum coke
	Other kerosene	Other products

2012 – Oil production/consumption (1/2)

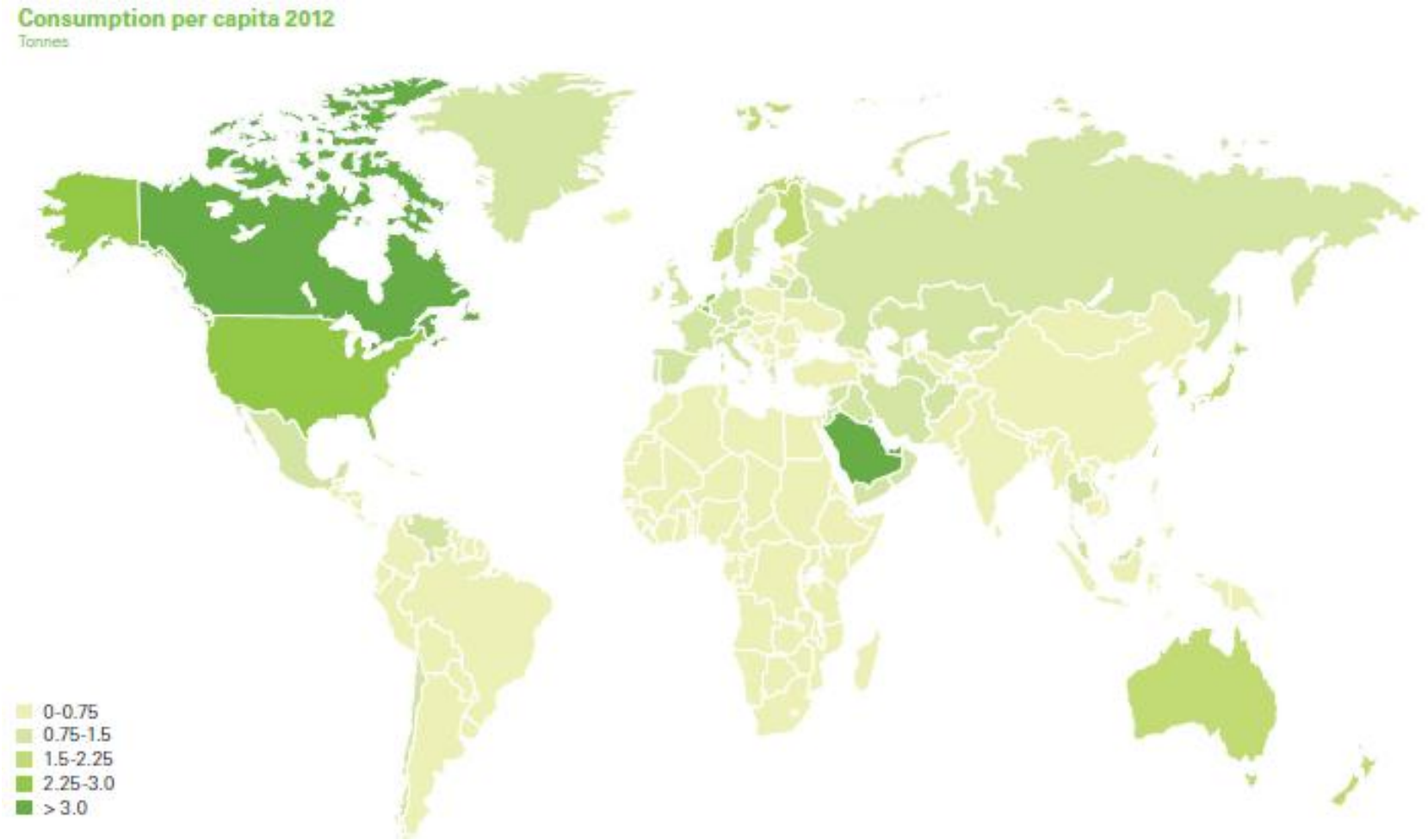


- World oil production increased by 1.9 mb/d in 2012, more than double the growth of global consumption.

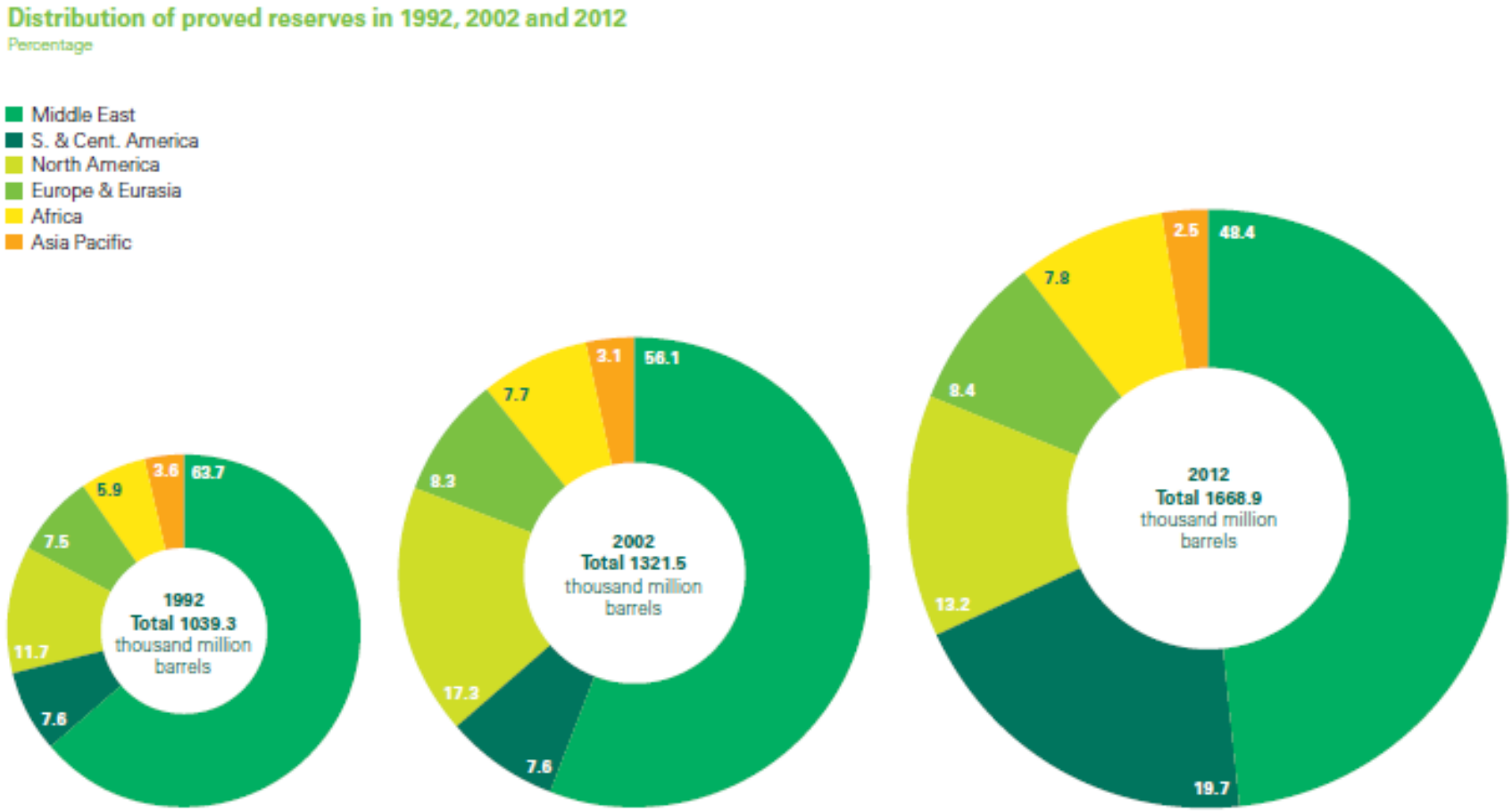
2012 – Oil production/consumption (2/2)



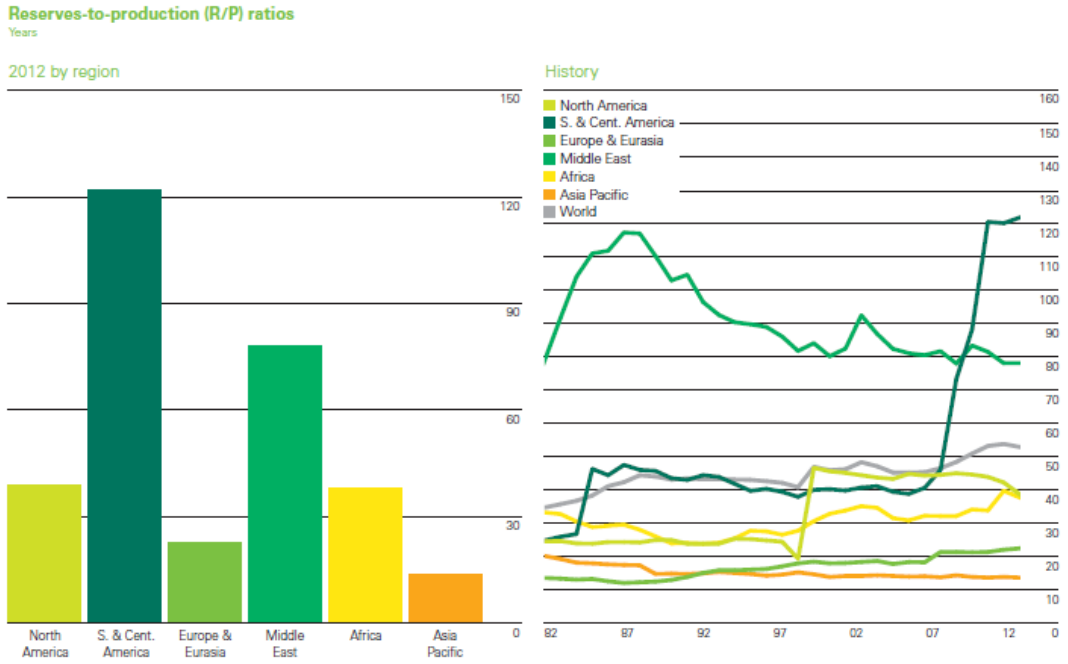
2012 – OIL CONSUMPTION PER CAPITA



2012 – OIL PROVED RESERVES



2012 – OIL
RESERVES TO PRODUCTION



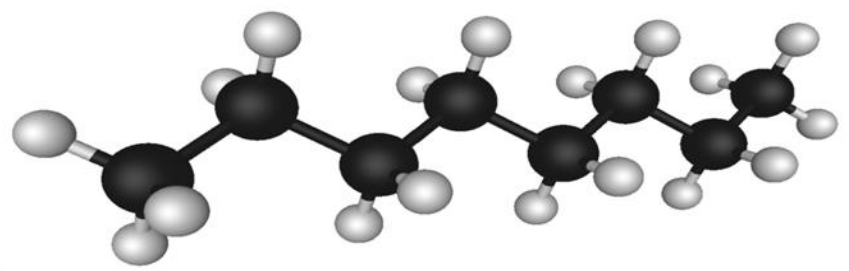
- World oil proved reserves are sufficient to meet 52.9 years of global production.
- OPEC members continue to dominate, holding 72.6% of the global total.
- Global proved reserves have increased by 26% over the past decade.

Origin: Chemistry

en.wikipedia.org/wiki/Image:Petroleum.JPG

Crude Oil

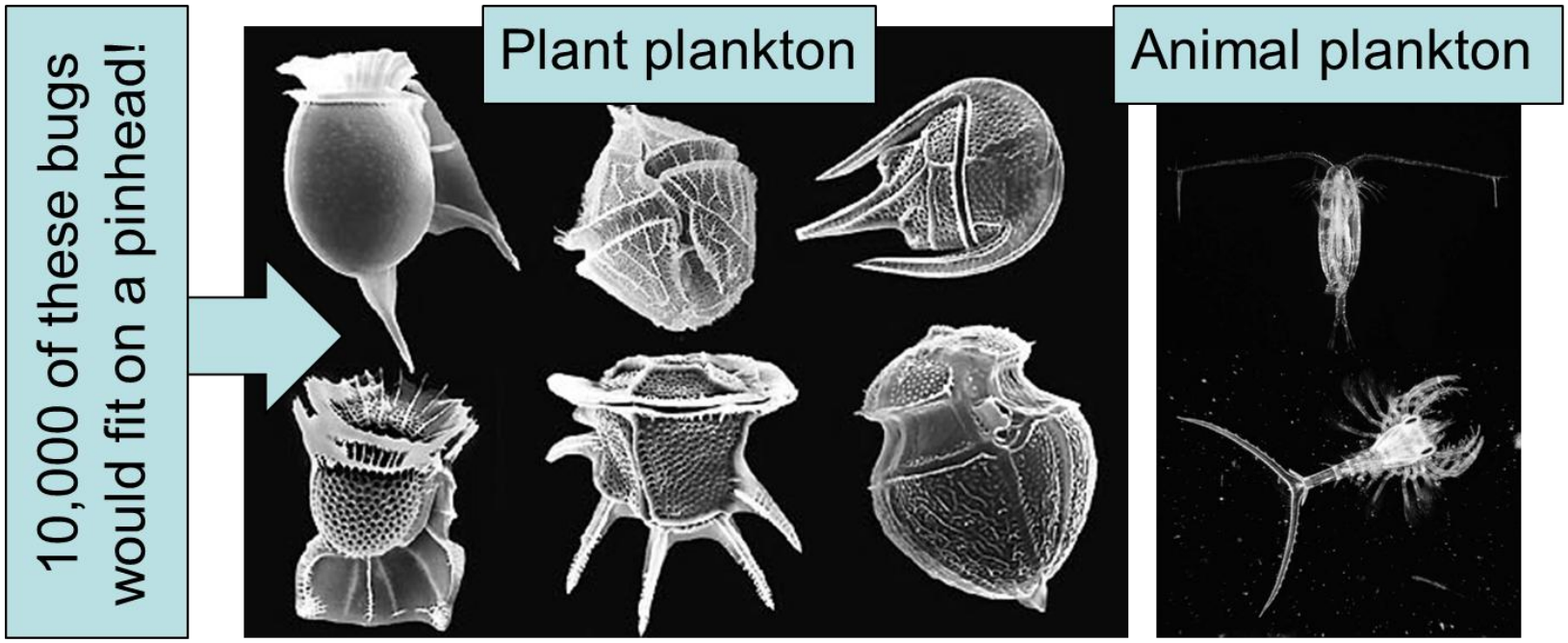
en.wikipedia.org/wiki/Image:Octane_molecule_3D_model.png



Hydrocarbon

- Oil is made of a complicated mixture of different **hydrocarbons.**
- As the name suggests these are large molecules made up of **hydrogen** atoms attached to a chain of **carbon**.
- Short chain HCs (methane) are gases; Medium chain HCs (paraffin) are liquids; Long chain HCs (bitumen) are solids.

Origin: Plankton



Most oil starts life as **microscopic plants and animals** that live in the ocean.

Origin: Blooms

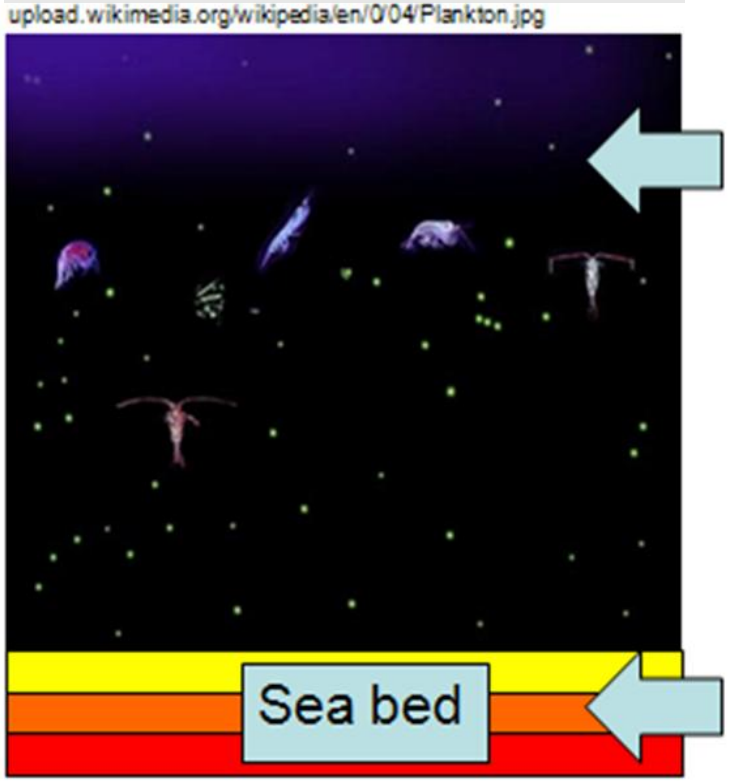
serc.carleton.edu/images/microbelife/topics/red_tide_genera.v3.jpg

Dinoflagellate bloom – red tide.

- Today, most plankton can be found where deep ocean currents rise to the surface.
- This upwelling water is rich in nutrients and causes the plankton to reproduce at high rates generating blooms.
- Blooms of certain plankton called dinoflagellates may give the water a red colour.

Origin: On the sea bed

upload.wikimedia.org/wikipedia/en/0/04/Plankton.jpg



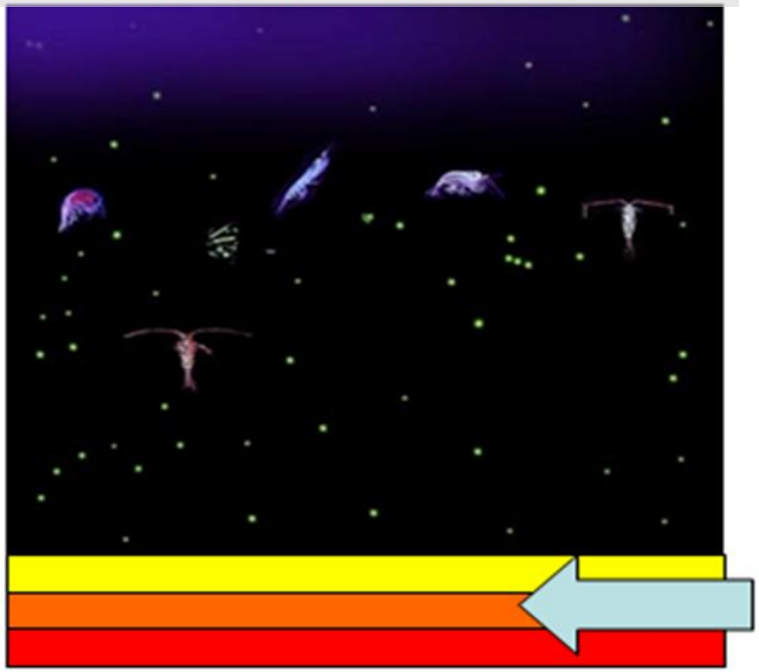
When the **plankton dies** it settles on sea bed to form an organic mass.

en.wikipedia.org/wiki/Image:Nerr0328.jpg

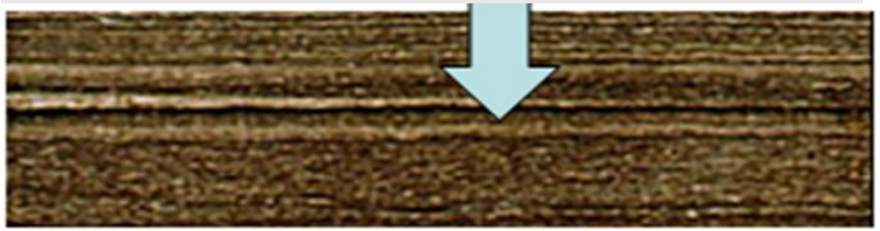
If there are any animals on the sea bed these will feed on the organic particles.

Origin: Black Shale

upload.wikimedia.org/wikipedia/en/0/04/Plankton.jpg



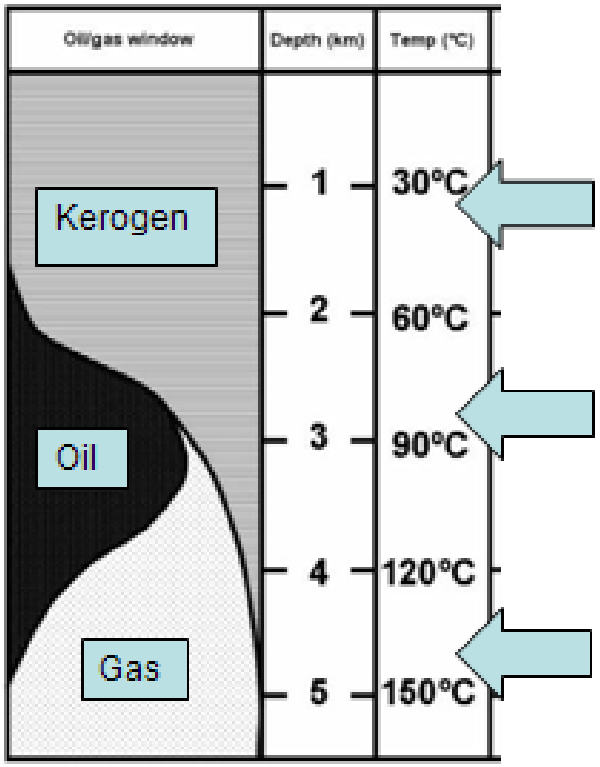
- However, if there is little or no oxygen in the water then animals can't survive and the organic mass accumulates.
- Where sediment contains more than 5% organic matter, it eventually forms a rock known as a **Black Shale.**



Black Shale turns to oil and gas

© Earth Science World Image Bank

Origin: Cooking

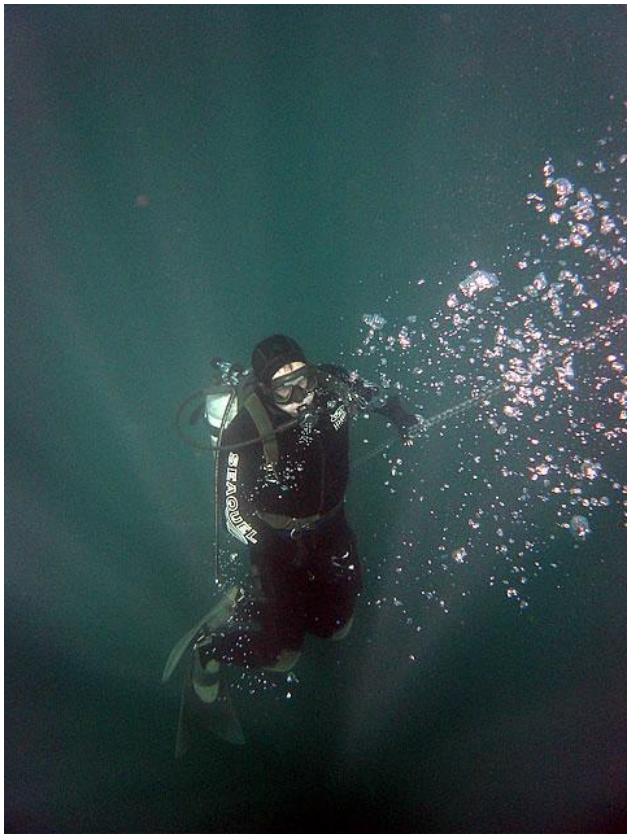


www.oilandgasgeology.com/oil_gas_window.jpg

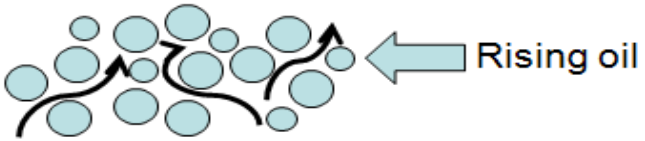
www.oilandgasgeology.com/oil_gas_window.jpg

- As Black Shale is buried in the Earth's crust, **it is heated**, due to the geothermal Gradient.
- Organic matter is first changed by the increase in temperature into kerogen, which is a **solid** form of hydrocarbon.
- Around 90°C, it is changed into a **liquid** state, which we call oil.
- Around 150°C, it is changed into a **gas.**
- A rock that has produced oil and gas in this way is known as a **Source Rock.**

Origin: Migration

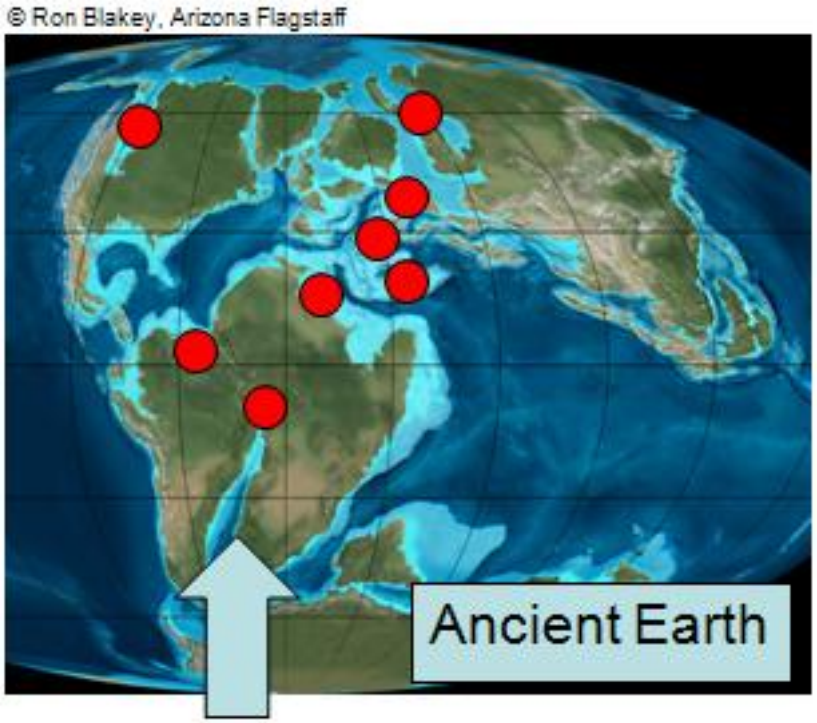


- Hot oil and gas is **less dense** than the water in the source rocks.
- Oil and gas **migrate upwards** up through the rock in much the same way that the air bubbles of an underwater diver rise to the surface.



- The rising oil and gas eventually gets trapped in pockets in the rock called **reservoirs.**

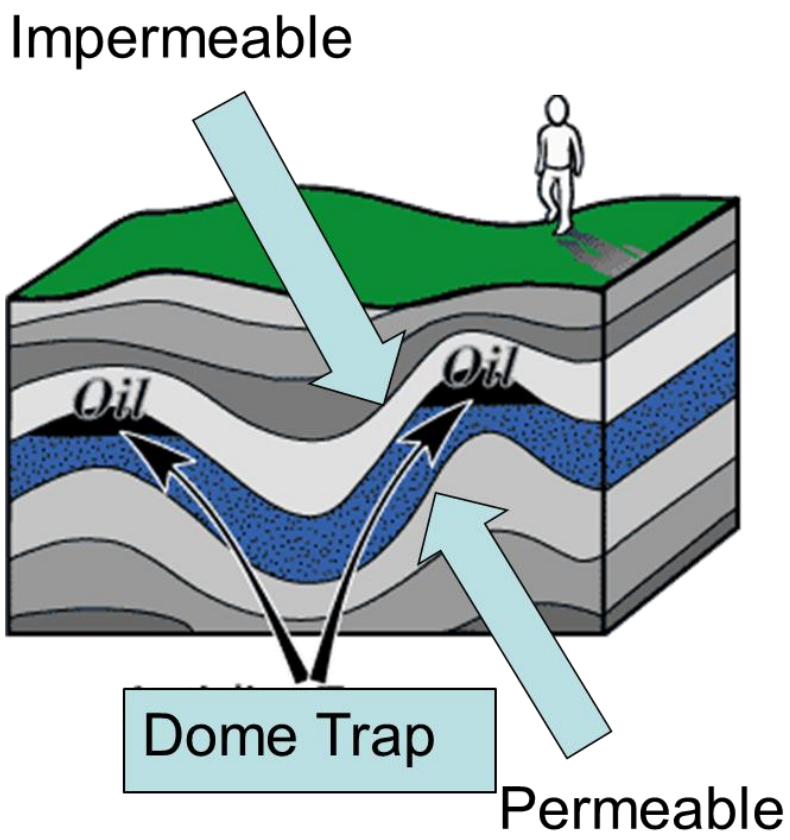
Origin: Ancient Earth



The world's main oil deposits all formed in warm shallow seas where **plankton bloomed but bottom waters were deoxygenated.**

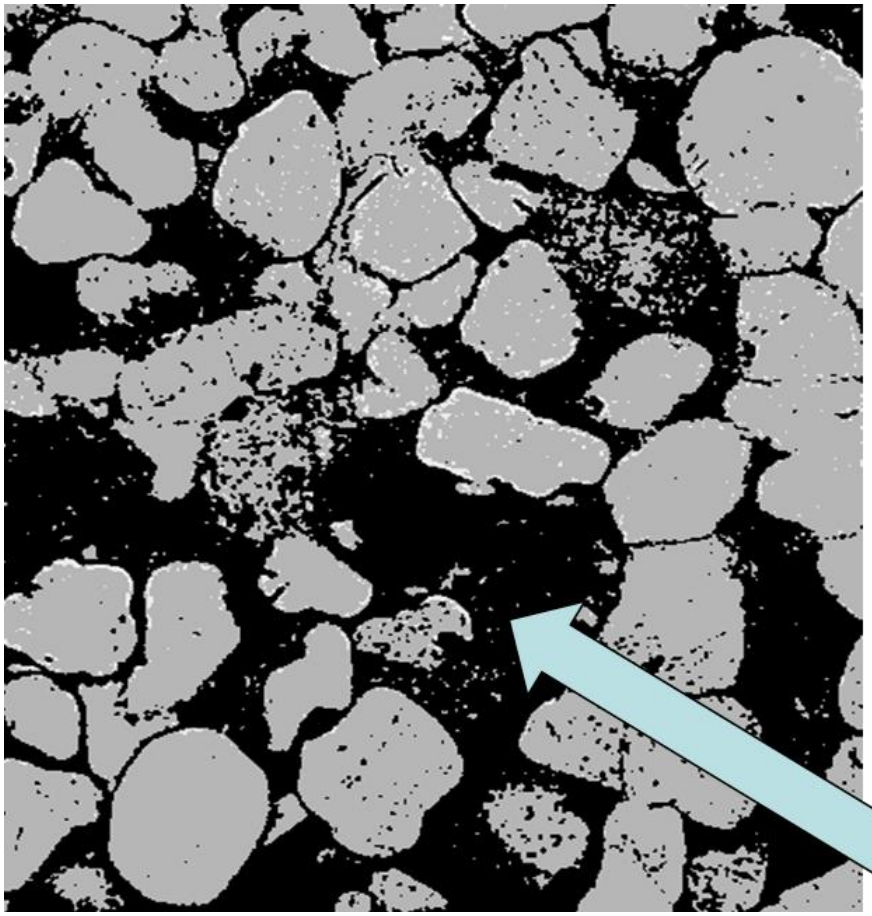
- During mid-Mesozoic times around 150 million years ago, **conditions were just right** to build up huge thicknesses of Black Shale source rocks.

Exploration and Production Oil Traps



- Some rocks are **permeable** and allow oil and gas to freely pass through them.
- Other rocks are **impermeable** and block the upward passage of oil and gas.
- Where oil and gas rises up into a dome (or anticline) capped by impermeable rocks it can't escape. This is one type of an **Oil Trap**.

Exploration and Production Reservoir Rocks

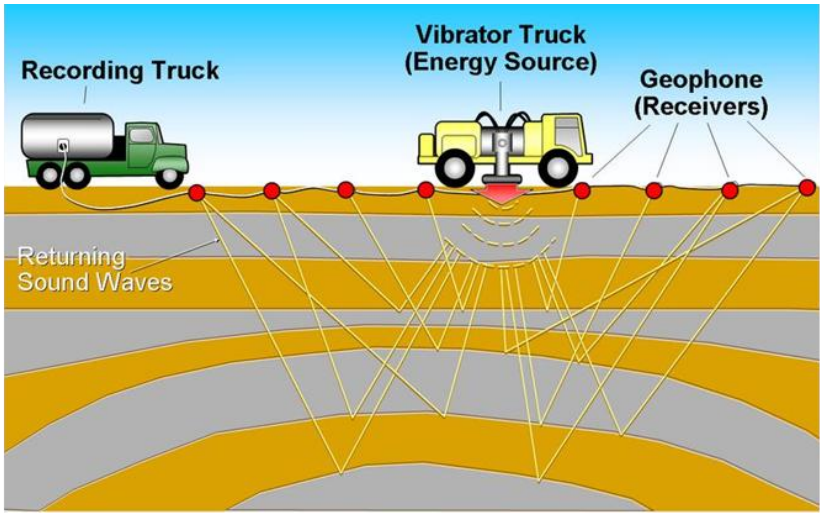


Earth Science World Image Bank Image #h5innl

- The permeable rocks in an oil trap is known as the **Reservoir Rock.**
- Reservoir rocks have lots of interconnected holes called **pores.** These absorb the oil and gas like a sponge.

As oil migrates it fills up the pores (oil-filled pores shown in black).

Exploration and Production Seismic Surveys



Earth Science World Image Bank Image #h5inor

Earth Science World Image Bank Image #h5inpj

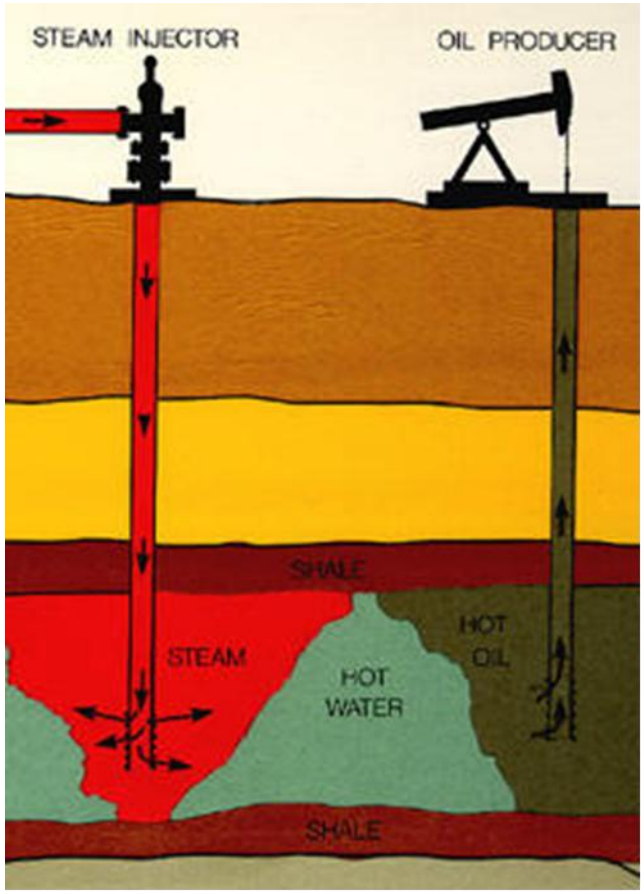
- Seismic surveys are used to locate likely rock structures underground in which oil and gas might be found.
- **Shock waves** are fired into the ground. These bounce off layers of rock and reveal any structural domes that might contain oil.

Exploration and Production Drilling the well

en.wikipedia.org/wiki/Image:Oil_platform.jpg

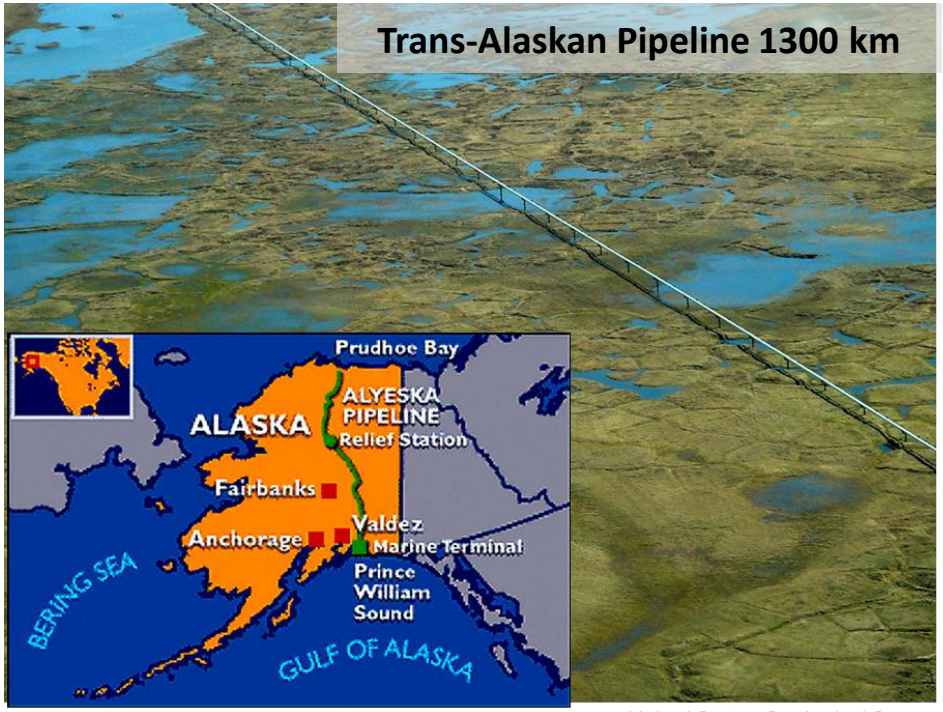
- Once an **oil prospect** has been identified, a hole is drilled to assess the potential.
- The cost of drilling is very great. On an offshore rig, it may cost **$10,000 for each meter drilled.**
- A company incurs vast losses for every “dry hole” drilled.

Exploration and Production Enhanced Recovery



- Although oil and gas are less dense than water and naturally rise up a well to the surface, in reality **only 40-50%** of the total will do so.
- To **enhance recovery**, a hole is drilled adjacent to the well and steam is pumped down. The hot water helps to push the oil out of the rock and up into the well.

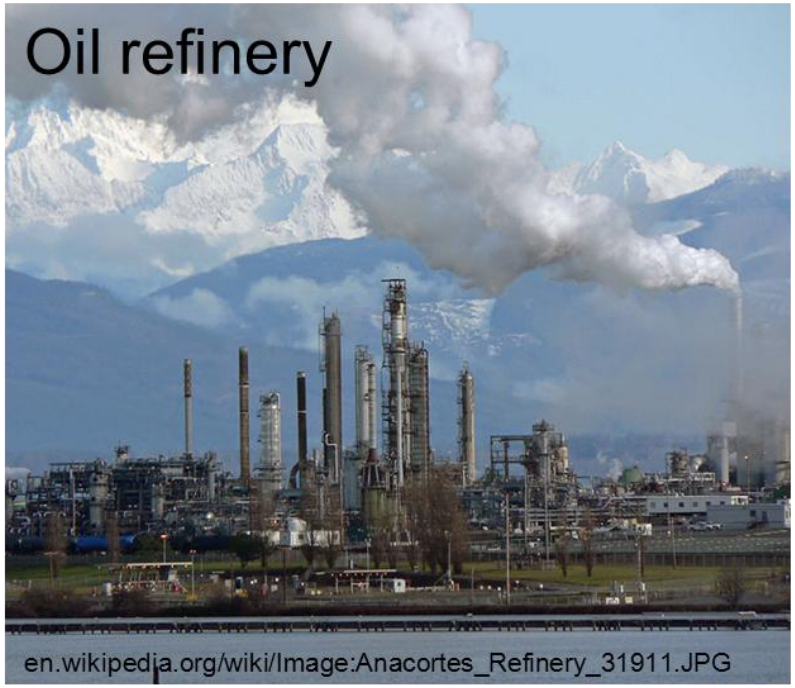
Exploration and Production Transport

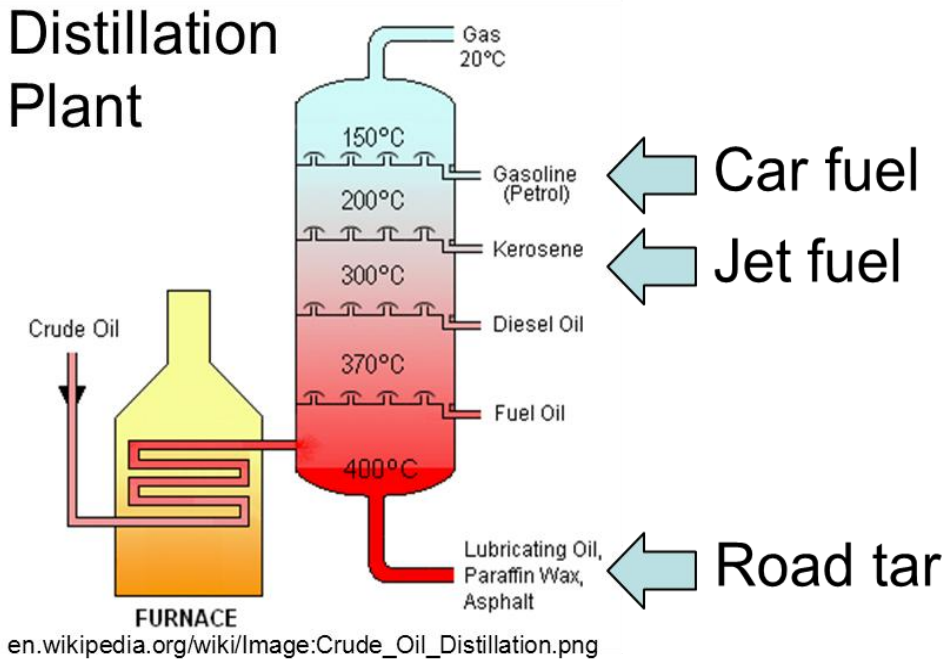


United States Geological Survey

- Once extracted oil and gas must be sent to a refinery for processing.
- **Pipelines** transport most of the world's oil from well to refinery.
- Massive **Oil Tankers** also play an important role in distribution.

Exploration and Production at the Refinery (1/3)

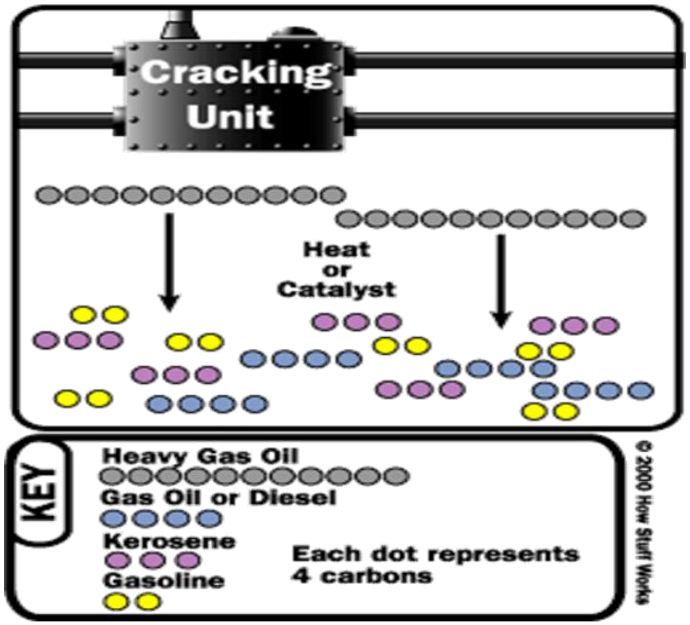




- Before it can be used crude oil must be refined.
- Hydrocarbons can be separated using **distillation**, which produces different fractions (or types) of oil and gas.

Exploration and Production at the Refinery (2/3)

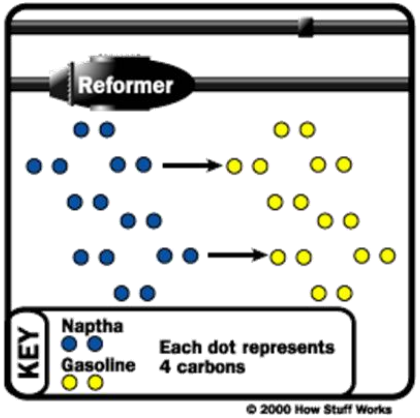
- Further chemical processing is required in order to make products such as gasoline of various grades, lubricating oils, kerosene, jet fuel, heating oil, chemicals for plastics and other polymers. It is possible to change one fraction into another through these three methods; cracking, unification, and alteration.
- Cracking takes large hydrocarbons and breaks them into smaller ones.



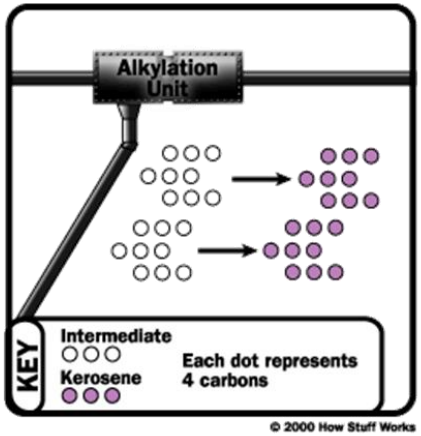
http://science.howstuffworks.com/oil-refining5.htm

Exploration and Production at the Refinery (3/3)

- Unification is the process where smaller hydrocarbons are combined to make larger ones. The main unification process is called catalytic reforming and uses a catalyst to combine low weight naphtha into aromatics which are used in making chemicals and in blending gasoline.
- Alteration: The structures of molecules in one fraction are rearranged to produce another. Commonly this is done using alkylation- low molecular weight compounds are mixed in the presence of a catalysts.



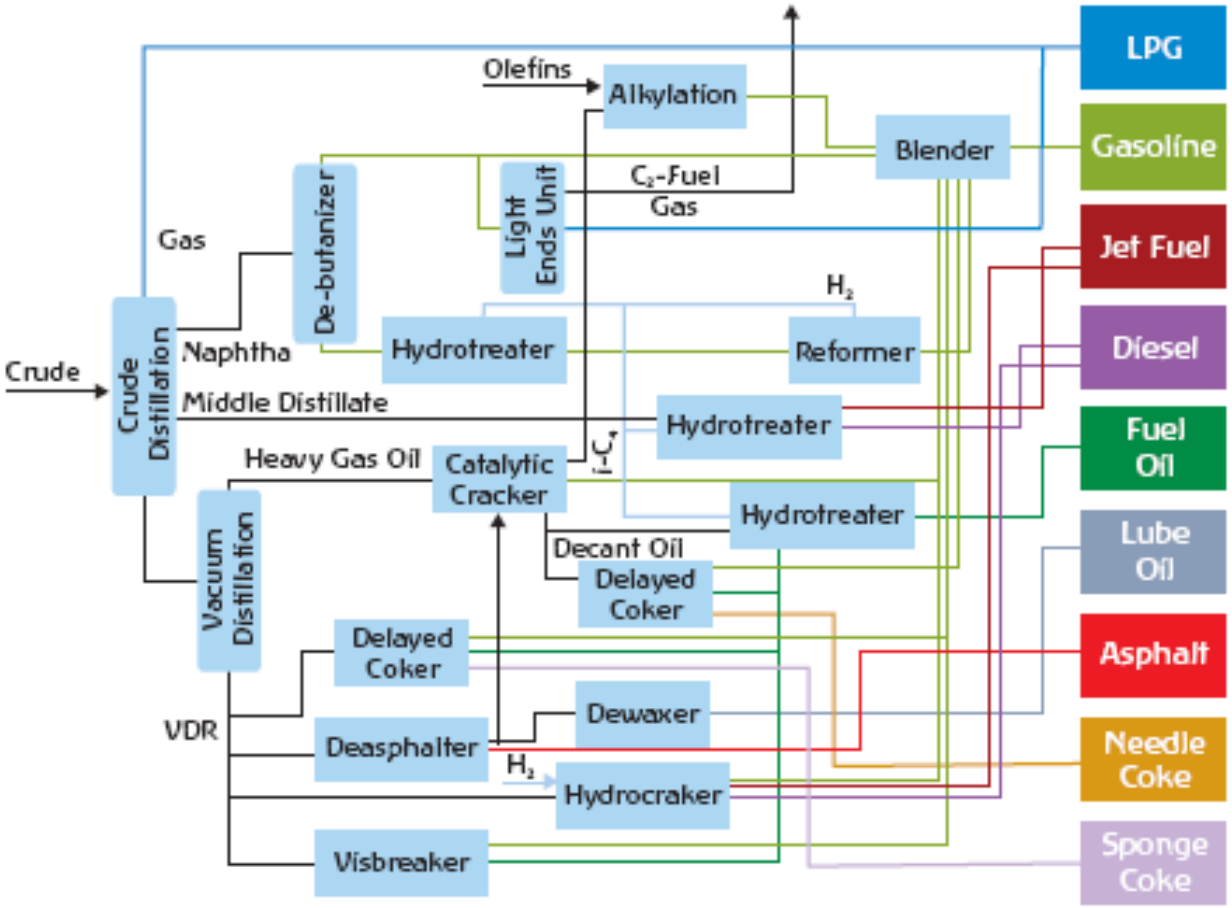
http://science.howstuffworks.com/oil-refining5.htm



http://science.howstuffworks.com/oil-refining5.htm

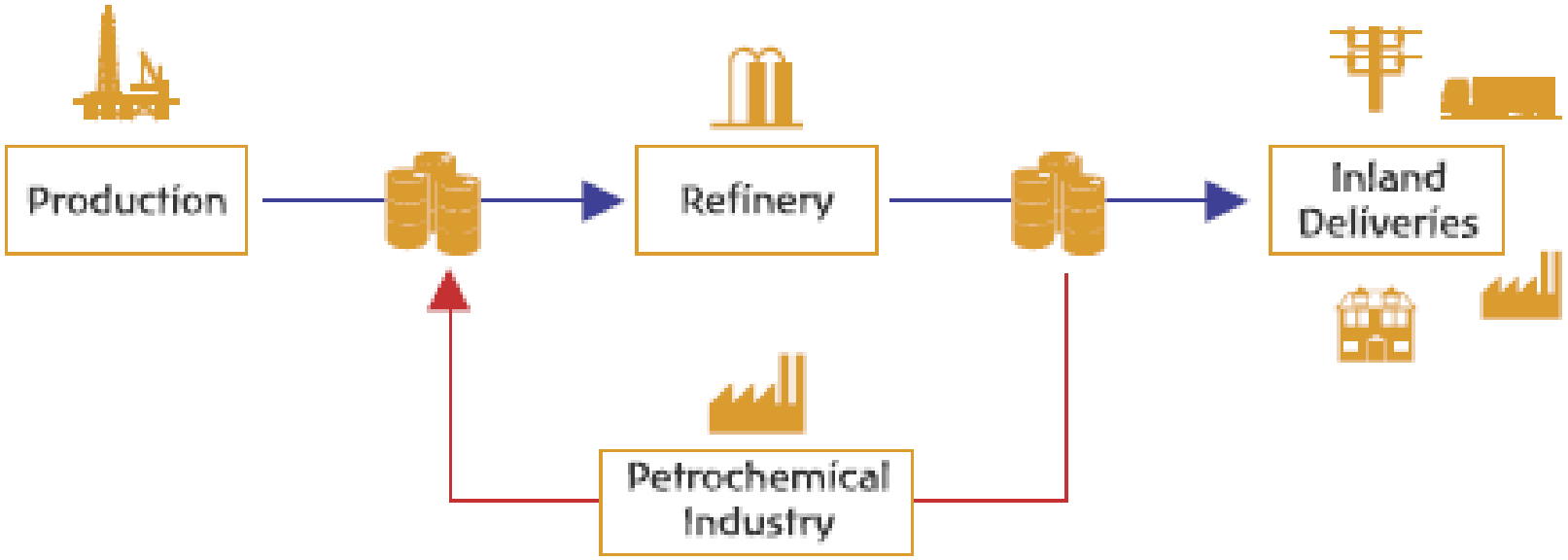
Processes in a Refinery

Figure A1.6 • Operation of a Typical Refinery

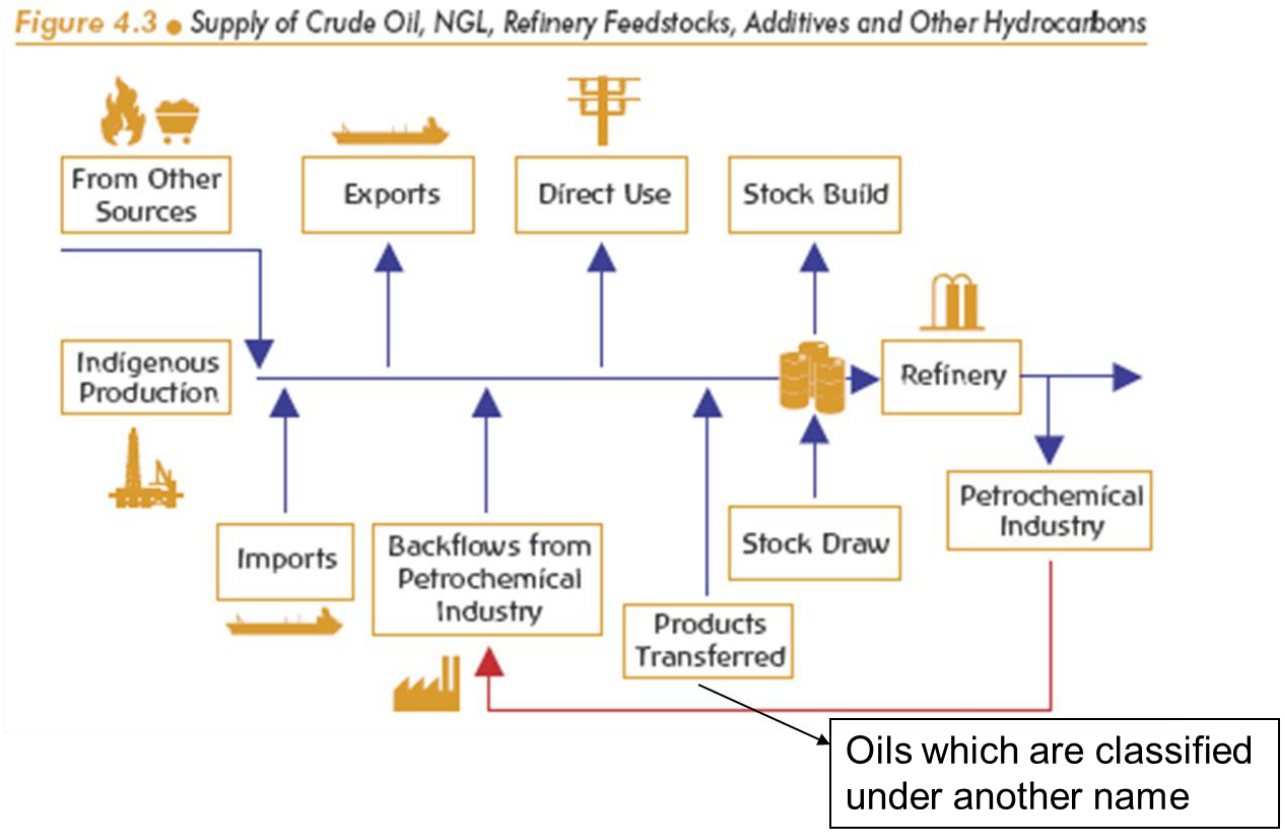


Oil flows

Figure 4.1 • Simplified Flow Chart for Oil



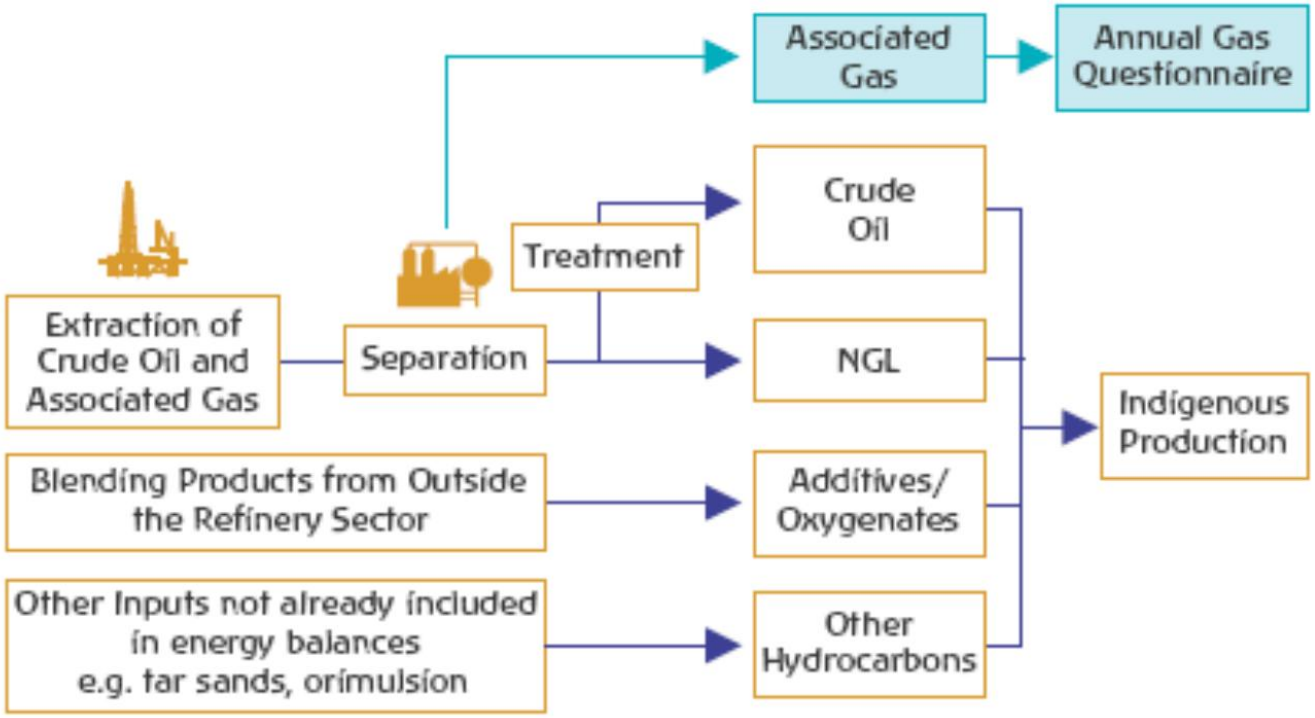
Oil supply (1/3)



The oil supply chain is consisting of the supplies of crude oil and finished products and flows of the petrochemical industry.

Oil supply (2/3)

Figure 4.4 • Simplified Flow Chart for Indigenous Production



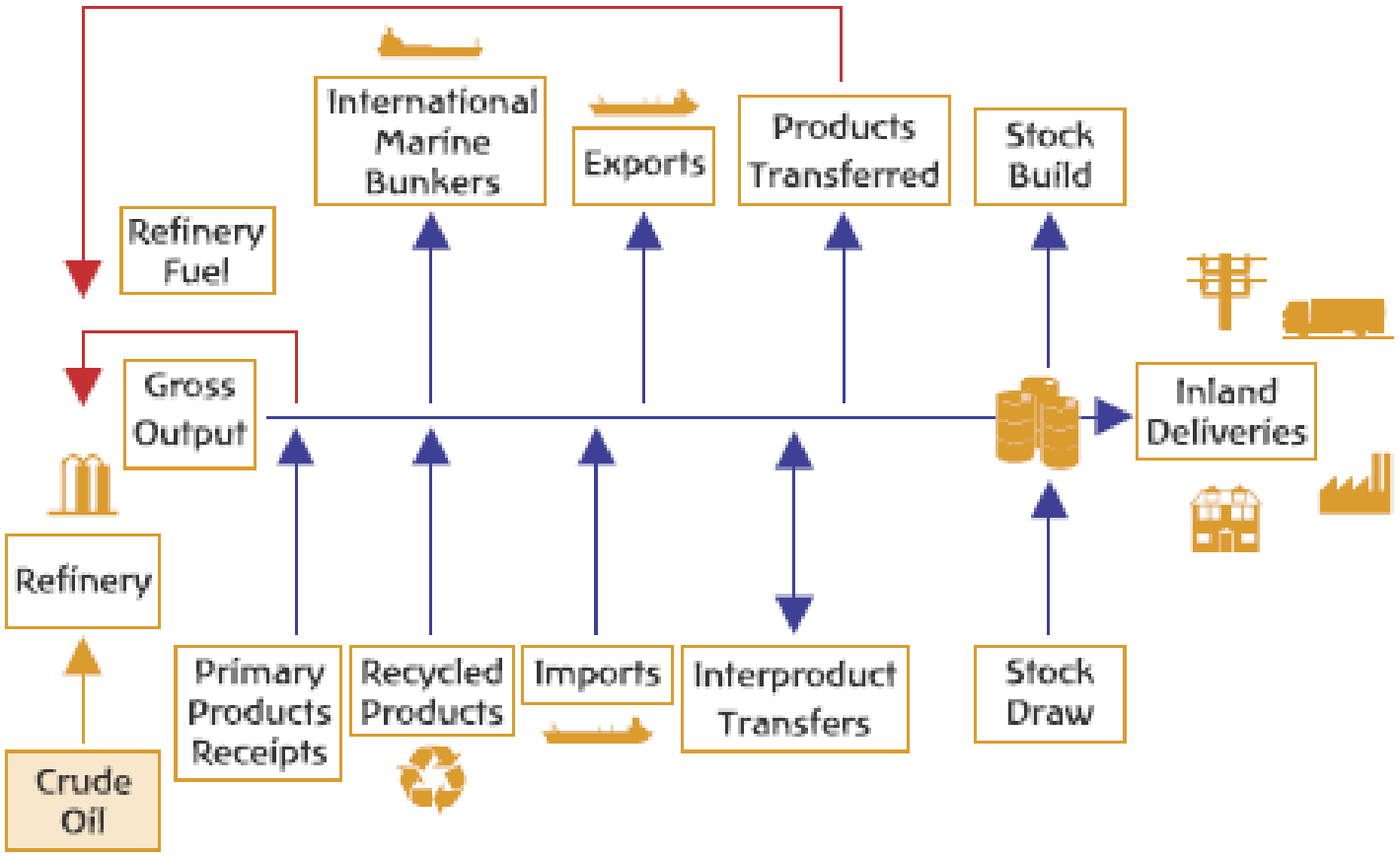
Refinery Output is the production of finished products.
NGL: Natural gas liquids

Oil Supply (3/3)

- Crude oil is produced from different locations, onshore or offshore fields or from different types of wells, in association with NG or not.
- Crude oil from the well, is a mixture of oil, water, sediment and dissolved gases (CH_4, C_2H_6, C_3H_8, butane, pentanes).
- Initially, all gases are separated from the oil/water mixture due to their high marketable value (e.g., LPG). In the following, the sediment and other unwanted substances are removed in treatment plants.
- The most important characteristics of crude oil are its specific gravity and S content that determine its quality and price.
- The energy balance also include the additives (oxygenates) and other hydrocarbons (e.g., shale oil).

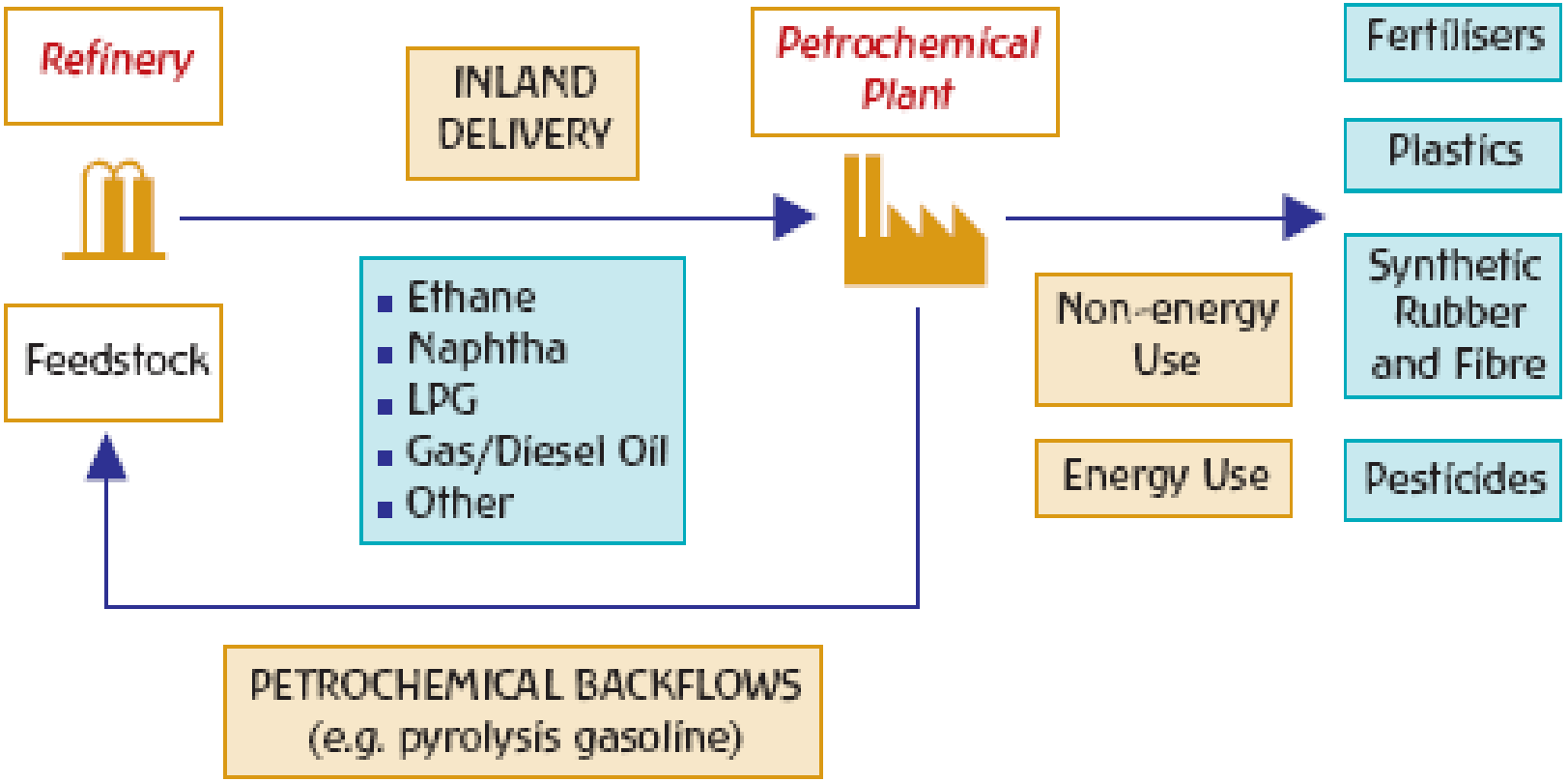
Supply of finished products

Figure 4.5 • Supply of Finished Products



Petrochemical Flows

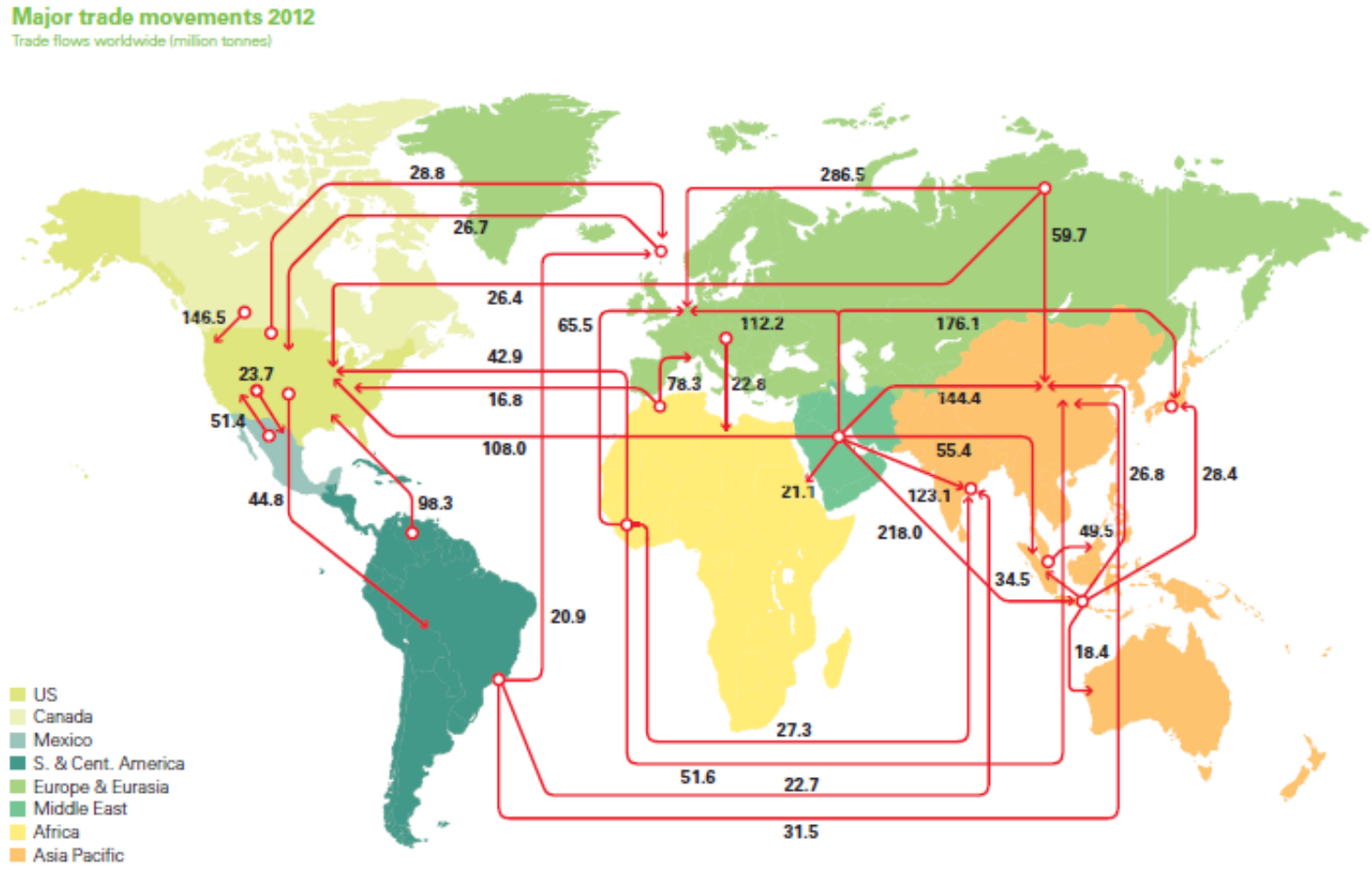
Figure 4.6 • Deliveries to the Petrochemical Sector



Imports and Exports of Oil

- Oil is often found far from consuming markets. 2/3 of the reserves of crude-oil are either in the Middle East or in Russia, while almost 90% is consumed in other areas.
- Oil can be transported in tankers, pipelines, railways and trucks (vast transportation network).
- Is important to know from which supplier country you are dependent.

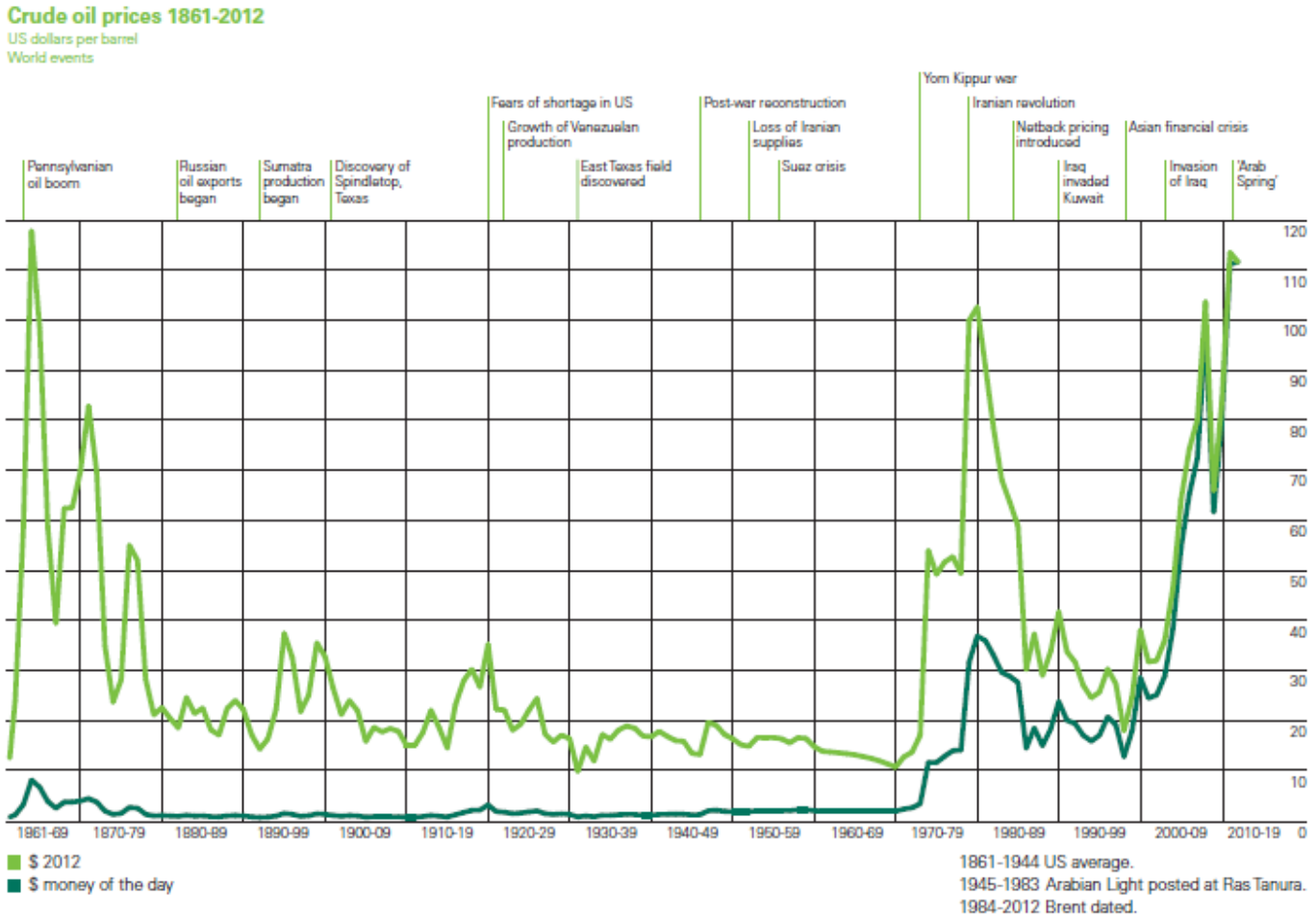
2012 – OIL – TRADE MOVEMENTS



Stock levels and changes of Oil

- Oil stocks are a critical element of information in an oil balance.
- Stocks allow for the balance between supply and demand; stocks are drawn to help meet demand when supply falls short, while a stock build offers an outlet for oil products to flow when supply exceeds demand.
- Stocks are a leading indicator of prices.
- Oil stocks are important for strategic decisions.
- Primary stocks are held by the various companies supplying the markets. They are held in refinery tanks, bulk terminals, pipeline tankage, barges and coastal tankers.
- Secondary stocks are those held in small bulk plants
- Tertiary stocks are corresponding to end-consumers.

2012 – OIL PRICES

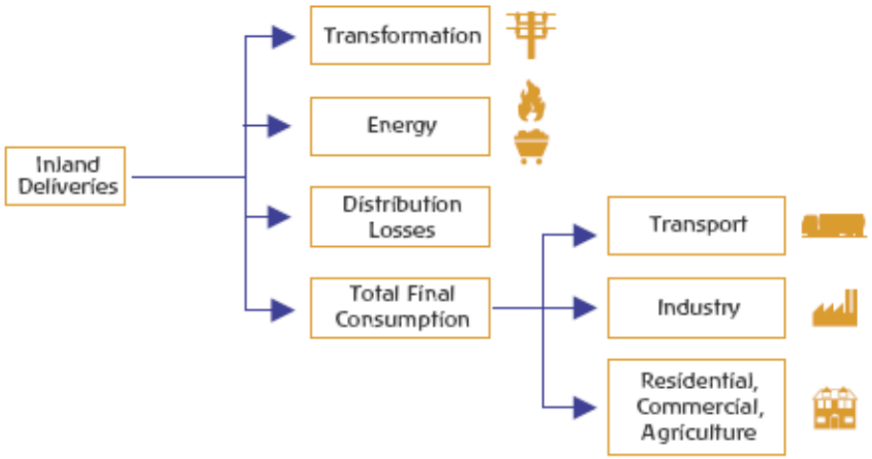


Oil Consumption

Oil consumption occurs in the following main sectors:

- In the transformation sector.
- By the energy industries in the energy sector.
- In the transportation and distribution of oil (although limited).
- In the various sectors and branches of final consumption (industry, residential, etc.), including both energy and non-energy uses of oil.

Figure 4.7 • Oil Consumption by Sector



- **The use of oil products in the generation of electricity (now 8%) has been in steady decline since the 1970s (25%).**

Oil Transport and Distribution losses

- The transportation and distribution of petroleum products often involve multiple episodes of handling and storage.
- Transporting means: by sea, pipeline, railway and roadway.
- Ways of oil-losses: a tanker splits at sea, pipeline leakages, train car derailments, tanker truck accidents.

Coal Overview

Solid Fossil Fuels & Manufactured Gases (1/3)

- Solid fuels and manufactured gases cover various types of coals and products derived from coals.
- Primary coal is a fossil fuel, usually with the physical appearance of a black or brown, consisting of carbonized vegetal matter.
- The higher the C content of a coal, the higher the quality.
- Coal types have different physicochemical characteristics determining their price and suitability for various uses.
- Derived fuels include both solid fuels and gases produced during coal processing and by coal transformation.

Solid Fossil Fuels & Manufactured Gases (2/3)

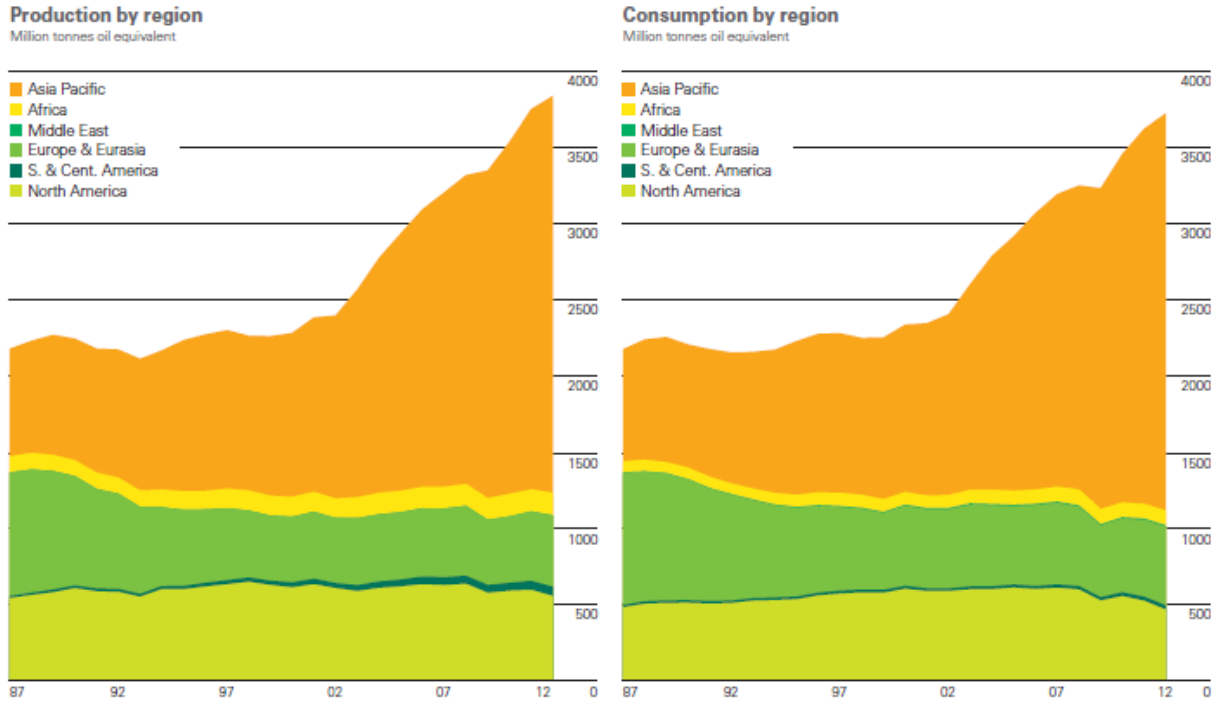
- Coal is categorized in hard coal (GCV= 23865 kJ/kg), sub-bituminous coal and brown coal (lignite, GCV= 17435 kJ/kg).
- Hard coal is divided to coking coal (blast furnaces), and other bituminous coal and anthracite (space heating) and steam coal.
- The secondary products include patent fuels, briquettes, gas and coke-oven cokes, gas-work gas, etc.
- The share of coal in global primary energy supply has been stable over the last 30 years at around 25%, a 56% growth compared to 1973.
- Coal consumption has dramatically increased for electricity production (250%), while the corresponding consumption in the residential sector decreased by 65%.

Solid Fossil Fuels & Manufactured Gases (3/3)

Table 5.1 • Primary and Derived Coal Products

PRIMARY COAL PRODUCTS	Coking coal	SOLID FOSSIL FUELS
	Other bituminous coal and anthracite	
	Sub-bituminous coal	
	Lignite/brown coal	
	Peat	
DERIVED FUELS	Patent fuels	
	Coke-oven coke	
	Gas coke	
	Briquettes	
	Gas-works gas	MANUFACTURED GASES
	Coke-oven gas	
	Blast-furnace gas	
	Oxygen steel-furnace gas	

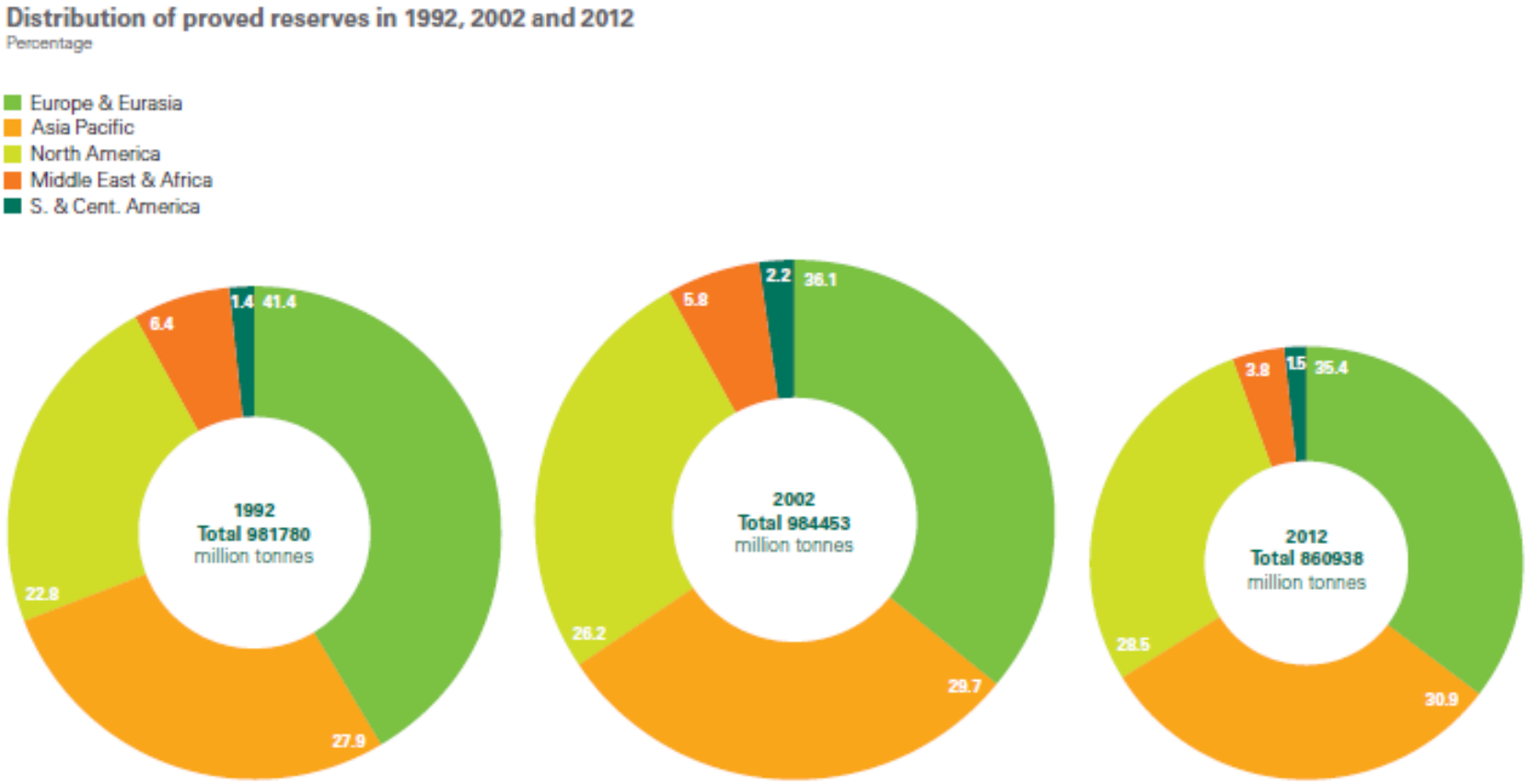
2012 – Coal Production / Consumption



- Global coal production grew by 2%. The Asia Pacific region accounted for all of the net increase, offsetting a large decline in the US.
- Coal consumption increased by a below-average 2.5%.
- A second consecutive large decline in N. America (-11.3%).

2012 – Coal Consumption per capita

2012 – Coal Proved Reserves



2012 – Coal Reserves to Production

- World proved reserves of coal are sufficient to meet 109 years of global production, by far the largest R/P ratio for any fossil fuel.
- Europe and Eurasia holds the largest regional reserves.

Coal Composition

- Carbon > 50%.
- Impurities:
    - Volatile Matter.
    - Sulphur.
    - Chlorine.
    - Phosphorus.
    - Nitrogen.
- Trace amounts:
    - Dirt.
    - Other elements.

Coal Varieties

- Lignite (brown coal)
  - Relative youngest, softest
  - Least valuable, lowest energy density
- Sub-bituminous
  - Higher energy density
  - Over 40 percent of US production
- Bituminous
  - Highest energy density
  - Half of US production
- Anthracite
  - Metamorphic, 86-97% carbon
  - Less abundant

Coal Rank

Ranks of Coal	Fixed Carbon	Volatile Matter	Moisture
Lignite	29	26	46
Subbituminous	42	34	23
Low-rank/volatile bituminous	47	41	12
Medium-rank/volatile bituminous	54	41	5
High-rank/volatile bituminous	65	32	3
Low-rank/volatile semibituminous	75	22	3
Semianthracite	86	12	3
Anthracite	96	1.2	3

Coal Grade

- Describes size, appearance, weight, structure, cleanliness, heat value and burning characteristics.
    - A: Superior < 8% ash.
    - B: Good: 8-12% ash.
    - C: Fair: 12-16% ash.
    - D: Poor >16% ash.

Coal Extraction

- Open Pit Mining:
  - Most minerals are extracted this way.
  - For near-surface ore bodies.
  - Series of ‘benches’ are cut.
- Used when coal is close to the surface.

Underground Mining

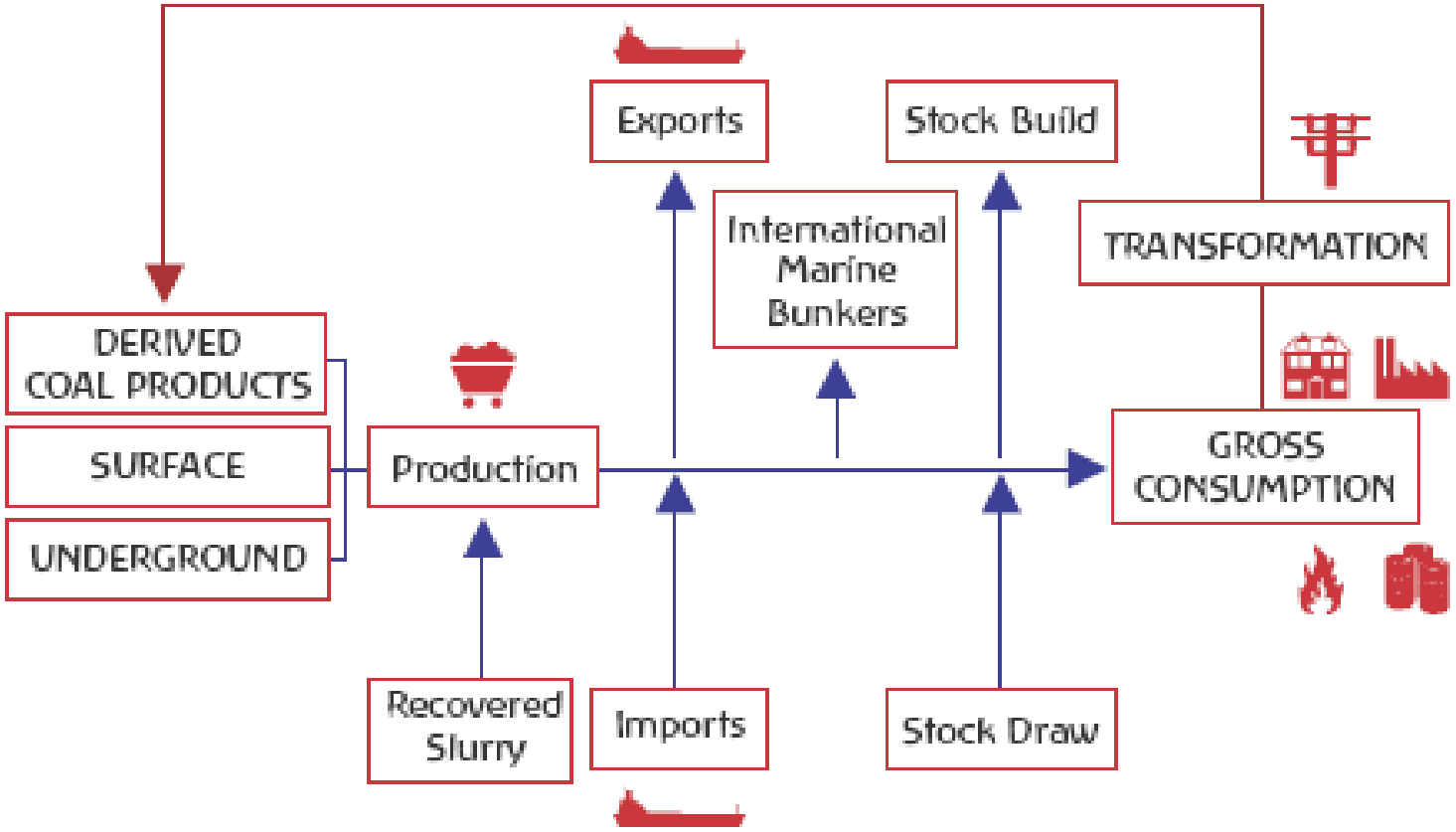
- Used when ore is far below surface.

Coal Supply and Coal Imports & Exports

- Most primary coal production occurs either in underground mines or in operational (surface) mines.
- Some production can also come from recovery of coal from waste piles, slurry ponds, etc.
- Coal is a product that is easily transported over long distances either by boat or train.
- Hard coal trade accounts for about 20% of the world hard coal consumption.
- For the other coal products, the amounts of imports and exports are usually extremely limited.
- Primary coal products due to their solid state and relatively inert character are often held in stock to cover periods of higher demand.
- Stocks are defining the price.

Coal Flows

Figure 5.1 • Simplified Flow Chart for Coal



Coal Consumption

- In the transformation sector.
- By the energy industry within the energy sector.
- In the transport and distribution of fuels (although very limited).
- In the various sectors and branches of final consumption (industry, residential, etc.). This includes both energy and non-energy uses of the fuels.

- Transformation plants to derive energy from solid fossil fuels include patent fuel plants, coke ovens, gas-works plants, blast furnaces as well as electricity plants, CHP plants and liquefaction plants for synthetic oil.
- The largest use of primary coal products is for the generation of electricity and heat (67% hard coal and 92% brown coal).
- The traditional use of gases manufactured at integrated steel mills is to heat the transformation plants.
- Besides the transformation plants, solid fossil fuels and manufactured gases can be use to produce energy (consumption of coal to support the extraction and preparation of coal within the coal-mining industry).

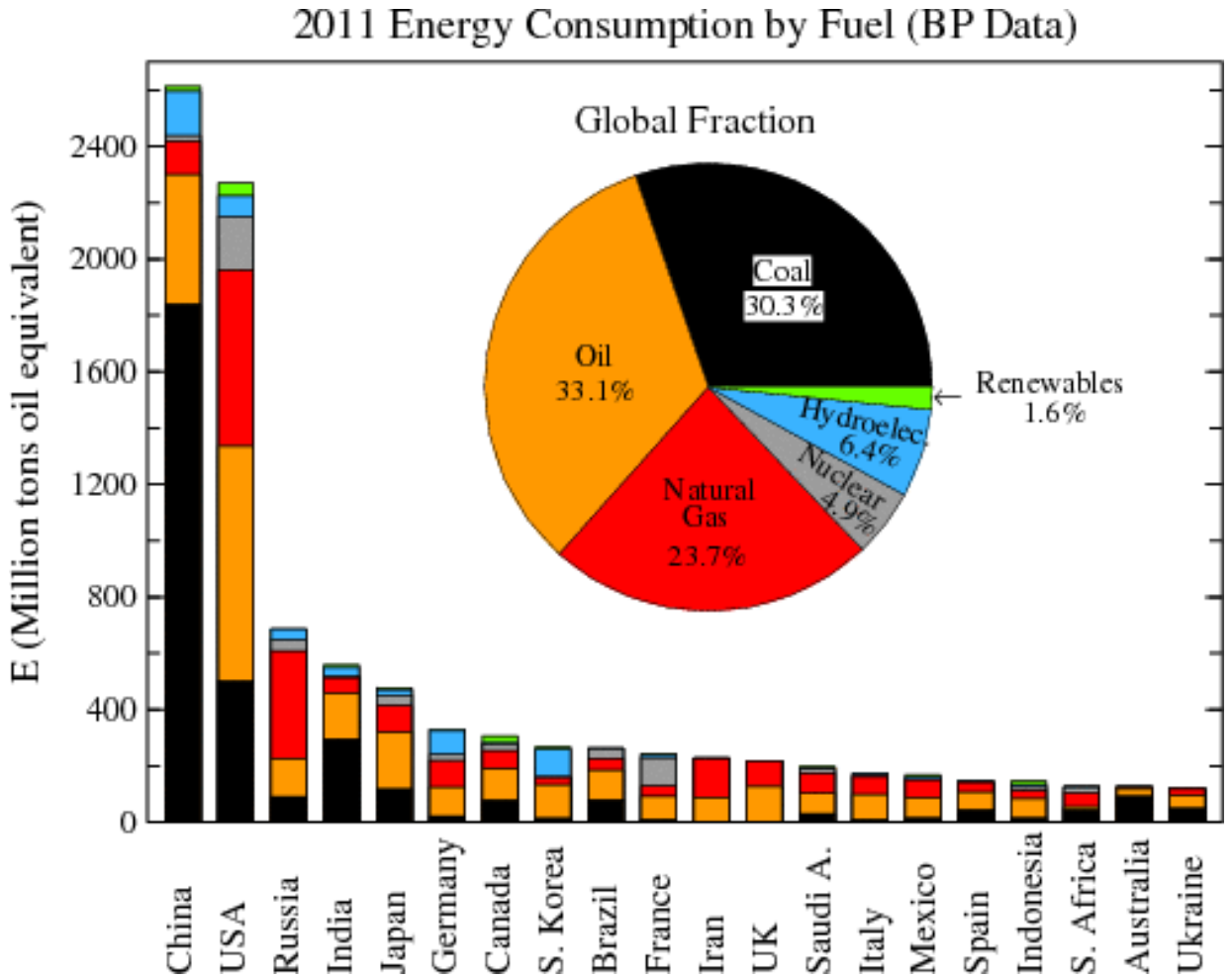
Coal Transport and Distribution losses

- Solid product is lost through various ways:
    1. Coals shipped by rail experience small losses during their movement in open hopper cars.
    2. Accidents and derailments on rail lines.
    3. During storage, coals and solid fuels tend to “settle” and a residue of fuel is left in the soil or in the pads.
    4. “Fugitive” dust.
  - Manufacturing gases are lost during distribution due to leaks, and accidental or deliberate venting reaching sometimes the losses observe in the case of NG that is transported over long distances.
- The losses of coal (0.04%) are much more limited compared to oil, NG (1%) and electricity (8.7%).
- The losses are minimal for solid fuels and apply mainly to manufactured gases.

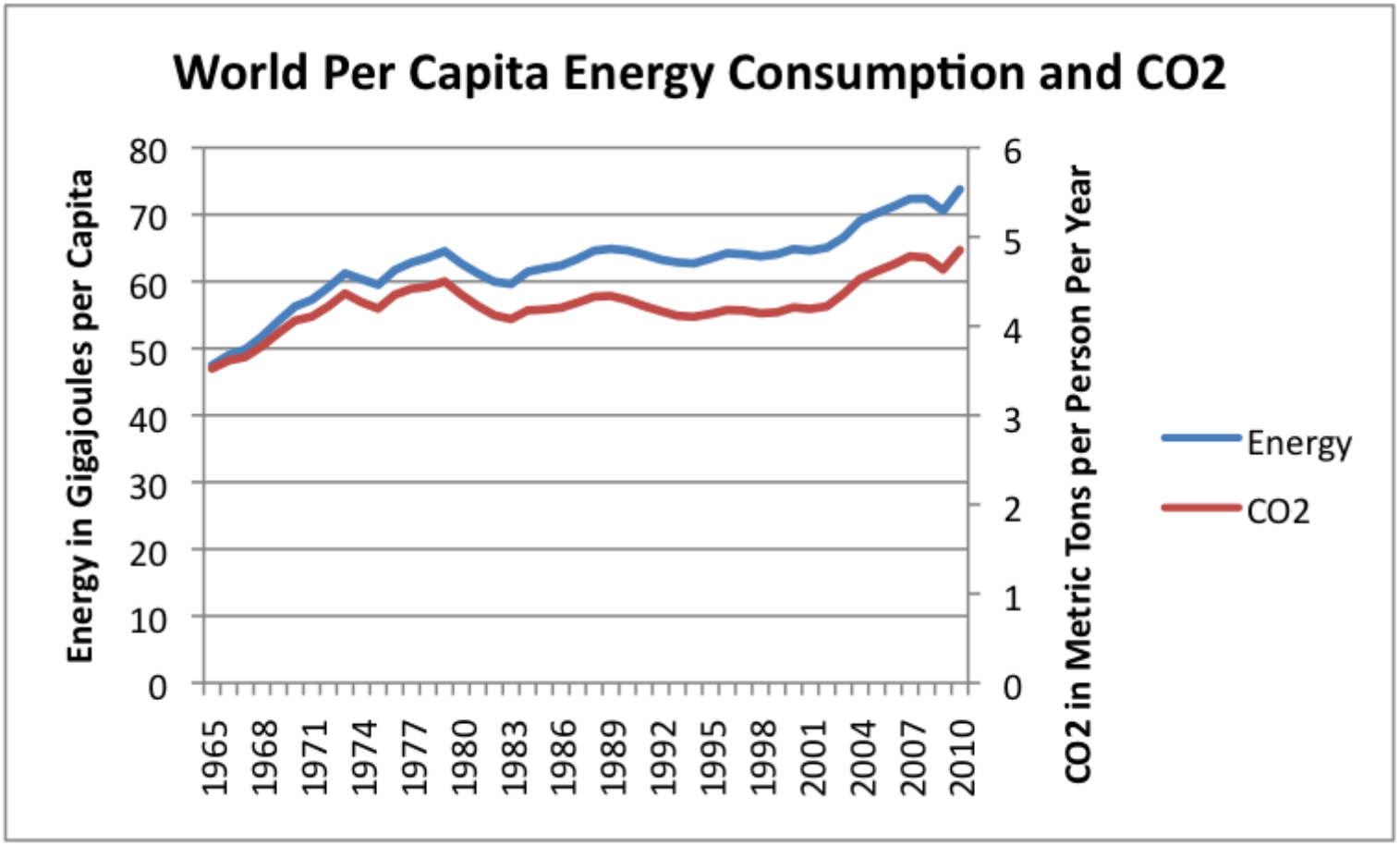
Coal Final Consumption

- Final energy consumption of coals and coal products outside the transformation sector is primarily in the industry (e.g., cement) sector accounting around 15% of total coal supply.
- In the past a large quantity of coal was used in the transport sector (e.g. ships, rail locomotives), however nowadays this consumption has declined to only 0.2%.
- Other sectors including services and residential, where coal is used for heating purposes account for 0.5% in global coal demand.
- The use of coal for non-energy purposes is very small (less than 0.1%).

Primary World Energy Consumption (2011)



Correlation
Energy & Environment



Air pollution - Definition

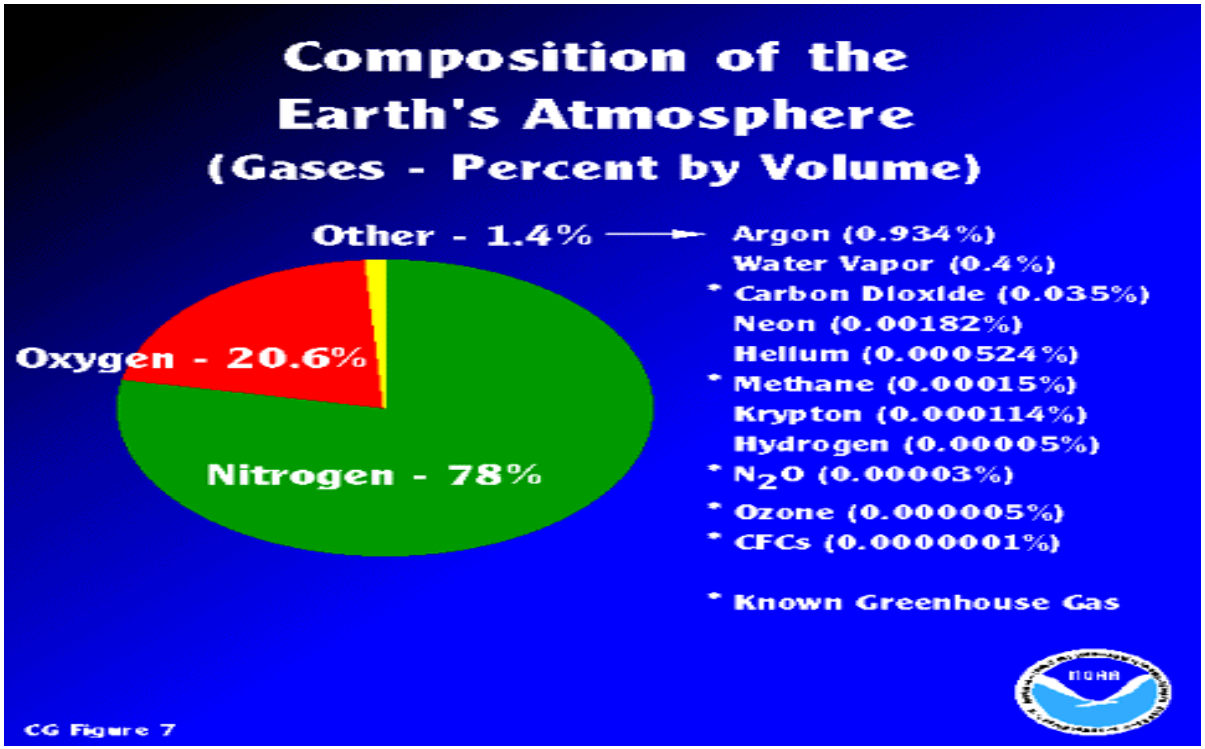
- *The presence of one or more chemicals in the atmosphere in sufficient quantities and duration to cause harm to humans etc.*

- Air pollution results from human activities such as burning fossil fuels to create electricity and power automobiles, and manufacture industrial products.

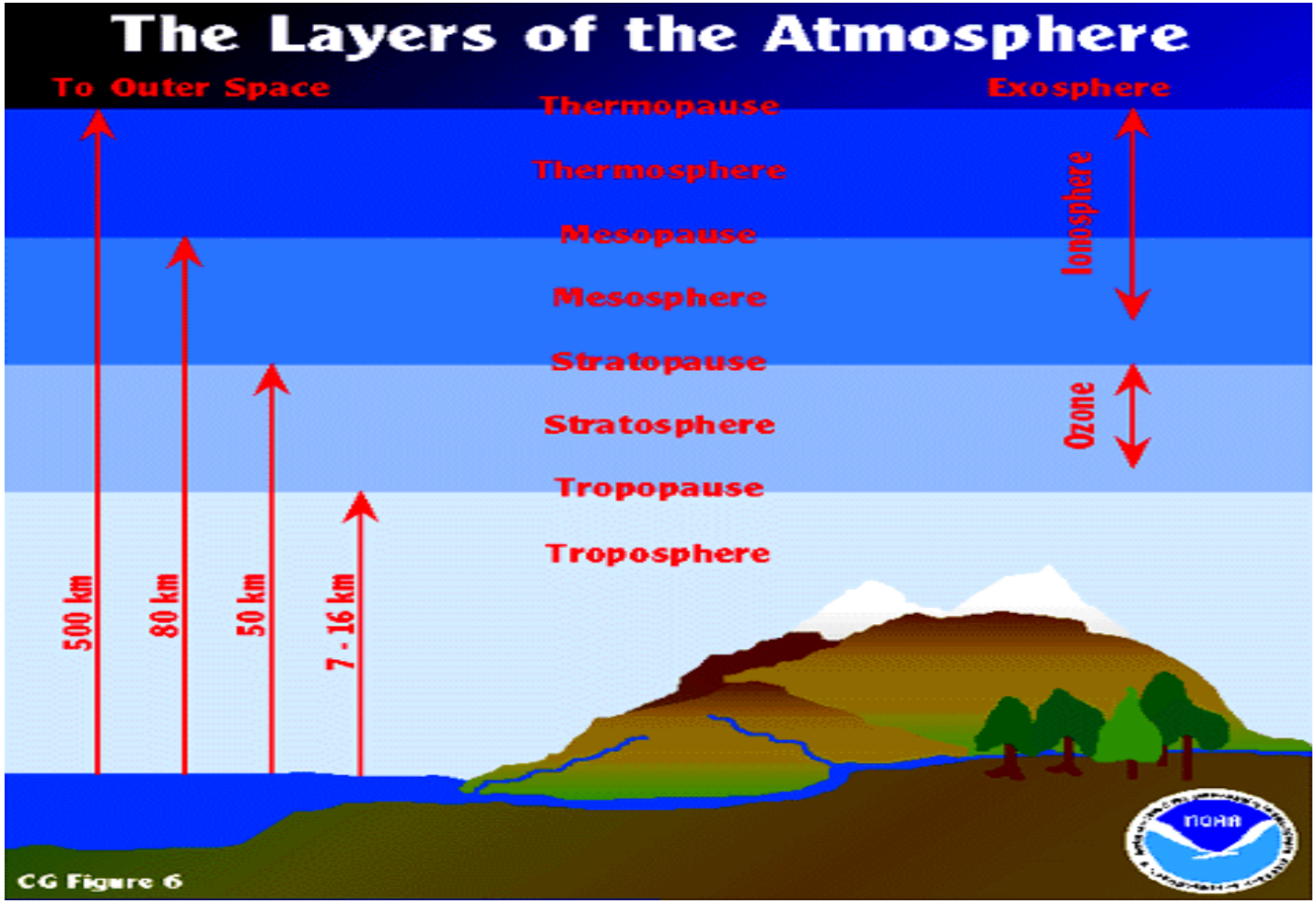
- The air Pollutants are particulates, HC, CO_2, CO, NO, NO_2, SO_2 .

The Atmosphere

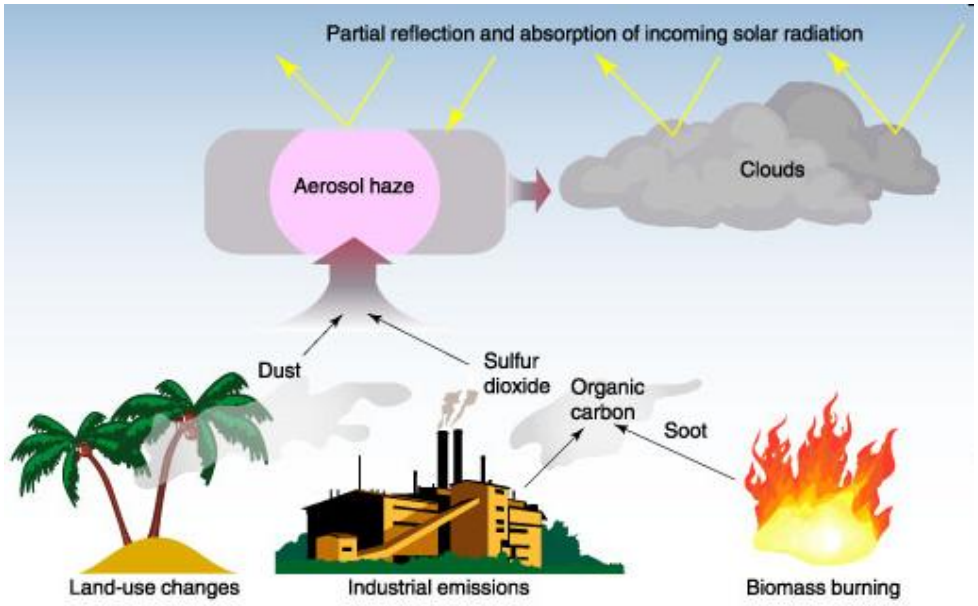
- **Gases that envelop the Earth.**



Layers of the atmosphere



Sources of Air pollution



- **Natural:**
  - volcanoes, fumaroles and hot springs,
  - increase ozone due to thunderstorms, fires.

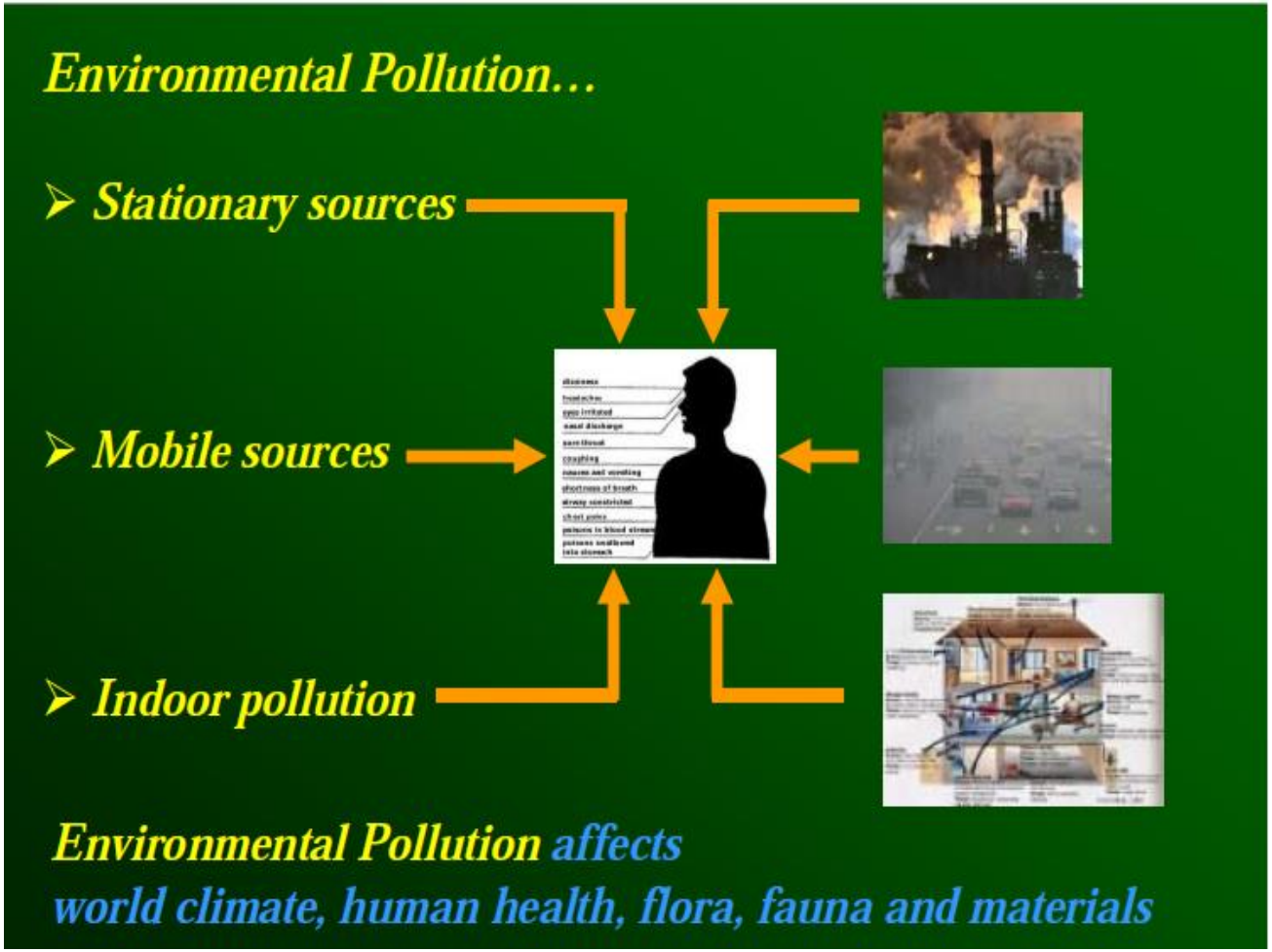
Man made

- **Stationary sources** - those that are fixed in location.
- point sources e.g. smoke stacks, 14% air pollution from plants generating electricity;
- fugitive sources e.g. construction sites, exposed areas;
- area sources e.g. dense urban community or agricultural area.
- **Mobile sources** - those that move while polluting, e.g. trucks, cars, busses etc. 60% of air pollution from motor vehicles. 80-88% in major cities!

The main categories of air pollutants

- **Primary:** those emitted directly into the air; e.g. sulfur dioxide (SO_2), carbon monoxide (CO), nitric oxide (NO), nitrogen dioxide (NO_2).
- **Secondary:** those that form as a result of a chemical reaction of the primary pollutant with a natural component of the environment.; e.g. some ozone, sulfuric and nitric acids.

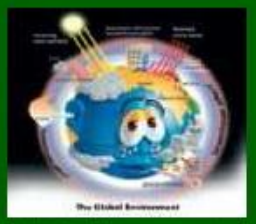
Environmental Pollution



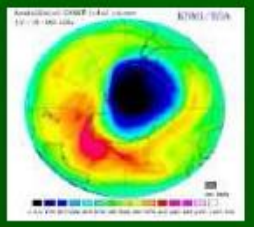
Environmental effects

Pollution Effects in worldwide scale…

- ***Greenhouse effect***
  (CO_2, CFCs, CH_4, N_2O, O_3)

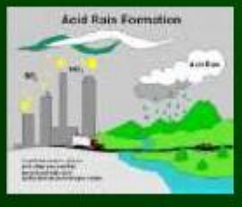


- ***Ozone depletion (CFCs)***



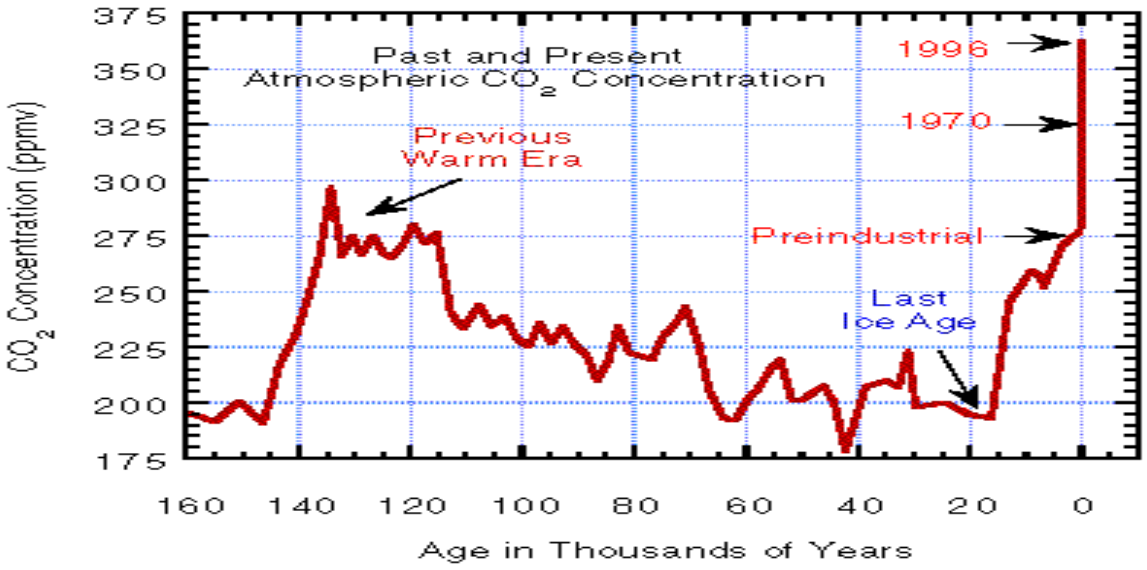
- ***Photochemical smog***
  (NO_X, C_XH_Y, O_3, PM)

- ***Acidification***
  (SO_X, NO_X, H_2S)

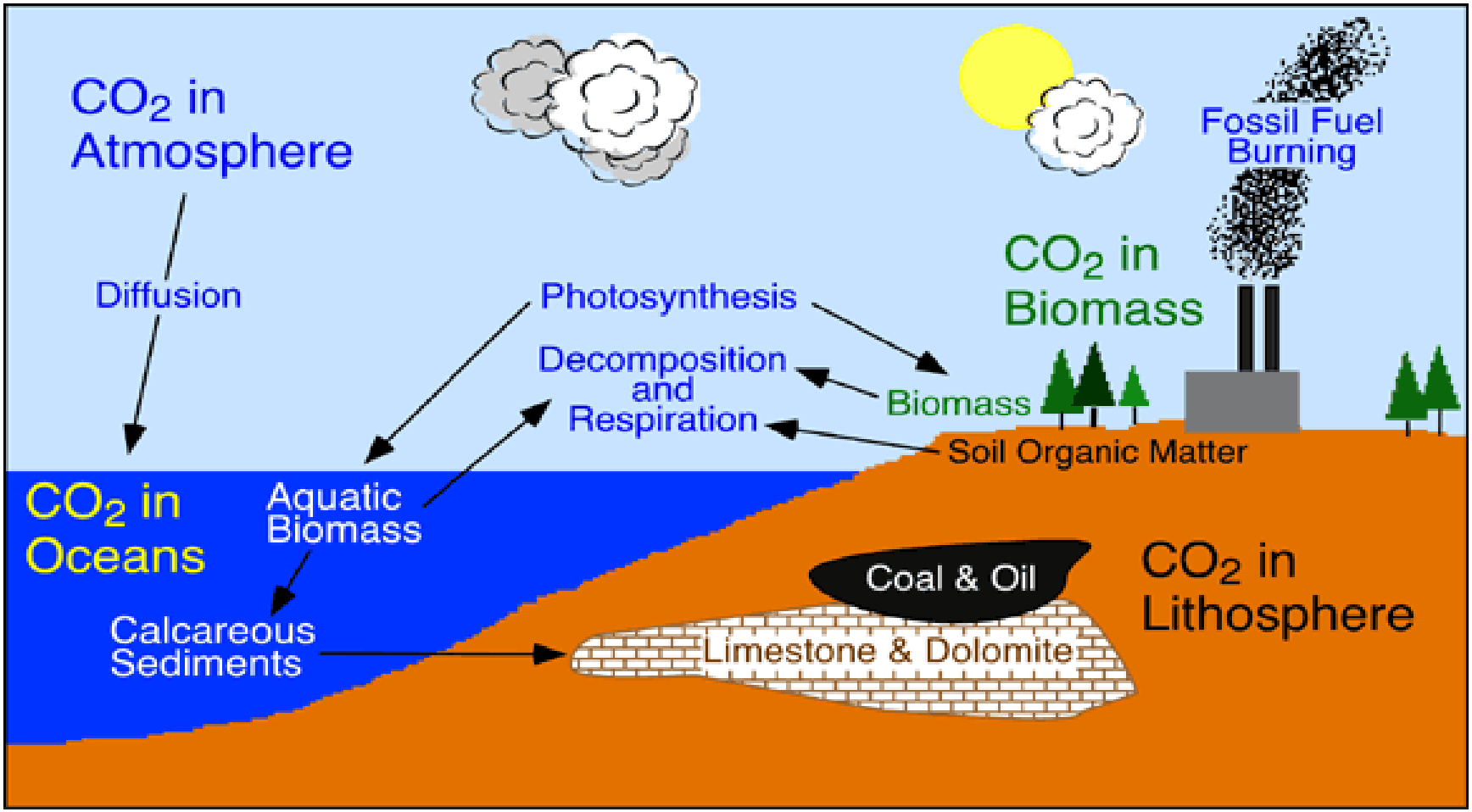


Doubling of carbon dioxide

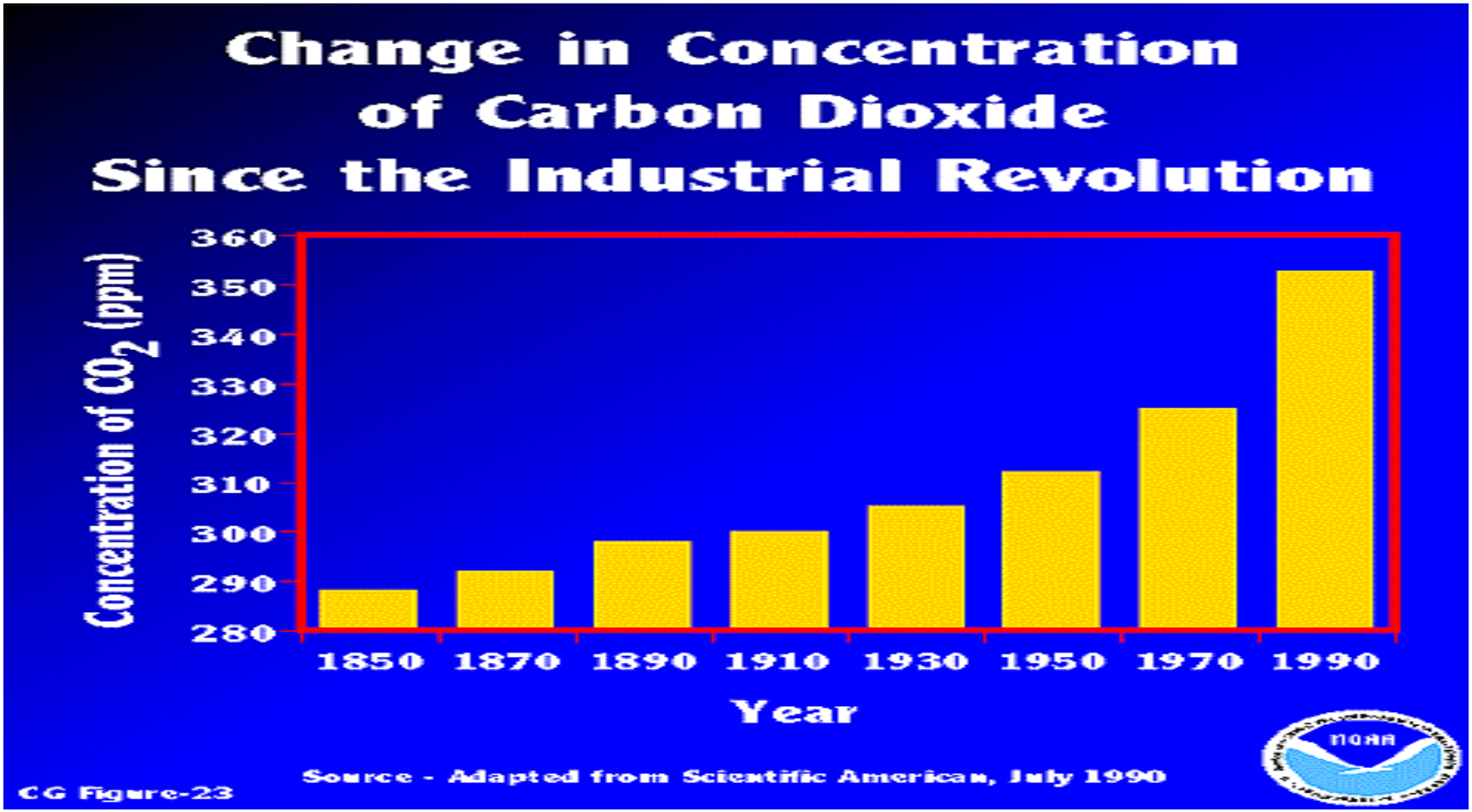
- In 1850, atmospheric carbon dioxide was about 280 ppm. Today, it is about 350 ppm.
- This increase is due largely to burning of fossil fuels and clearing of forests.
- Oceans (and photosynthetic organisms) currently absorb half of the carbon dioxide emitted.



Cycle of carbon dioxide

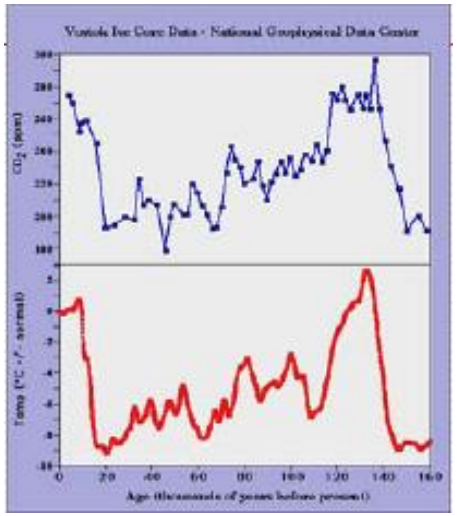


Concentration of carbon dioxide

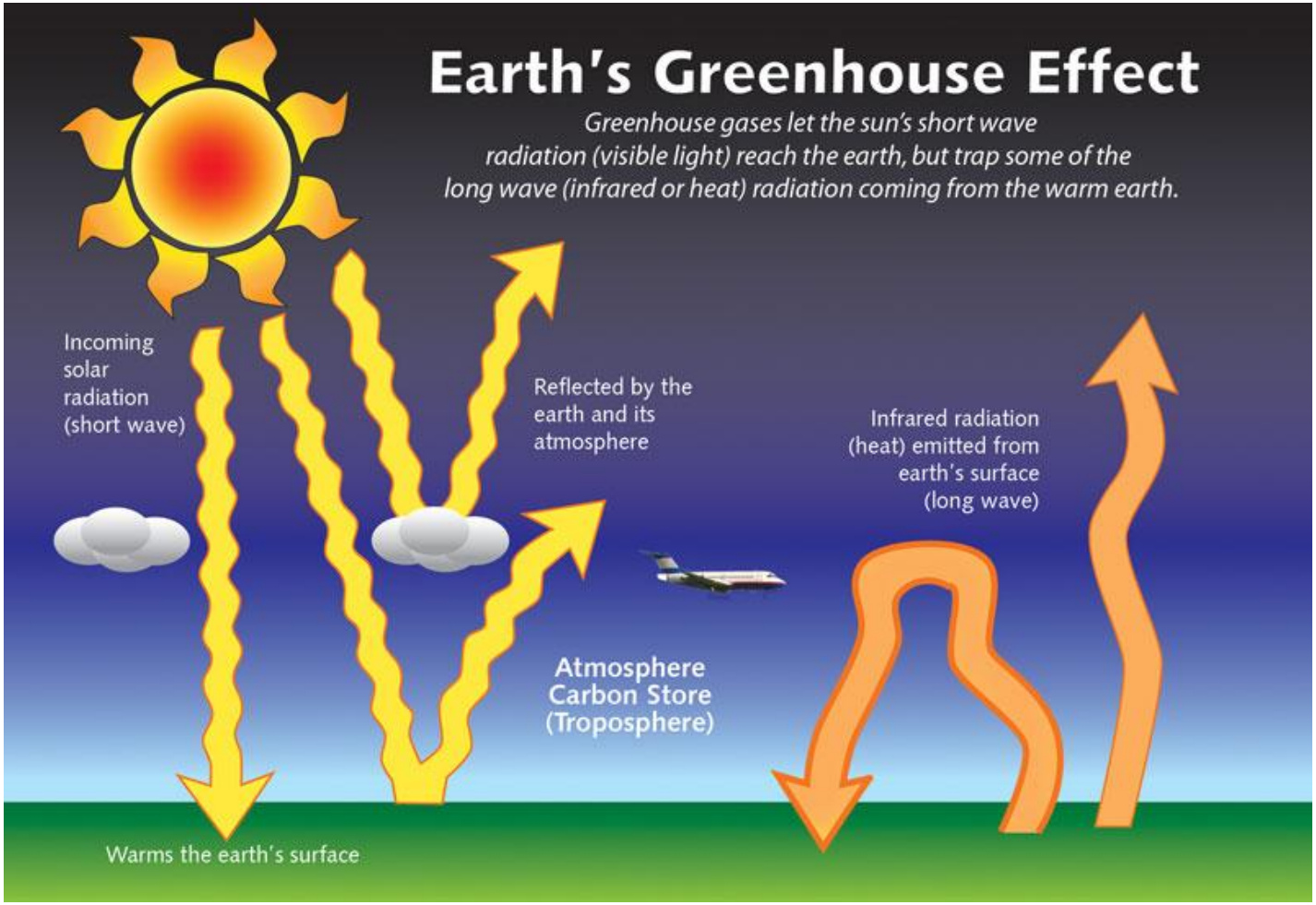


Impact of increasing CO2 levels

- Increased photosynthesis and productivity by the earth's vegetation.
- Increased plant production also means increased respiration.
- Elevated atmospheric CO_2 is **global warming.**
- Elevated CO_2 means an increase in global temperature - **the greenhouse effect.**
- Global temperatures may increase by 3-4^oC by the end of the next century .



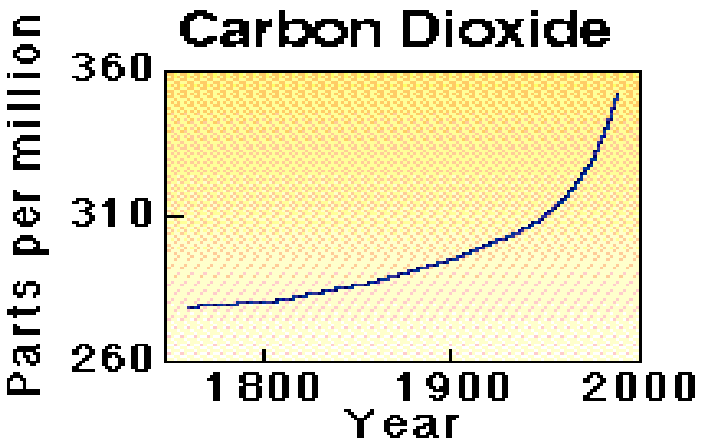
Greenhouse effect

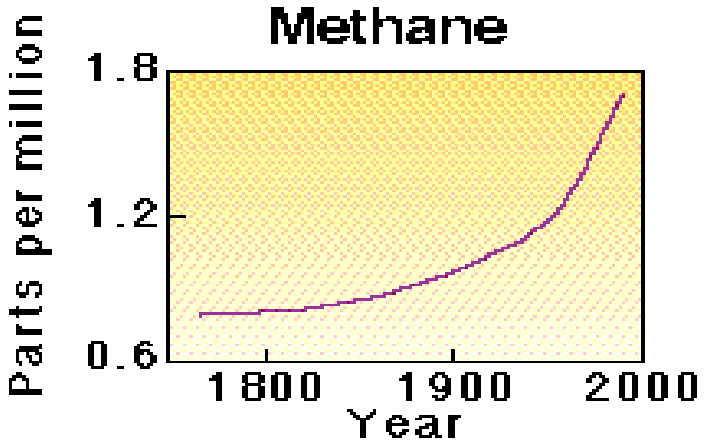


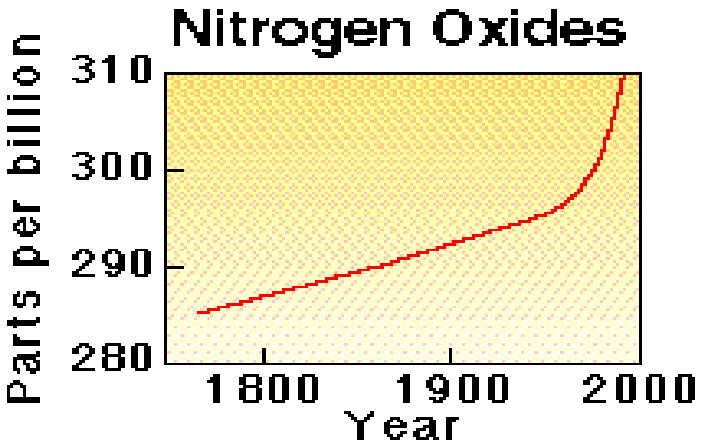
Greenhouse gases (GHGs)

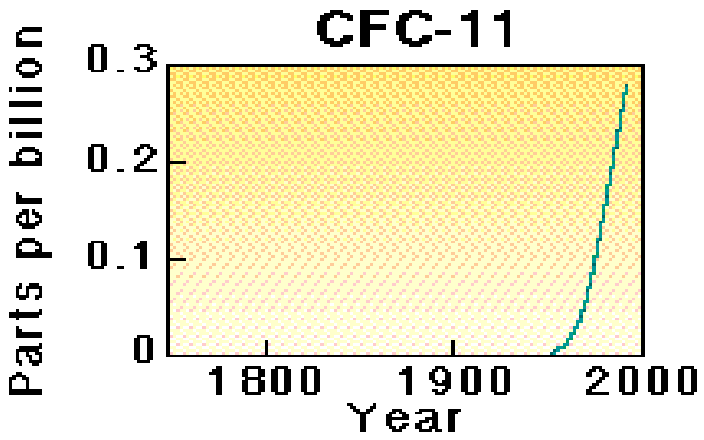
- Some greenhouse gases occur naturally in the atmosphere, while others result from human activities.
- Naturally occuring greenhouse gases include water vapor, carbon dioxide, methane, nitrous oxide, ozone.
- Carbon dioxide is a product of burning fossil fuels.
- Nitrous oxide, produced by fertilizer use and released from decomposition of animal wastes.
- Methane is produced by bacteria from sediments.
- Chlorofluorocarbons (CFCs), Freon (a refrigerant) deplete the ozone layer in the upper atmosphere.
- Water vapor in clouds reradiate heat back to Earth.

Greenhouse gases





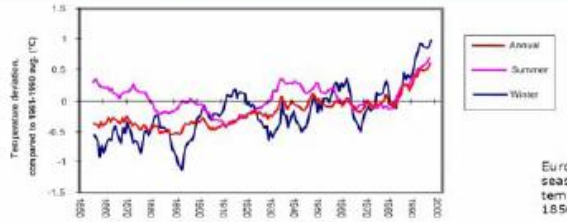




Impact of Global warming

Air Temperature

- Global temperature: + 0.7 ±0.2 °C over past 100 years
- Europe: mean annual +0.95 °C
- Summer +0.7°C ; Winter +1.1°C



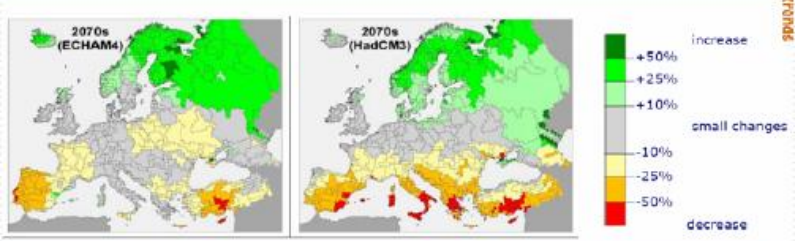
European annual / seasonal mean temperature devia 1850-2002

- Global projection (1990–2100): + 1.4–5.8 °C
- Europe: + 2.0–6.3°C

River discharge

past trends

- River discharge has changed over the last decades across Europe



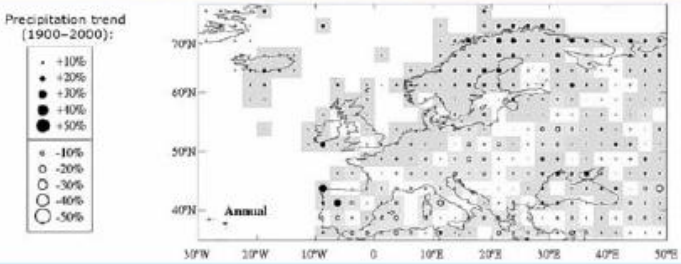
future pro.

- Projected changes in precipitation and temperature will mean further changes in river discharge
- Strong decline in southern and south-eastern Europe
- Increase in almost all parts of northern and north-eastern Europe

Precipitation

past trends

- Heterogeneous trends (1900–2000):
  - northern Europe 10-40 % wetter
  - southern Europe up to 20 % drier

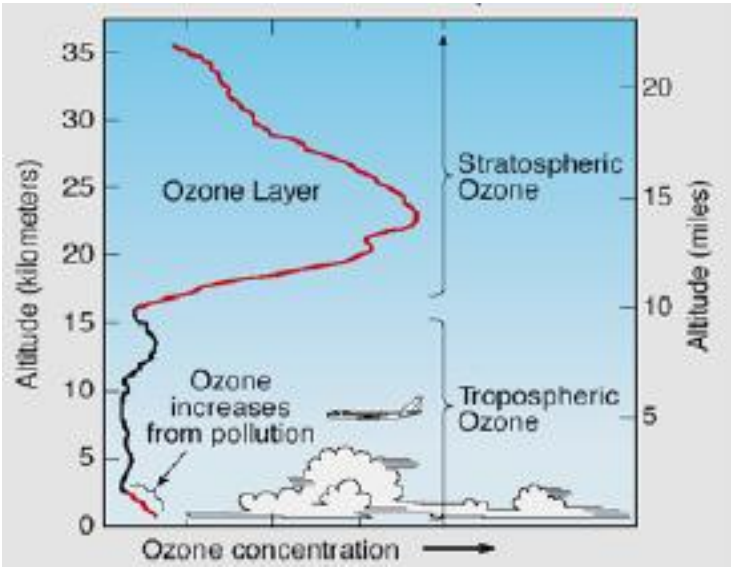


future project

- Projection: - 1-2% increase per decade for northern Europe
  - up to 1 % per decade decrease in southern Europe

Ozone Layers

- Ozone (O_3) is a key constituent of the troposphere.
- Ozone is considered a pollutant at ground level.
- Breathing O_3 affects both the respiratory and nervous systems.
- Ozone is damaging to plants.
- The stratosphere contains the ozone shield, a layer of ozone (O_3) in the stratosphere, 50 km above the ground.



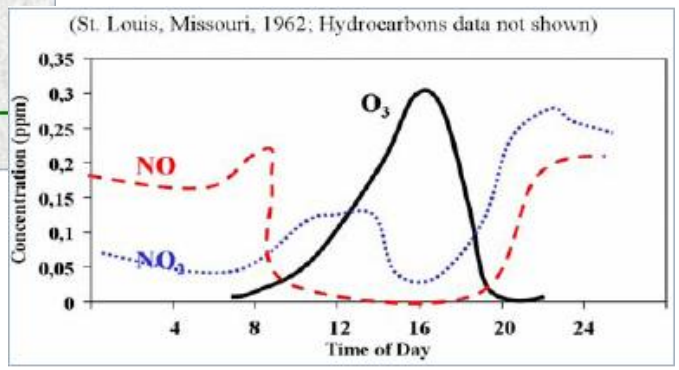
Photochemical Smog (1/3)

Photochemical Smog (2/3)

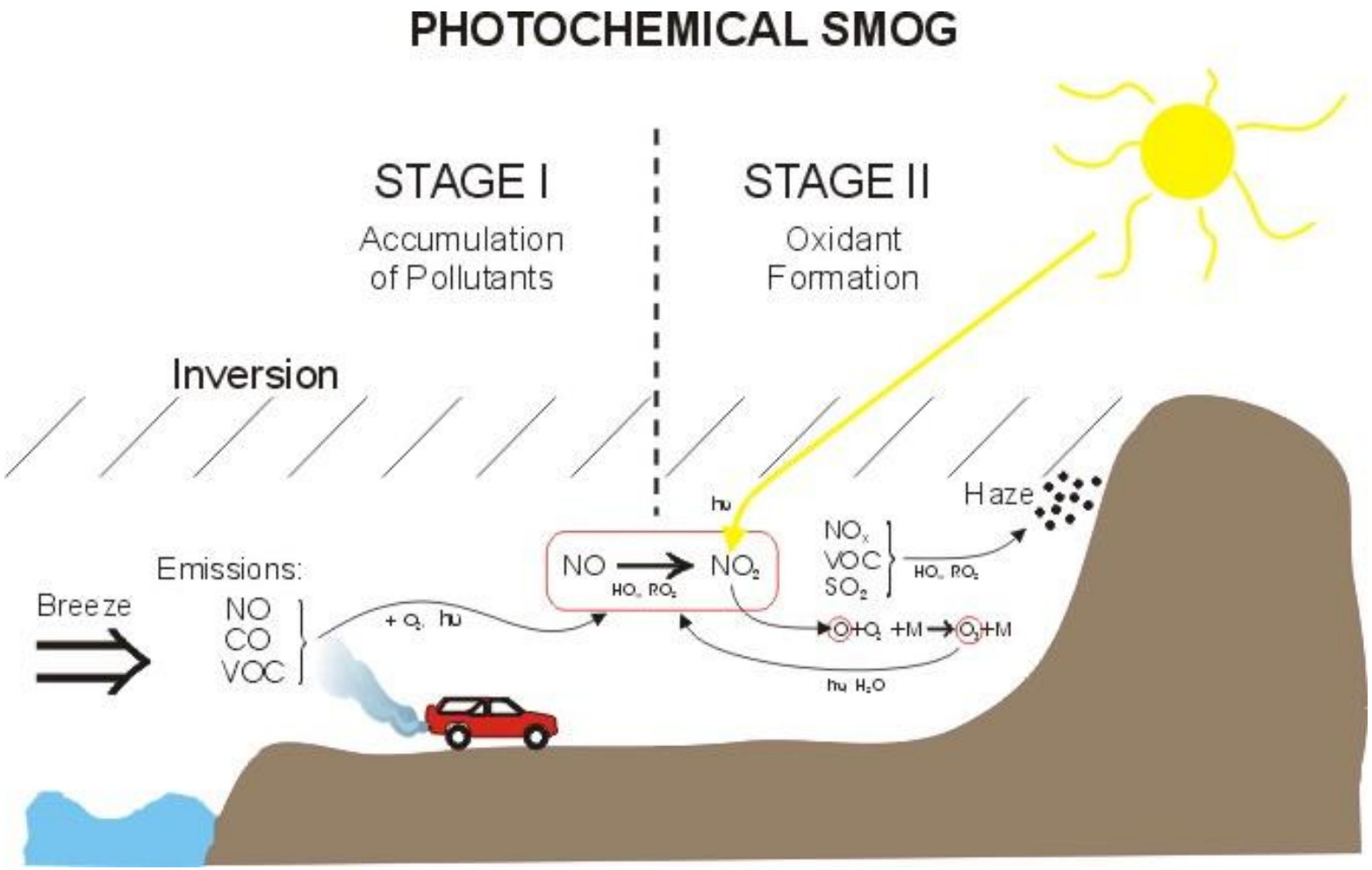
- Smog is a kind of air pollution, originally named for the mixture of smoke and fog in the air.
- HC and NO react in presence of sunlight to produce ozone and PAN (peroxy acetyl nitrate).
- Nitrogen oxides + hydrocarbons + Ultraviolet radiation -----> Peroxyacetyl nitrate PAN + O_3 ozone.

Species	Polluted Area ($\mu g/m^3$)	Unpolluted Air ($\mu g/m^3$)
CO	10,000-30,000	<200
NO	100-400	<20
HC (excluding CH_4)	600-3,000	<300
O_3	50-150	<5
PANs	50-250	<5

Most values are estimates based on data in *Air Quality* in Ontario 1991, Environment Ontario, Queen's Printer for Ontario; 1992



Photochemical Smog (3/3)

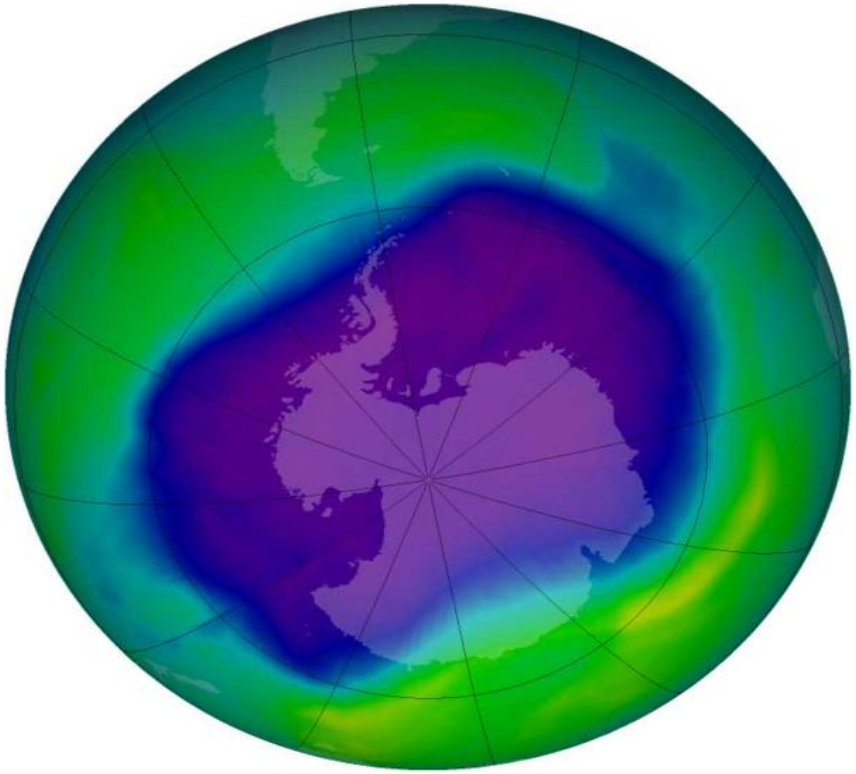


Stratospheric ozone layer

- Formed by a natural process.
- Produced by O_2 interacting with lightning and UV radiation.
- Absorbs most of the shorter wavelengths - UV radiation which is damaging to living things causing cancer, sunburn, etc.
  - allows life to live on earth,
  - ozone depletion - a reduction of the layer.

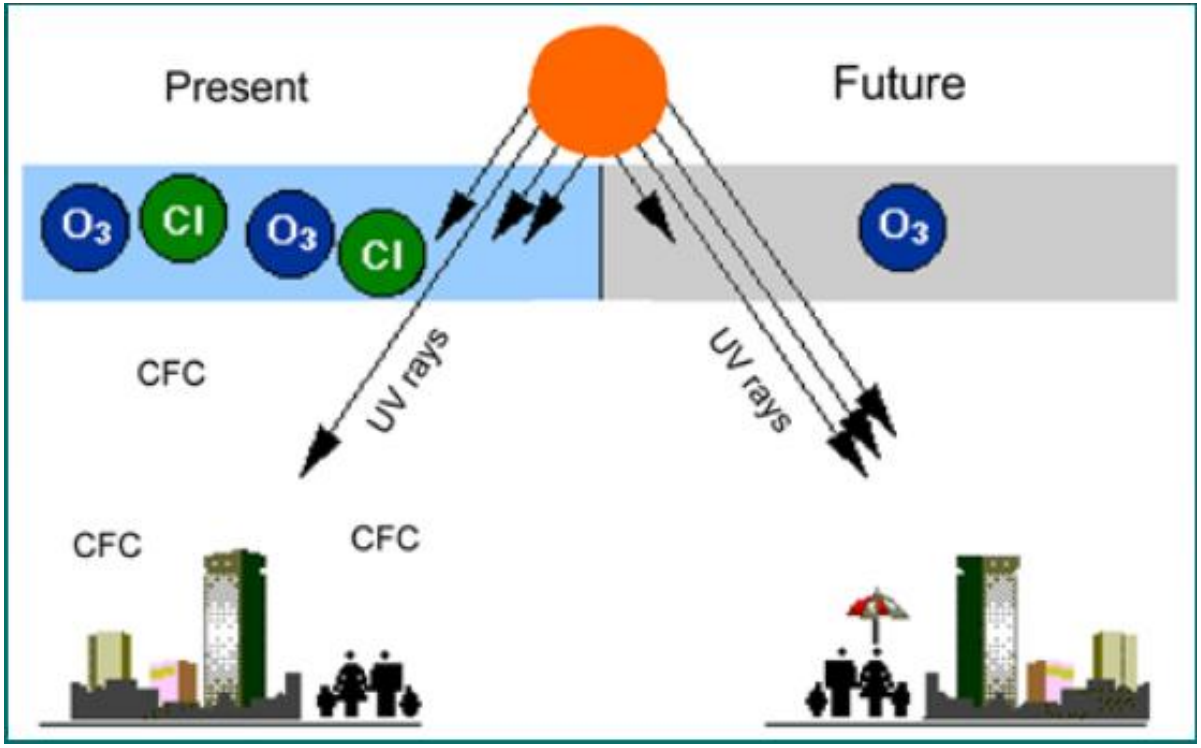
$$O_2 + h\nu \rightarrow O + O \qquad \lambda < 242 \text{ nm}$$
$$O + O_2 + M \rightarrow O_3 + M$$
$$O_3 + h\nu \rightarrow O_2 + O \qquad \lambda < 290 \text{ nm}$$

The largest Antarctic ozone hole ever recorded (September 2006)



- The Antarctic ozone hole is an area of the Antarctic stratosphere in which the recent ozone levels have dropped to as low as 33% of their pre-1975 values.

The Ozone Depletion



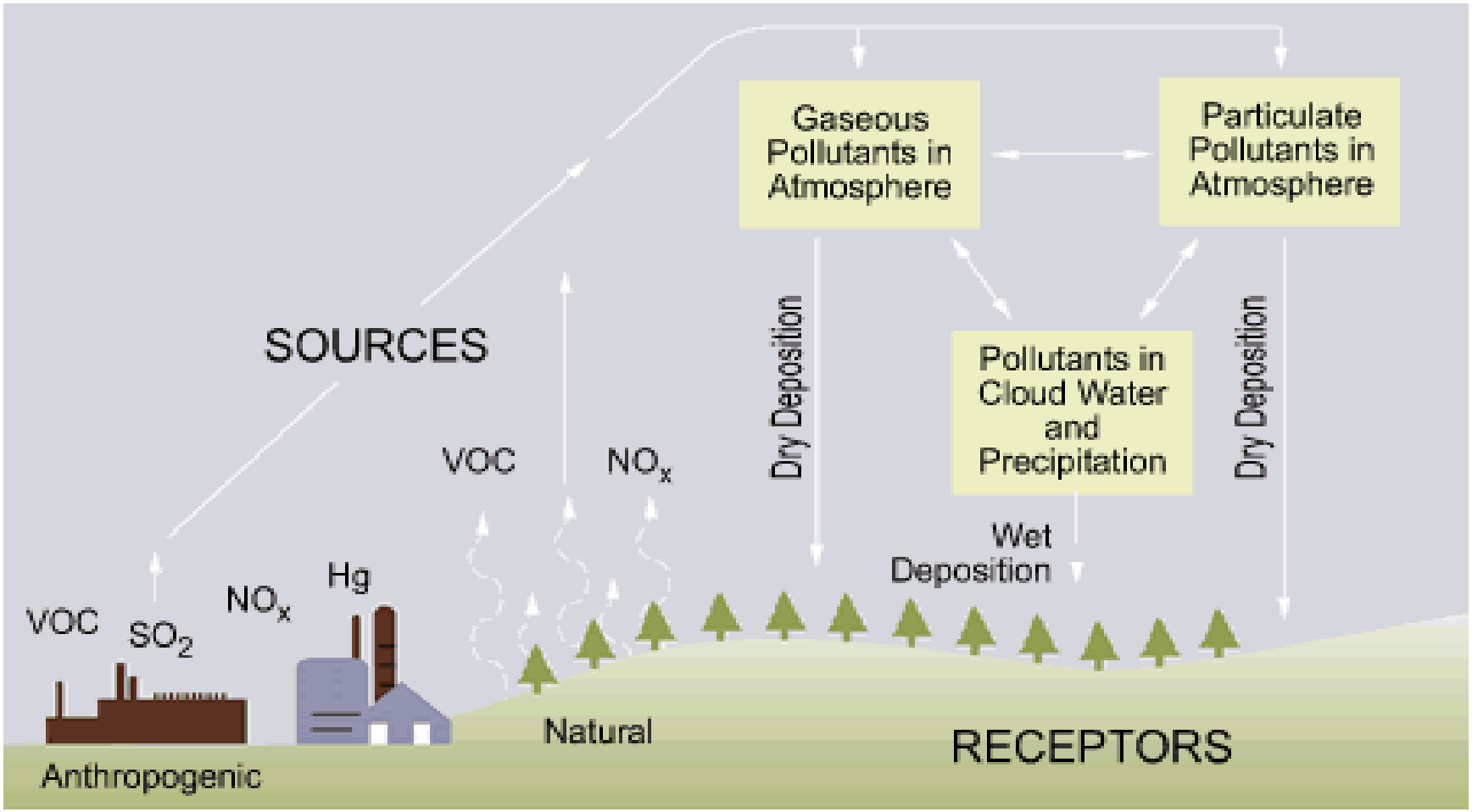
$CCl_3 + hv \rightarrow CCl_2F + Cl$

$Cl + O_3 \rightarrow ClO + O_2$

$ClO + O \rightarrow Cl + O_2$

$O + O_3 \rightarrow O_2 + O_2$

Acid Precipitation



Acid Rain

- Nitric oxide & sulfur dioxide released primarily from electric power plants & motor vehicles.
- SO_2 + water vapor + ozone ---> H_2SO_4 .
- NO + hν + O_2 ---> NO_2 + atmospheric gases ---> HNO_3 .

Environmental Impact of Acid deposition

- Sterilization of lakes and forests.
- Reducing agricultural yields.
- Causing extensive structural damage by corroding marble, metal, and stonework.
- Degrading water supplies.

Why we have to move to RES?

Increasing energy demands

↓

Depletion of fossil fuels

↓

Environmental pollution

(greenhouse effect, ozone depletion, acidification, photochemical smog)

↓

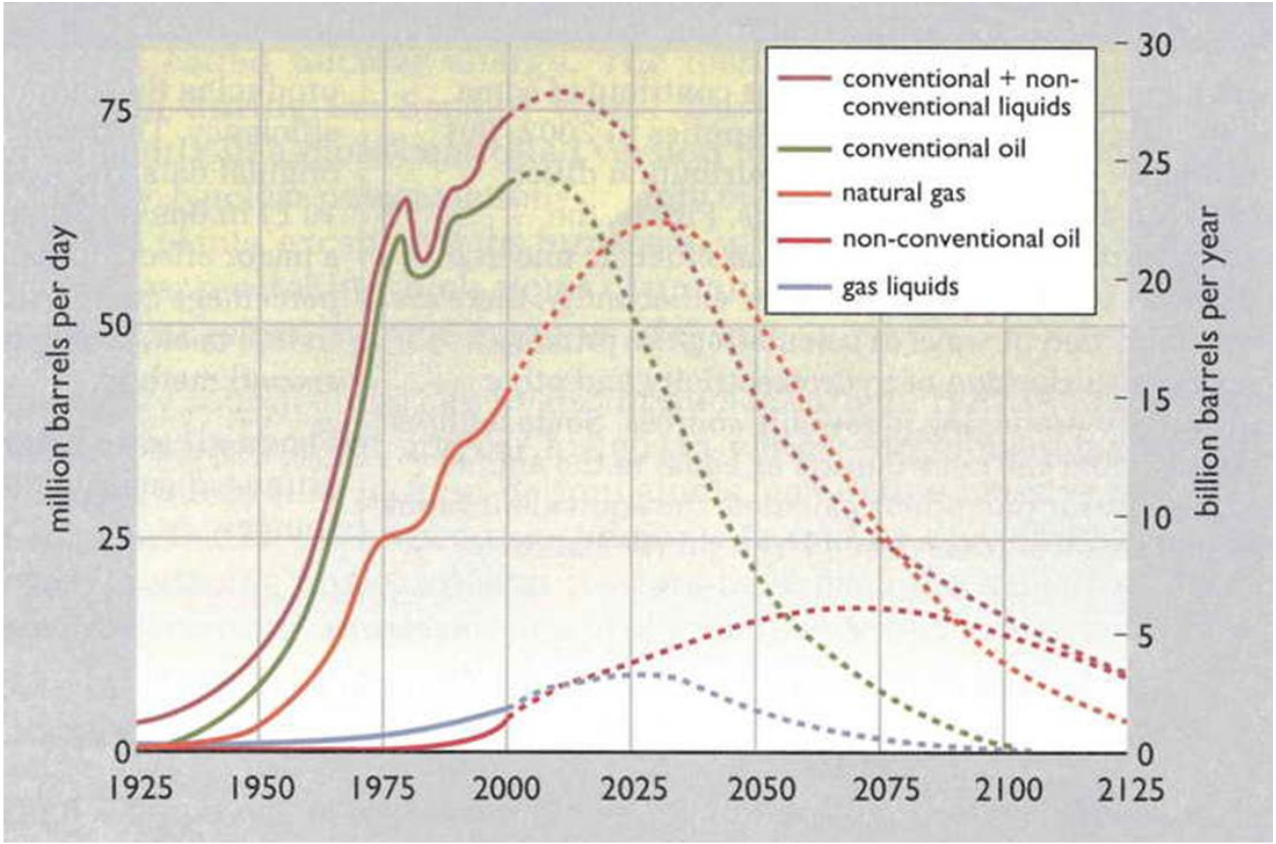
EU Directive 20-20-20 (2008)

20% reduction of GHG emissions
20% energy savings
20% increase of RES portion in the energy mix

Reasons for Renewable Energy

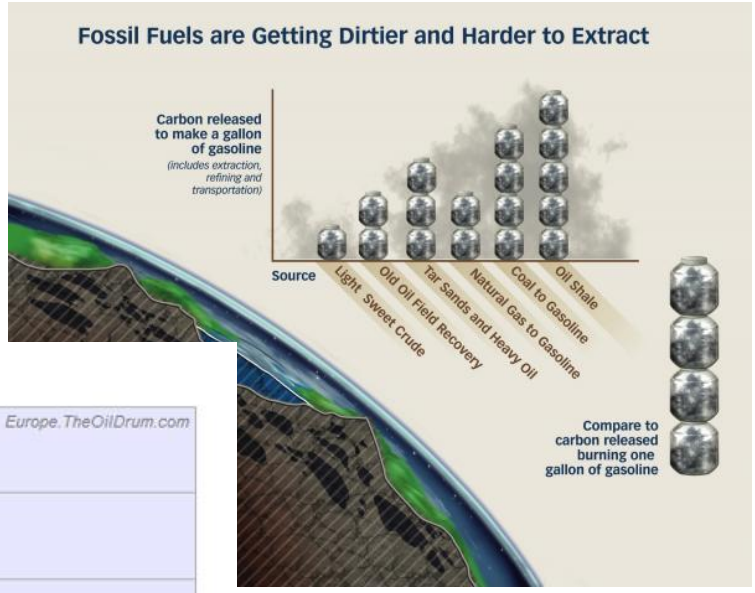
- Declining Fossil Fuel Supplies.
- Environmental Concerns:
  - Global warming, Ozone Depletion, etc.
- Political Concerns (EU target 20-20-20).
- Increasing Cost of Fossil Fuels.
- Business Opportunities.
- Other Reasons.

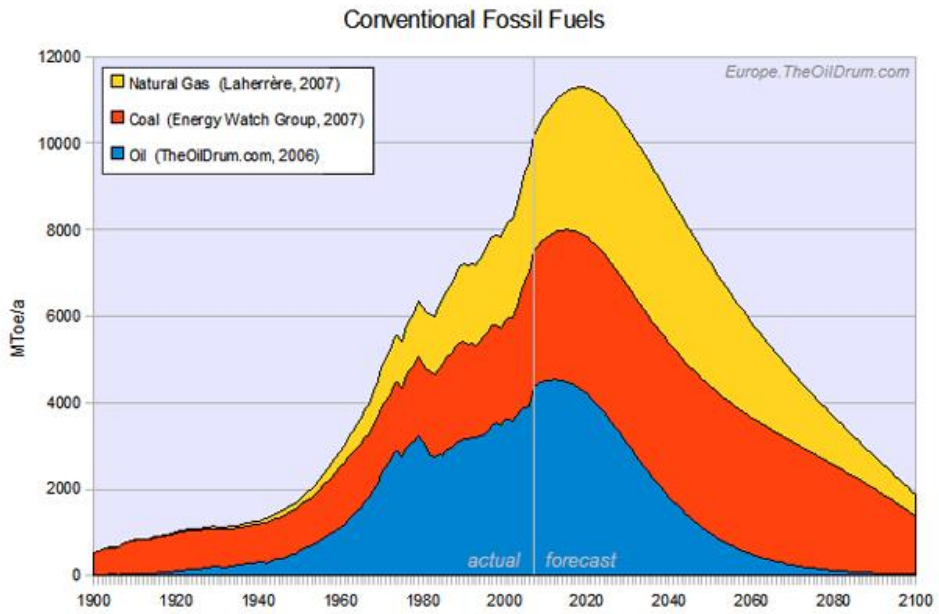
Declining Fossil Fuel Supplies (1/2)



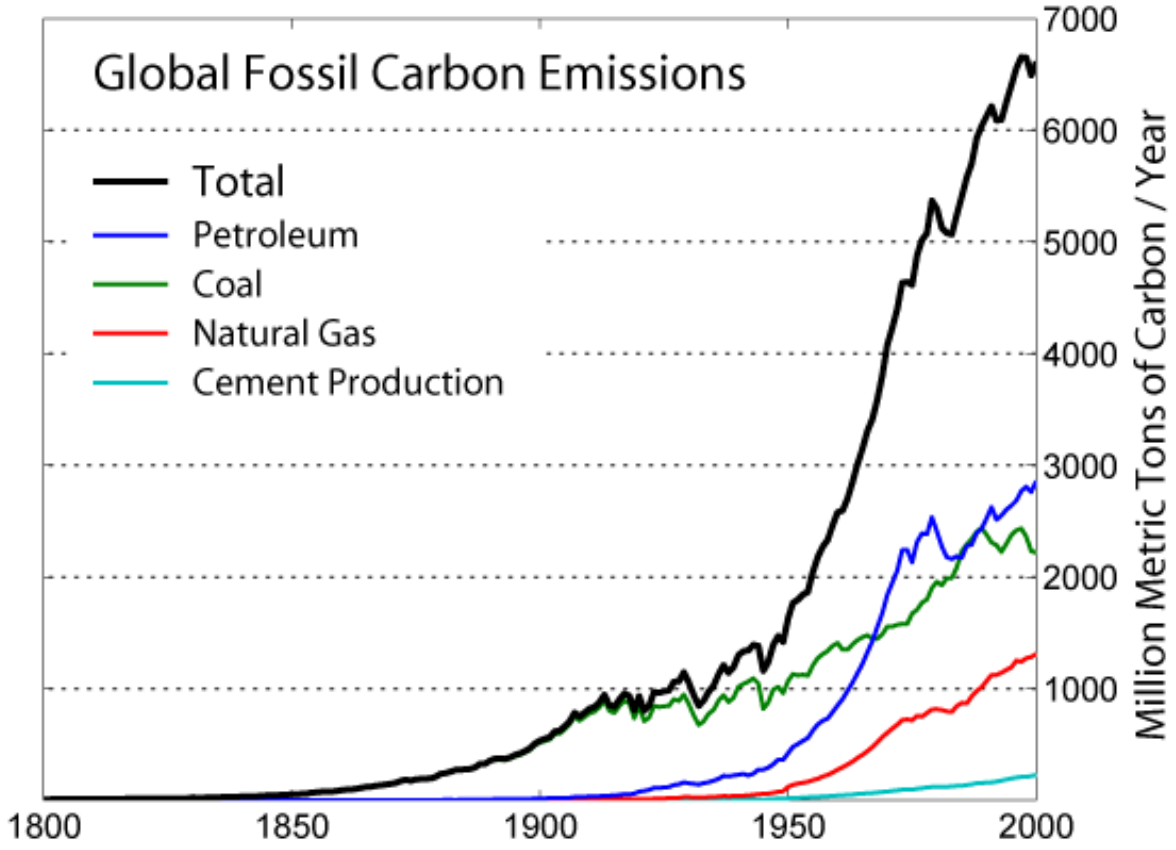
Boyle, *Renewable Energy*, Oxford University Press (2004)

Declining Fossil Fuel Supplies (2/2)



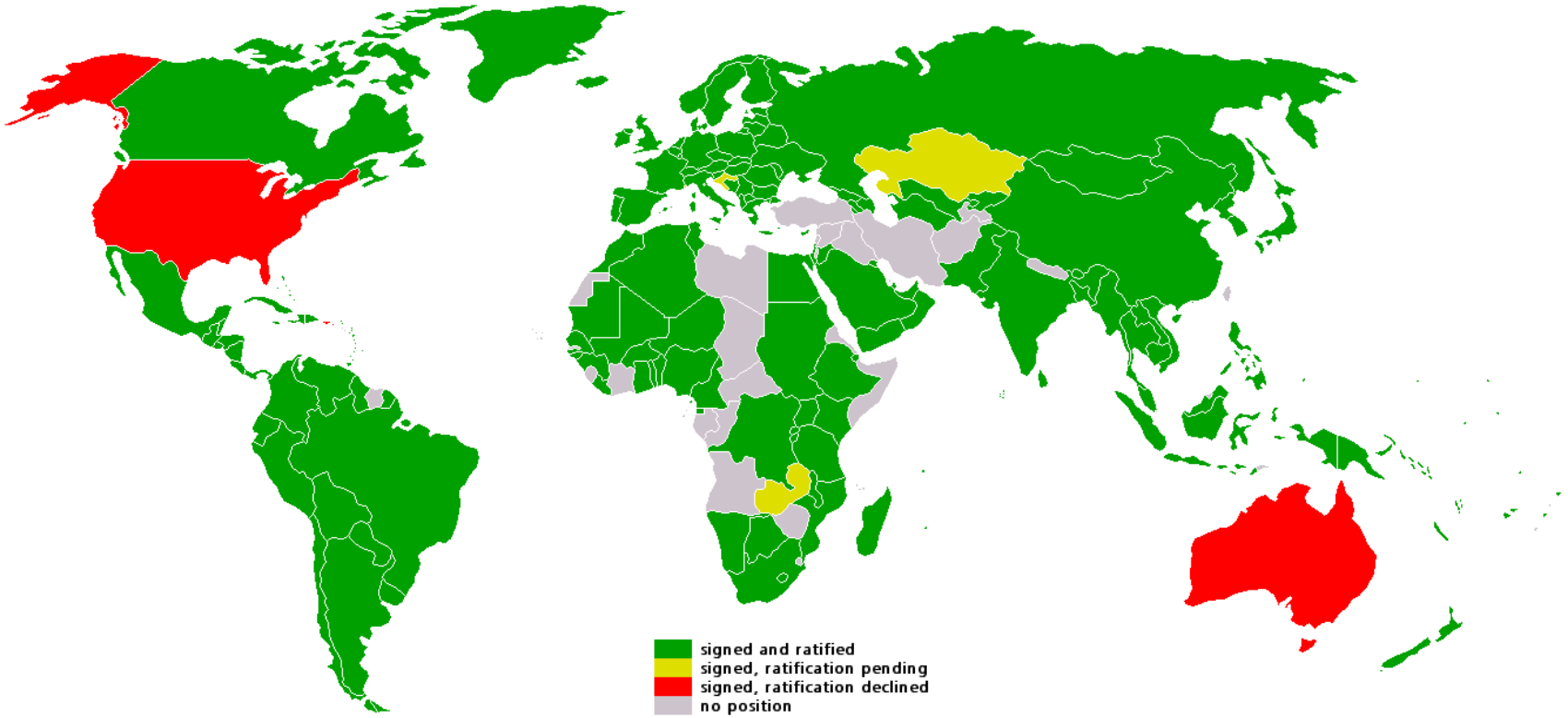


Global Fossil Carbon Emissions



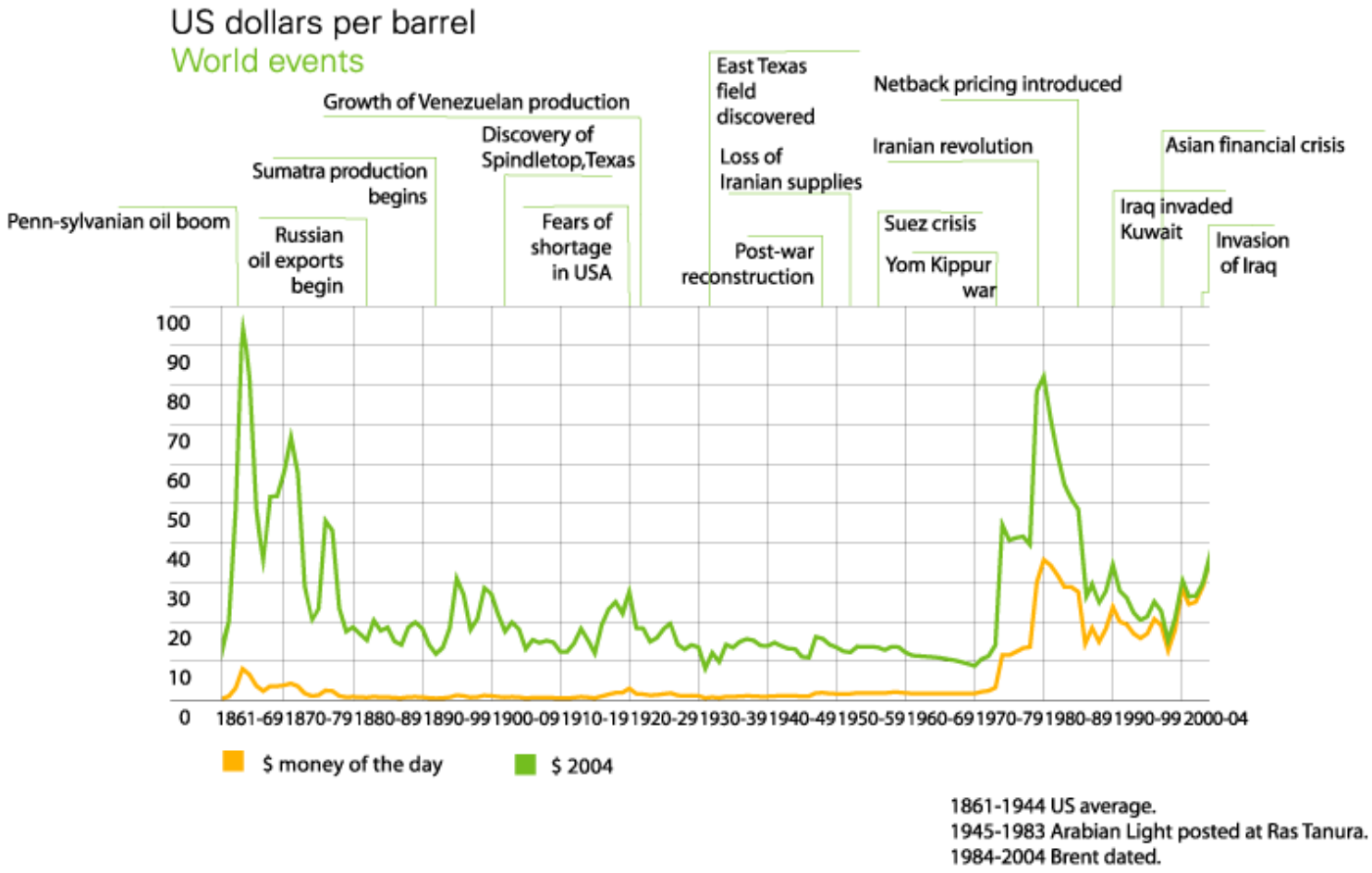
Wikipedia.org, *Climate Change, Global Warming* articles.

Kyoto Protocol Signatories



Political Concerns

Crude oil prices since 1861



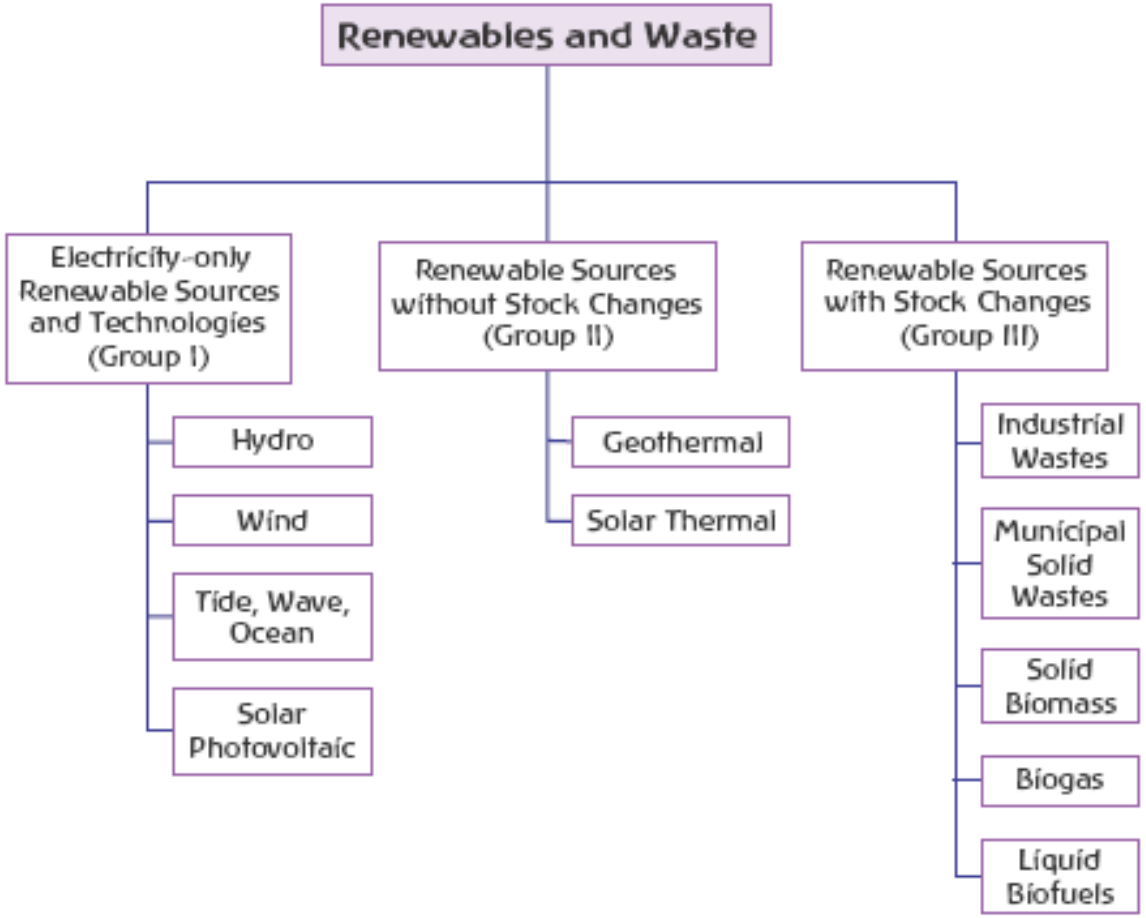
Business Opportunities

Renewables and Wastes

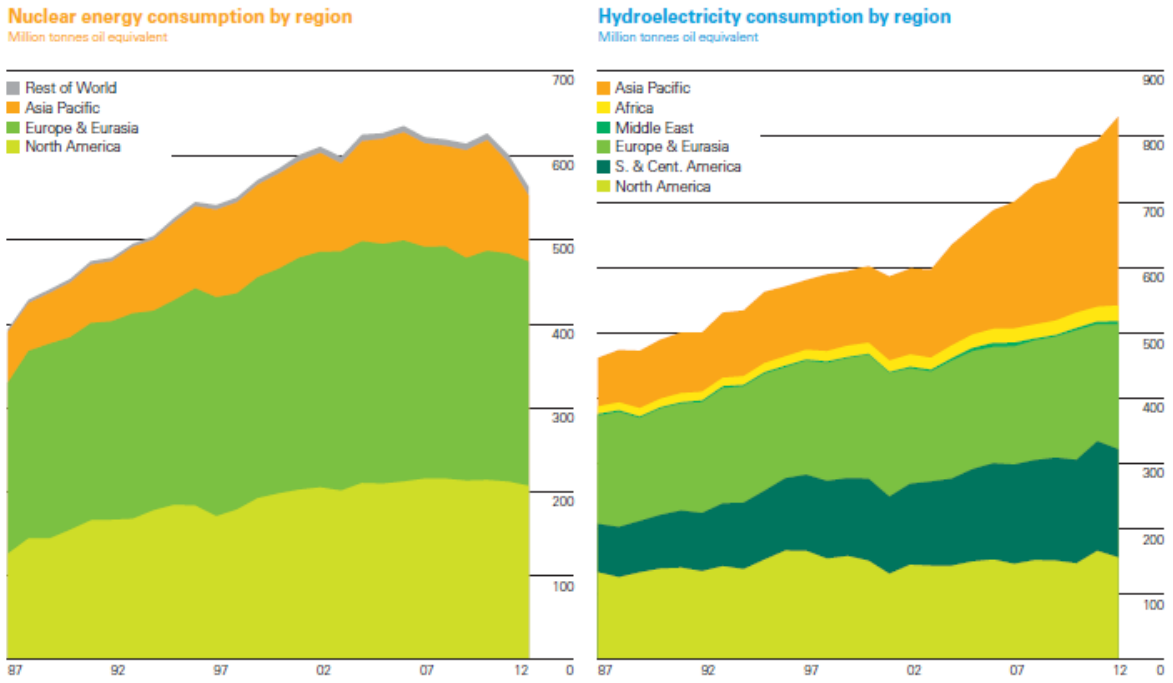
- Renewable energy is energy that is derived from natural processes that are replenished constantly.
- There are various forms of renewable energy generated from solar, wind, biomass, geothermal, hydropower and ocean resources, solid biomass, biogas and liquid biofuels.
- Waste is a fuel consisting of many materials coming from combustible industrial, institutional, hospital and household wastes.
- Wastes are either solid or liquid in form, renewable or non-renewable, biodegradable or non-biodegradable.
- Solid biomass is by far the largest renewable energy source representing more than 10% of world total primary energy supply, or ¾ of global renewables supply.
- Since 1990, RES in the world have grown at an average annual rate of 1.7%. Growth has been especially for “new” renewables (wind and solar), which grew at an annually rate of 19%.

Renewables and Wastes Classification

Figure 6.1 • Renewables and Waste Classification into Three Groups

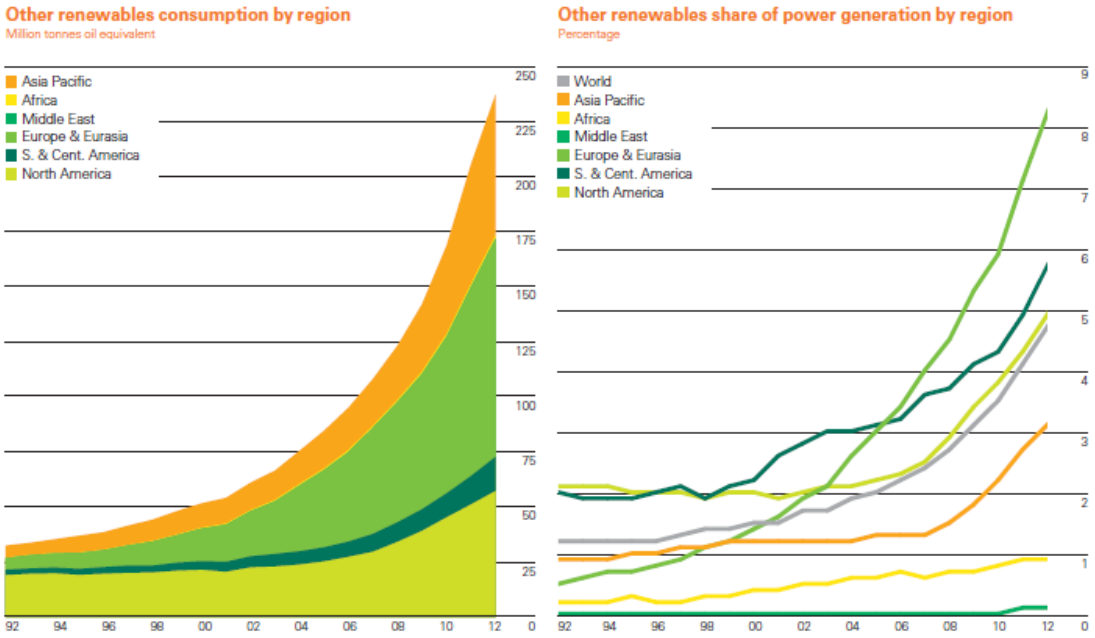


2012 – Nuclear & Hydroelectricity Consumption



- World nuclear power generation declined by 6.9%.
- Global hydroelectric output grew by an above average 4.3%.

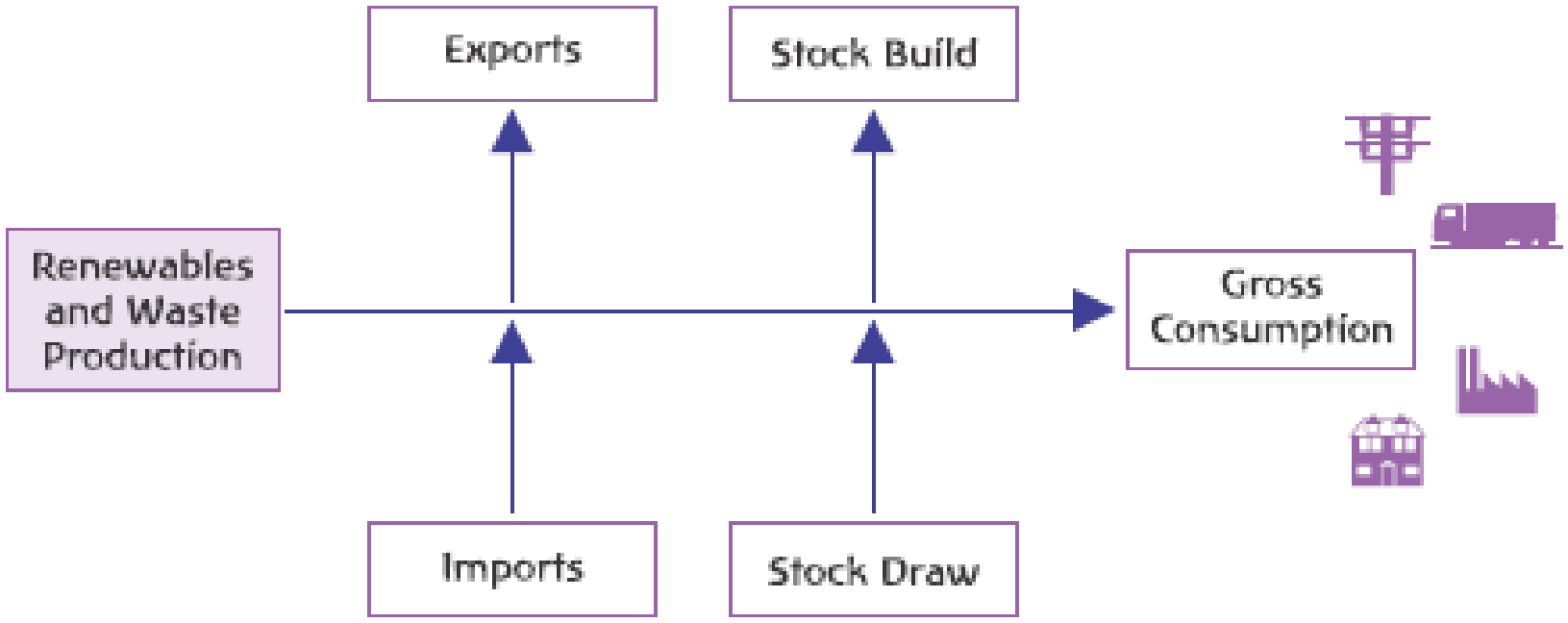
2012 – Renewable Consumption



- RES grew by an above average 15.2%. Europe and Eurasia delivered the largest growth increment.
- RES accounted for a record 4.7% of global power generation, with an 8.2% share in Europe Eurasia.

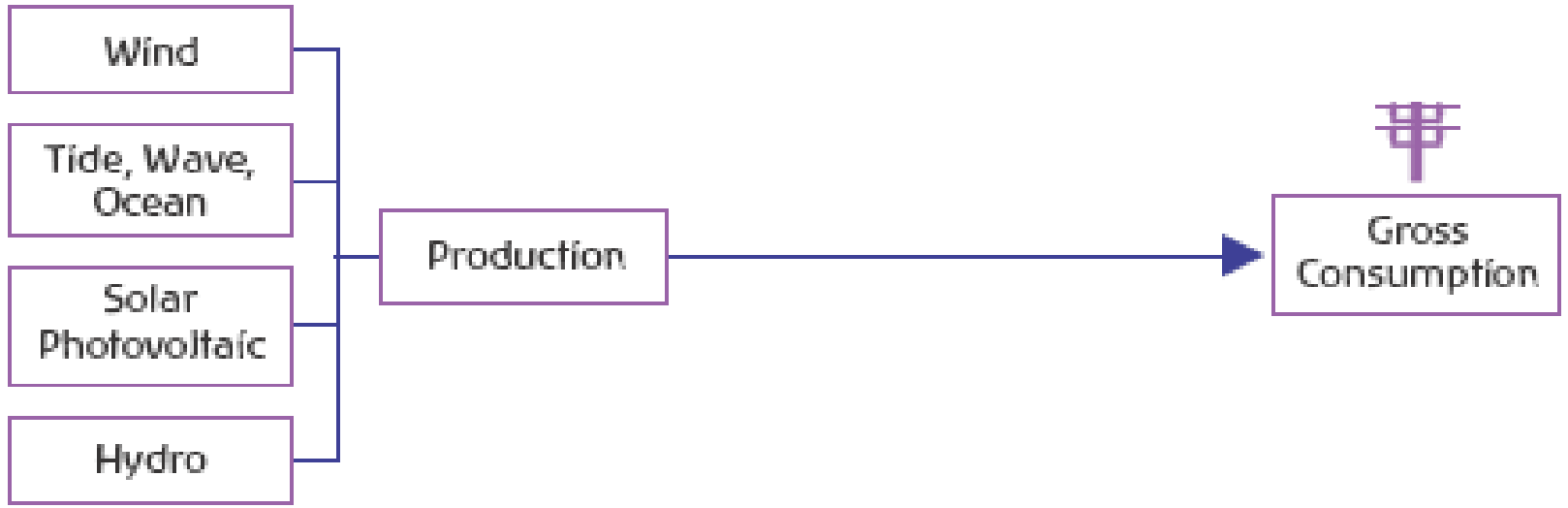
Renewables and Wastes flows

Figure 6.2 • Simplified Flow Chart for Renewables and Waste



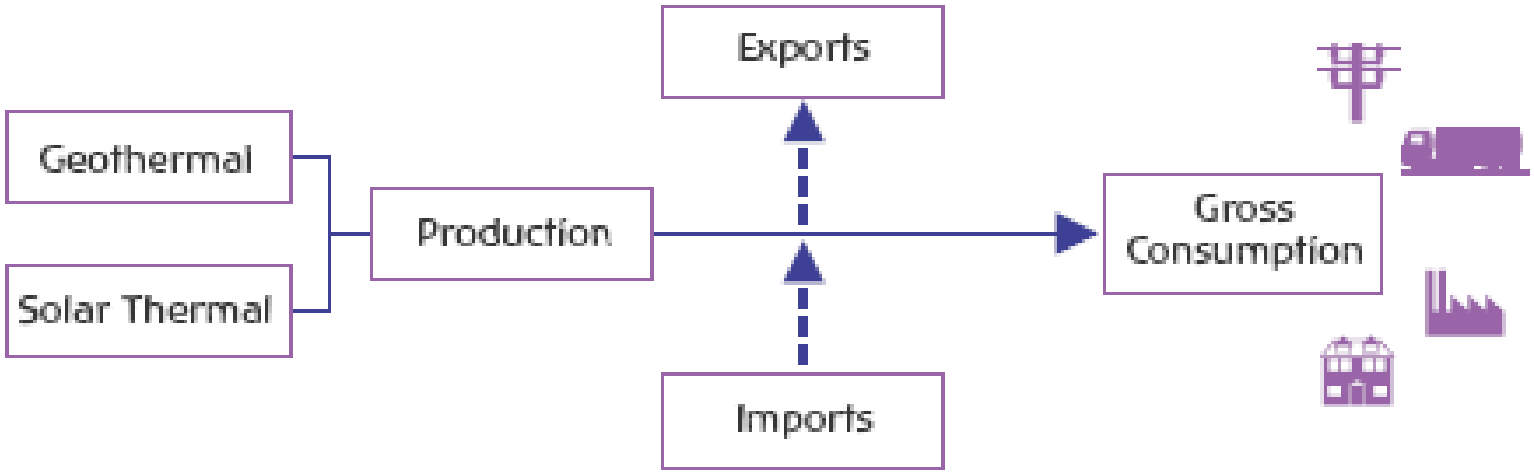
Renewables and Wastes Supply (1/3)

Figure 6.4 ● Simplified Flow Chart for Group I Renewables and Waste



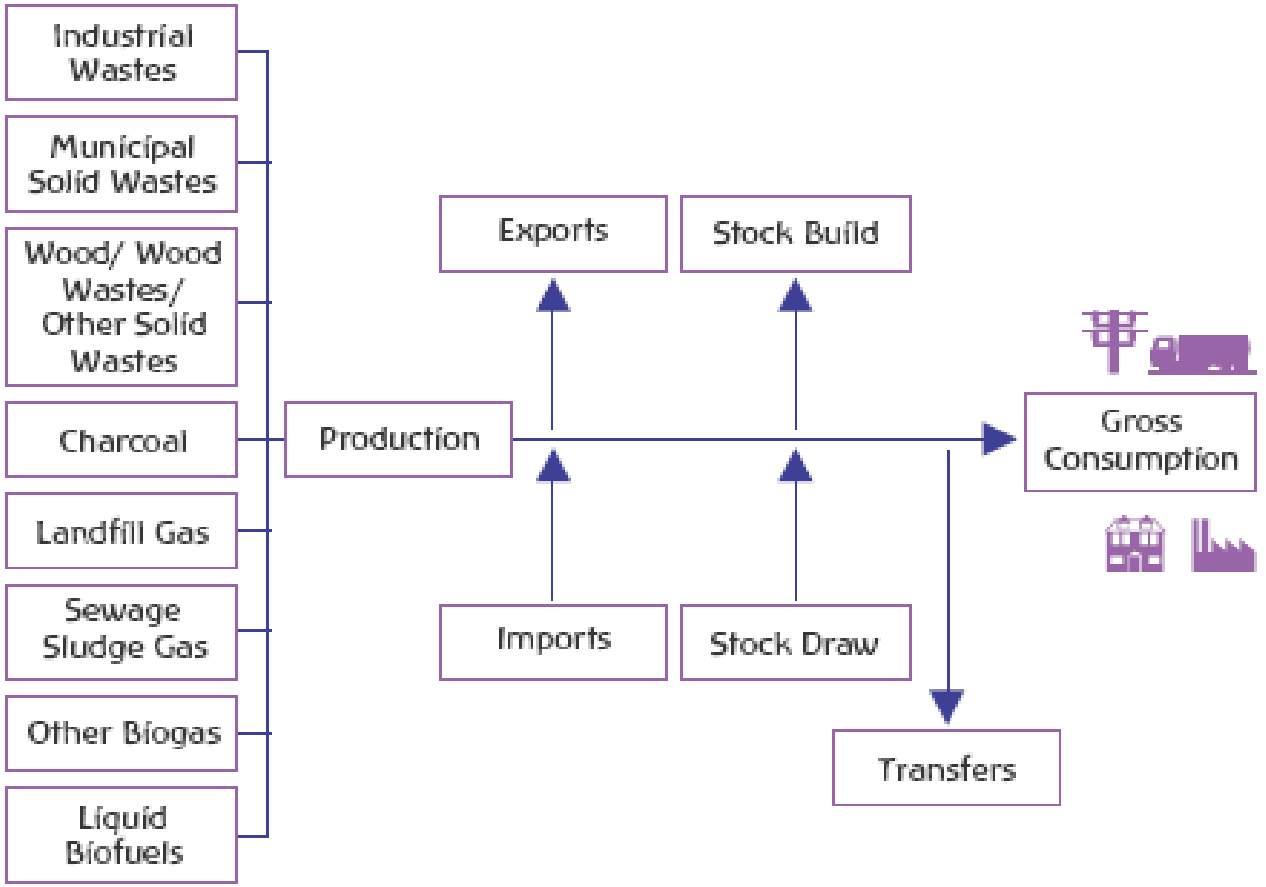
Renewables and Wastes Supply (2/3)

Figure 6.5 • Simplified Flow Chart for Group II Renewables and Waste

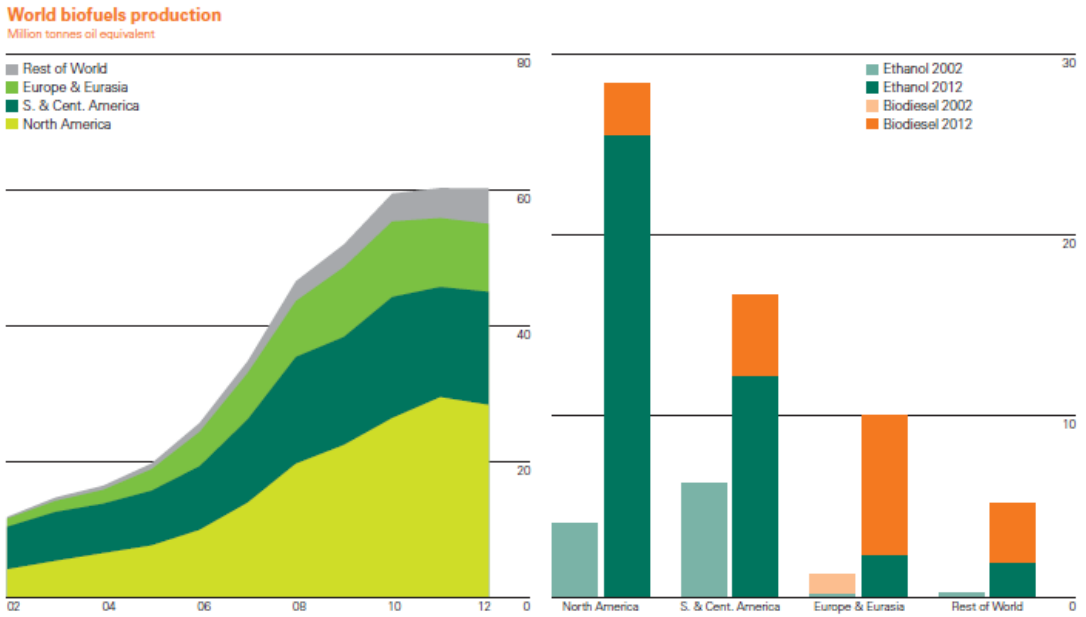


Renewables and Wastes Supply (3/3)

Figure 6.6 • Simplified Flow Chart for Group III Renewables and Waste



2012 – Biofuels Production



- World biofuels production declined by 0.4% in 2012, the first decline since 2000.
- Global ethanol output declined by 1.7%, the 2nd straight annual decline.
- Biodiesel production grew by 2.7% and has doubles in the last 5 years and now makes up 31% of total biofuel supply.

Renewables & Wastes Imports and Exports

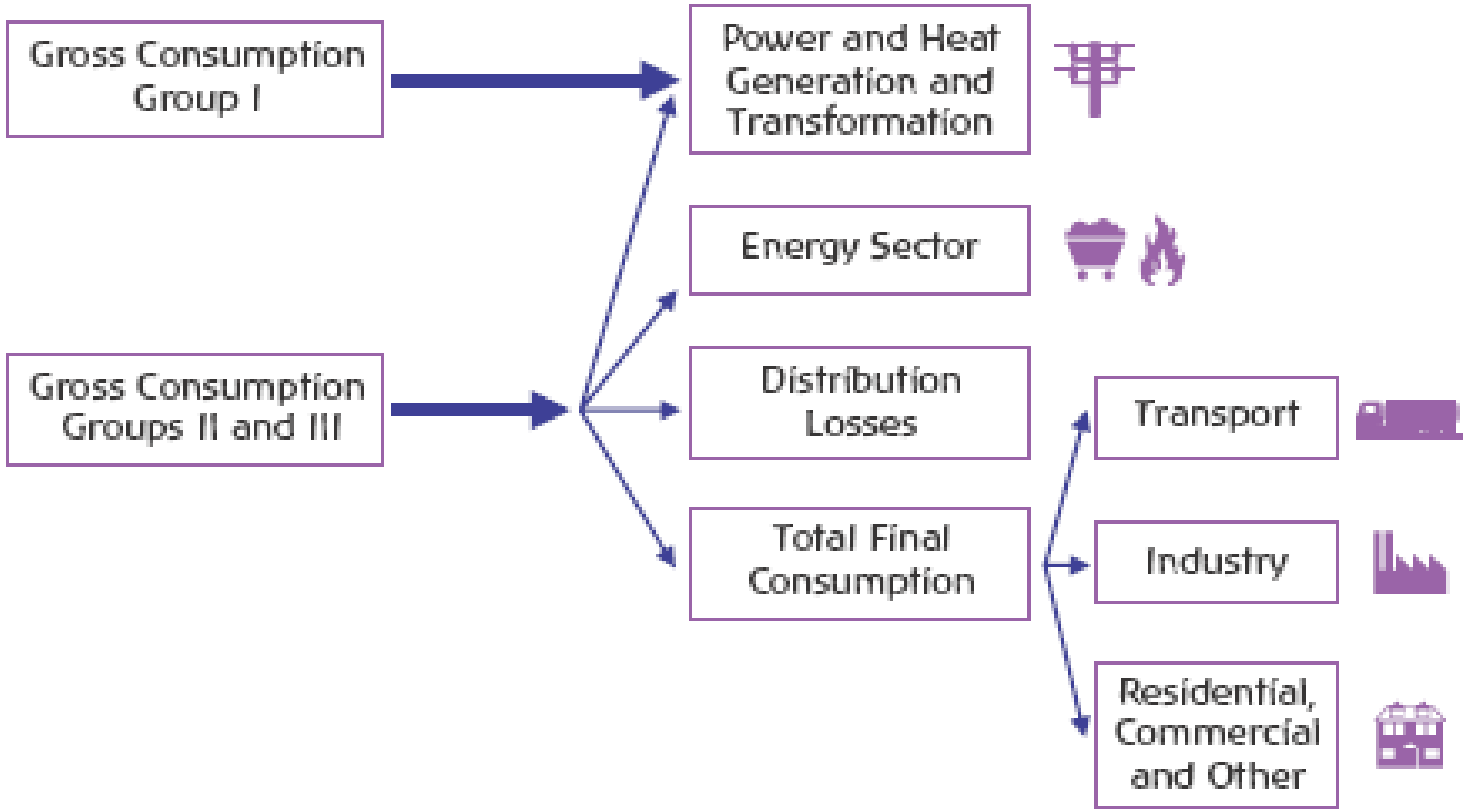
- The trade of renewable and wastes are still very limited.
- Group 1 RES is based entirely on electricity and heat generation.
- Supply of Group II RES products involves extraction and further use of heat derived from the earth's crust or the sun.
- The only real possibility for trade can only come from the Group III products.
- Wood fuel and agricultural residues can cross the borders. However their low calorific value limits their exchange.

Renewables & Wastes Stocks

- The same as in the case of Imports and Exports.
- Only Group 3 RES can be potentially stored.
- Stocks of fuelwood and agro-residues are not stable over time because of several phenomena, such as production of methane and consequently are often seasonal and depend on the culture.
- Since the quantities of stocks are very limited and locations very remote, it is extremely difficult to calculate the stocks.

Renewables and Wastes Consumption

Figure 6.7 • Renewables and Waste Consumption by Sector



Renewables & Wastes Energy Consumption

- The largest part (>80%) of the final consumption occurs mainly in the residential and services sectors. Over 90% occurs in non-OECD countries.
- Less than 1% of RES and wastes are used in transport.

Τέλος Ενότητας