

L3:  
Online  
1/3/2021

# Renewable Energy and Photovoltaic Power Systems

## L2- Energy Sources



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# Overview

- Renewable Energy modified definition
- Harnessing Energy
- How Fossil Fuels are formed?
- Energy Content in different types of fuel

محتوى الطاقة



Fossil fuels {  
Natural Gas X  
Coal X  
Oil X

# Renewable?

- Which one of the following would you consider as renewable energy source?

• Wind ✓

• Solar ✓

• Coal X

• Natural Gas X

Tidal ✓

Wave ✓

Geothermal ✓

Hydro ✓

Biomass ✓

Hydrogen ✓

Oil X

# Renewable Energy

- Why is solar considered renewable but energy derived from burning coal is not?
- Remember from physics that energy cannot be created or destroyed, but only converted from one form to another

# Renewable Energy

- A better way of defining renewable energy is with respect to the time scale considered (e.g. 1000 years or 1,000,000 years)
- \*• ***Renewable energy are energy flows***  
***which are replenished at the same (or***  
***greater ) rate than they are used over***  
***the timescale considered***

# Renewable?

- Coal could be considered renewable if we used it at the same rate at which it is formed
- Solar energy is considered renewable because the sun will supply energy throughout the time scale considered.
- What we commonly consider renewable resources come from only three origins:
  - Solar Radiation
  - Heat from the earth
  - Gravity

# Solar Radiation

- The Sun's solar radiation is responsible for:
  - Solar ✓
  - Biomass (photosynthesis) ✓
  - Hydro (evaporation) ✓
  - Wind (uneven heating of the atmosphere) ✓
  - Wave ( a result of wind) ✓

# Interesting Statistics!

- Sun provides 5.4 YJ/yr (yotta joules:  $1 \times 10^{24}$  J) to Earth's atmosphere
- Approx 30% is deflected into space
- Remaining 3.8 YJ is approximately 10,000 times the amount of energy used by fossil and nuclear fuels per year
- Solar radiation also drives wind, waves and photosynthesis
- Wind and waves: 11.17 ZJ/yr (zetta =  $1 \times 10^{21}$ )
- Photosynthesis: 1.26 ZJ/yr

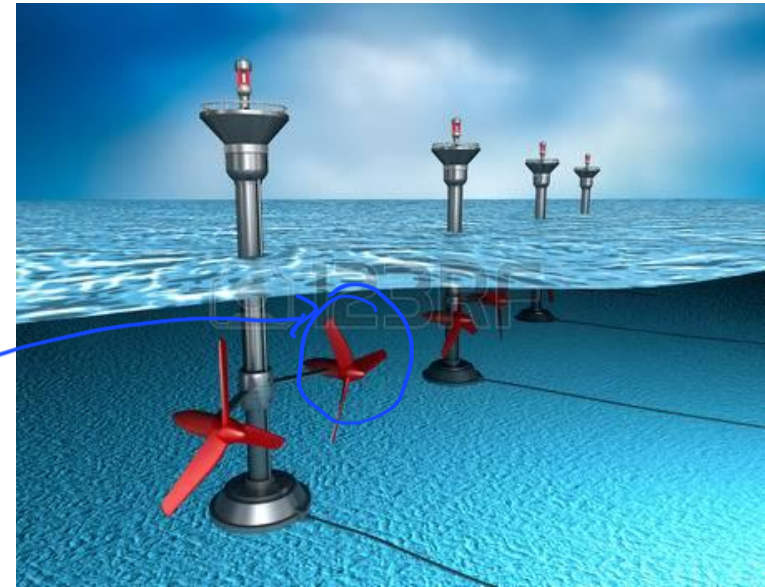


# Heat From the Earth

- Interior of the earth is at high temperature
- Causes:
  - Decay of radioactive material
  - Residual heat from formation of the earth
- Note : scientist's knowledge of the core of the earth is still limited
- We can only harness the heat that makes way to the crust (5-50 km depth)
- Approximately 4 ZJ of energy is stored as water or steam at depth of 10 km
- Pockets of heat can be used to drive steam turbines in geothermal plants

# Gravity

- Gravity from the moon and sun cause tides (mostly the moon)
- Approx. 93.6 EJ/yr (exajoule:  $1 \times 10^{18}$  J)
- Result is very gradual slowing down of the earth (not to any appreciable time scale)
- Tidal action can be harnessed by tidal generators

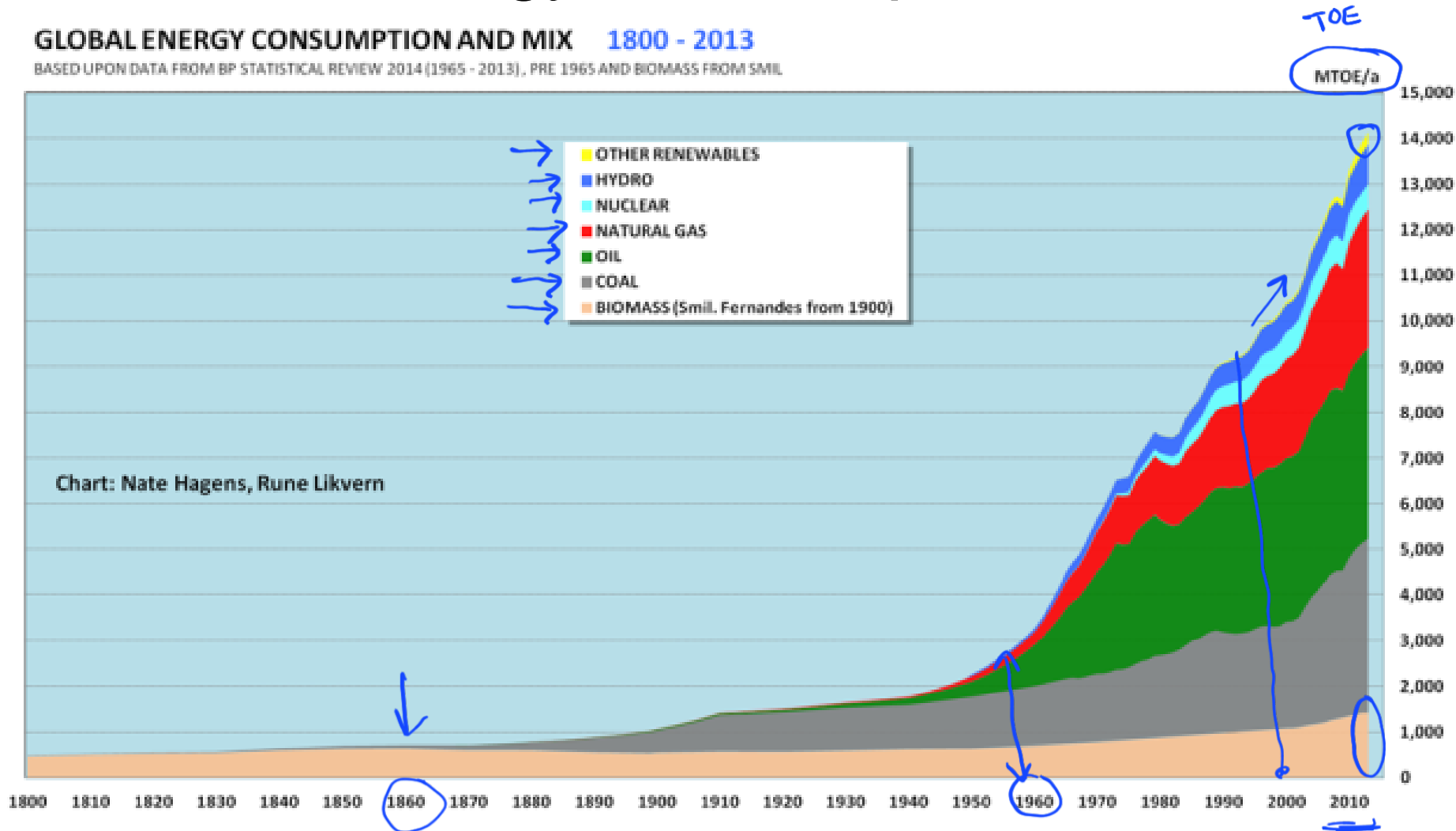


# Some Energy Statistics

# Global Energy Consumption and Mix

## GLOBAL ENERGY CONSUMPTION AND MIX 1800 - 2013

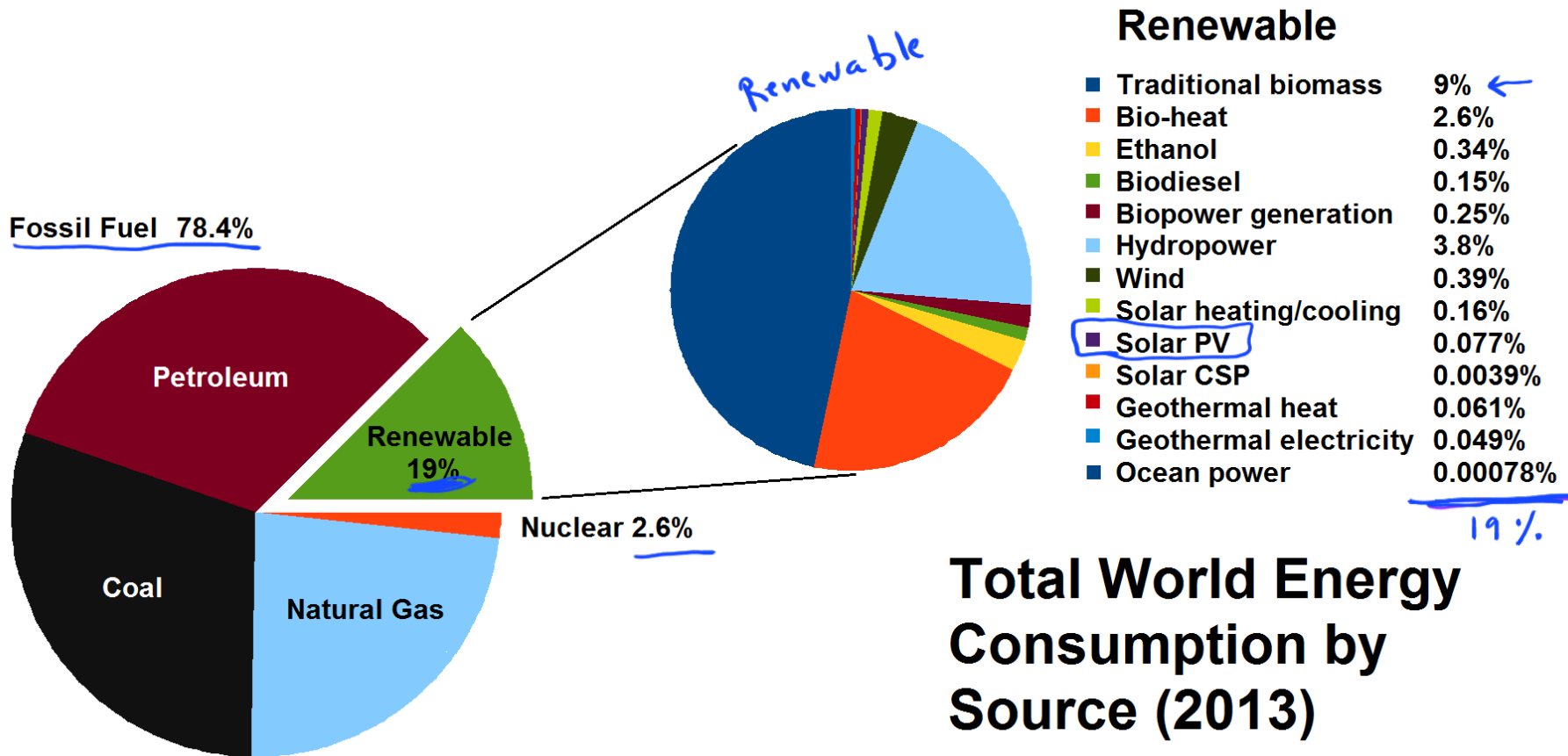
BASED UPON DATA FROM BP STATISTICAL REVIEW 2014 (1965 - 2013), PRE 1965 AND BIOMASS FROM SMIL



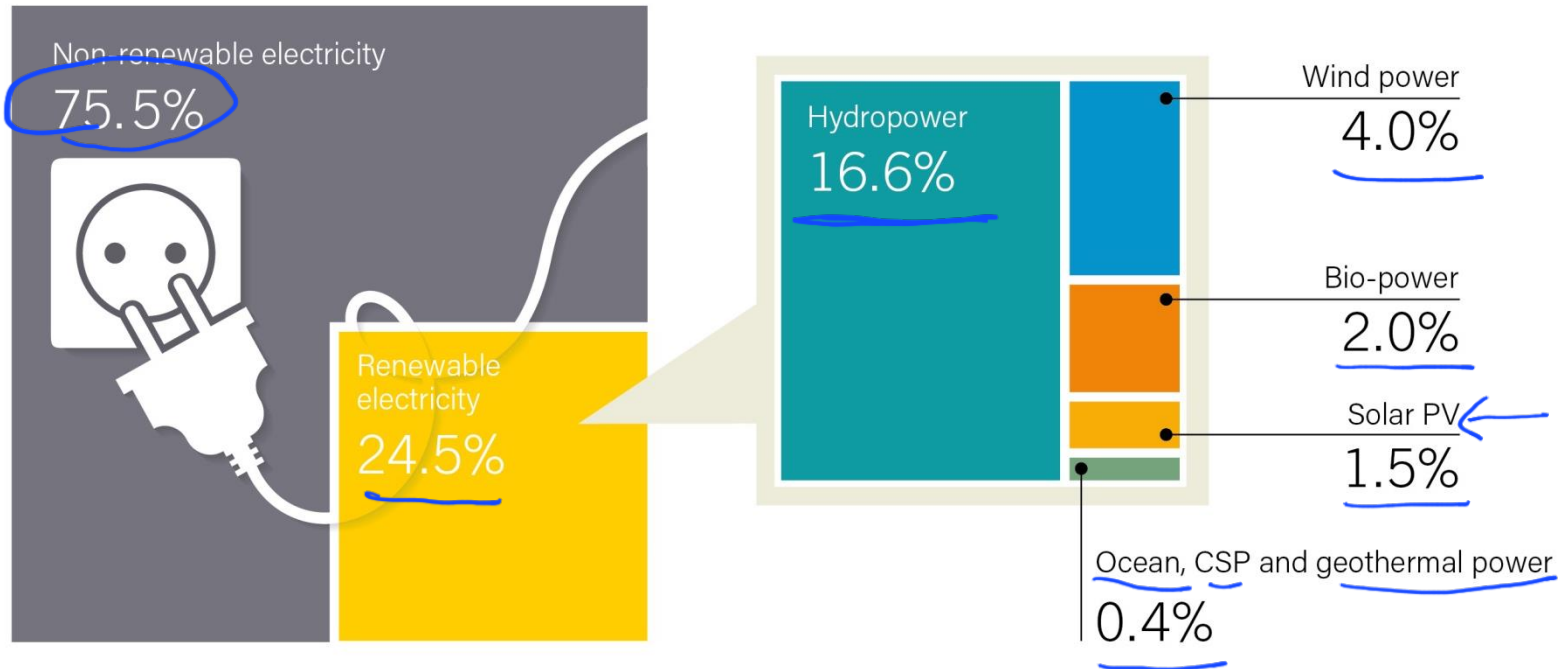
1 toe = 11.63 [megawatt-hours](#)

1 toe = 11.63 [megawatt-hours](#)

1 toe = 39,683,205.411 british thermal unit (BTU)

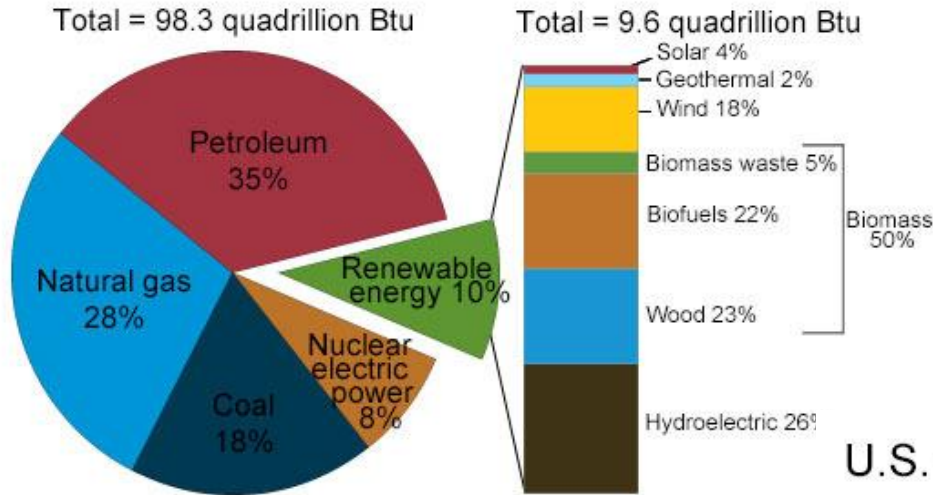


# Renewable Energy Share of Global Electricity Production , 2016



# US Energy consumption

## U.S. energy consumption by energy source, 2014

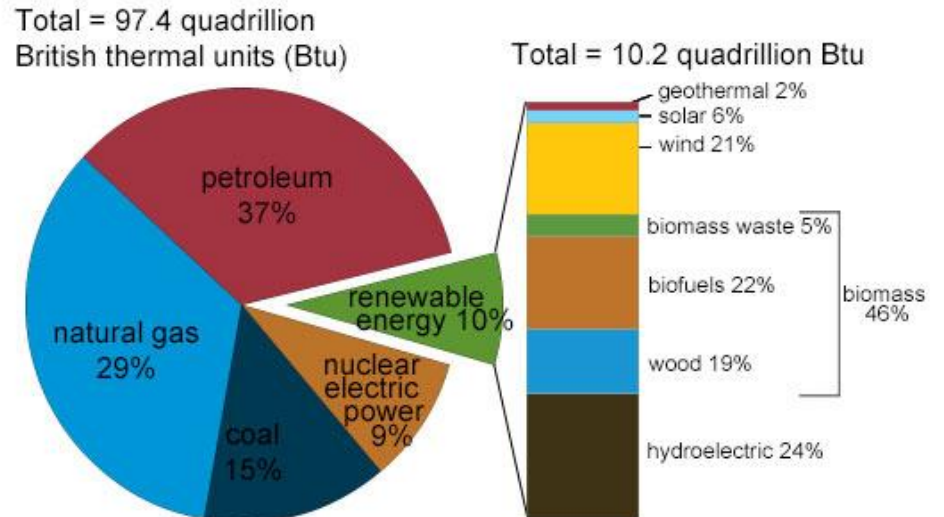


للعلم فقط

Note: Sum of components may not equal 100% as a result of independent rounding.

Source: U.S. Energy Information Administration, *Monthly Energy Review*, Table and 10.1 (March 2015), preliminary data

## U.S. energy consumption by energy source, 2016



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

Source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 1.3 and 10.1, April 2017, preliminary data

# Fossil Fuels Formation

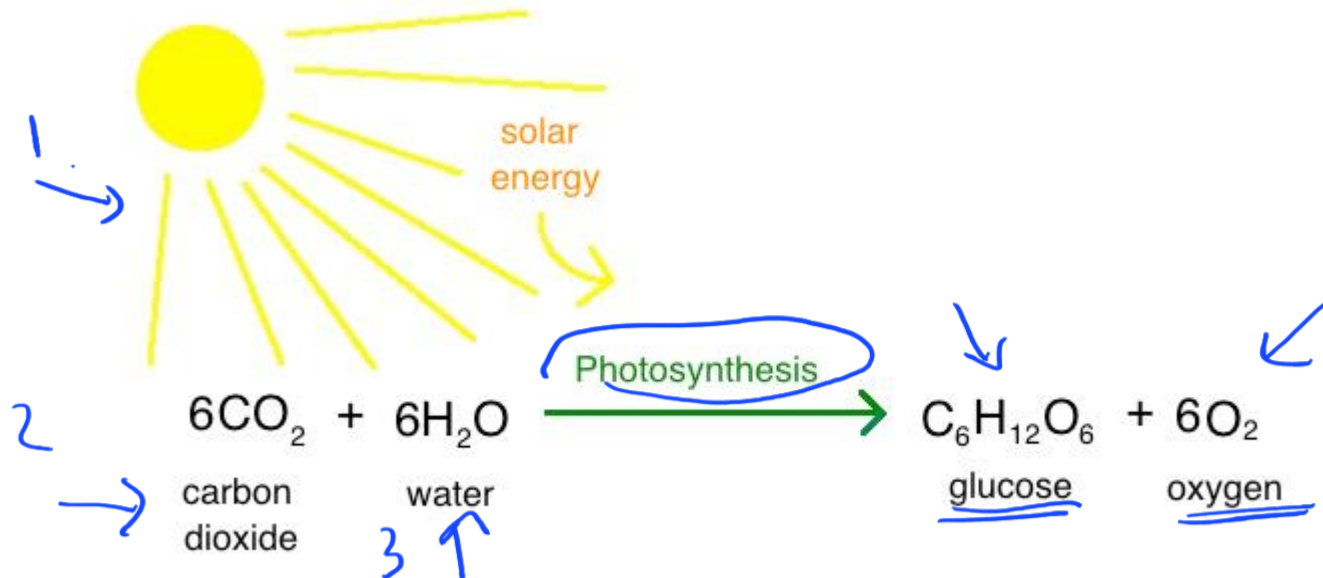
- Fossil Fuels: Coal, Oil, natural gas
- Contain Hydrocarbons and are found in the Earth's crust
- Formed under very specific conditions:
  - Temperature ✓
  - Pressure ✓
  - Oxygen level ✓
  - Time ✓
- Hydrocarbons (organic matter)



# Fossil Fuels

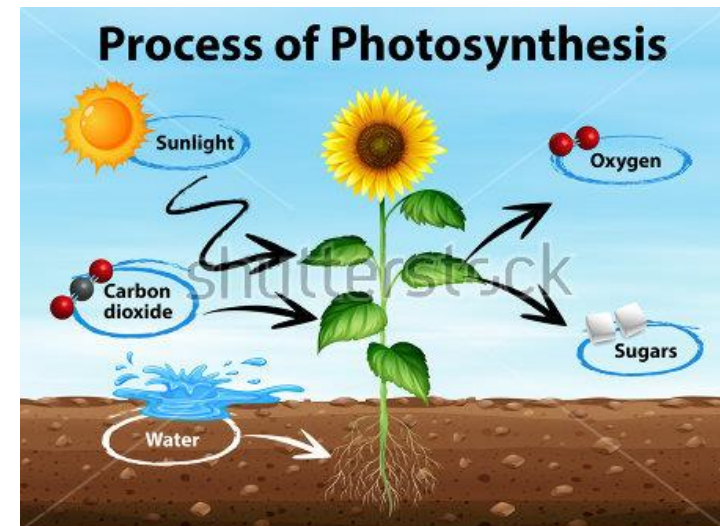
- Energy in Fossil Fuels originates from the sun
- Photosynthesis stores energy from the sun in organic matter
- CO<sub>2</sub> and water form sugar and Oxygen using energy from the sun

التمثيل الضوئي



# A Few Notes about CO<sub>2</sub>

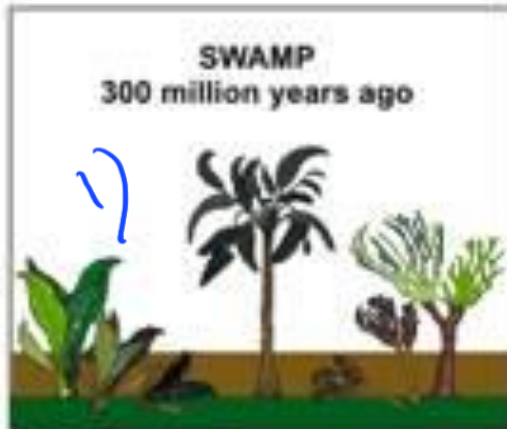
- Since CO<sub>2</sub> is absorbed from the atmosphere, plant matter act as carbon sinks
- Burning fossil fuels releases CO<sub>2</sub> that was previously stored (it does not create carbon)
- Oxygen produced by approximately 1 tree offsets the oxygen used by each person
- Fossil Fuels can be thought of as stored solar energy



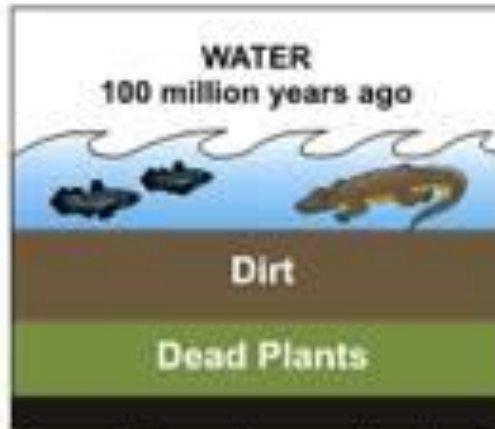
# Coal Formation

- Coal Formation begins with peat جفت which is a decayed plants (نباتات متحلله) and plant parts (bark لحاء, roots)
- Overtime, peat becomes buried with sediment ( رواسب )

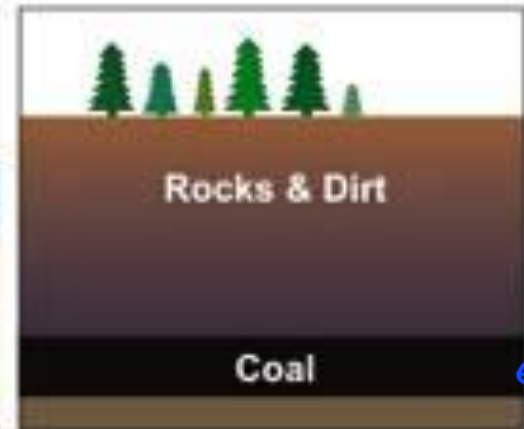
## HOW COAL WAS FORMED



Before the dinosaurs, many giant plants died in swamps.



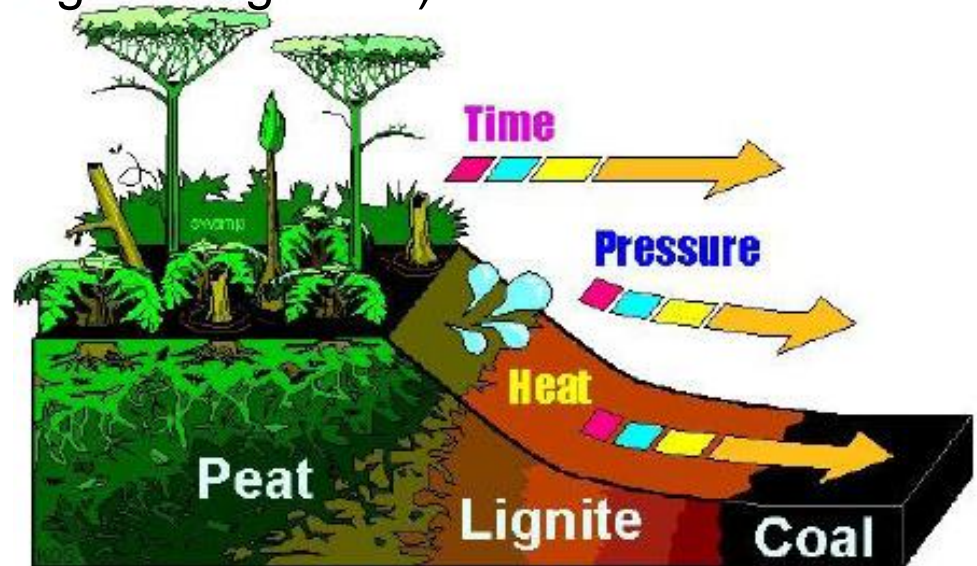
Over millions of years, the plants were buried under water and dirt.



Heat and pressure turned the dead plants into coal.

# Coal Formation

- +1 million years later: complex hydrocarbons break down into simpler ones
- Hydrocarbons with low carbon/hydrogen ratios (methane) escape to the surface
- Remaining hydrocarbons are carbon rich
- Types of coal (descending heating value):
  - Anthracite
  - Bituminous
  - Subbituminous
  - Legnite



# Coal

- Most of the organic matter was deposited during the Carboniferous Period
  - 354 to 290 million years ago
- Earth was hot, humid and swamp-like



Swamp : مستنقع

# Oil Formation

- Remaining Hydro carbons are of the form:
- $C_nH_{2n+1}$  where n is the number of carbon atoms
- Gasoline : n is between 5 and 12
- Diesel: n is 16 or more
- Gasoline and Diesel often contain non-hydrocarbons (e.g. sulfur)

كبريت



# Oil Formation

- Originated as marine life (algae) طحاب
- Dead matter sinks to the oxygen deprived bottom of oceans, sea, rivers, etc
- Over time it is buried and heats up
- Between 7500 to 15000 ft (much deeper than for coal) the temperature is sufficient for oil formation
  - 180 F
  - Requires 10,000-1,000,000 years
- Very specific geological features are needed to prevent the oil from seeping to the surface

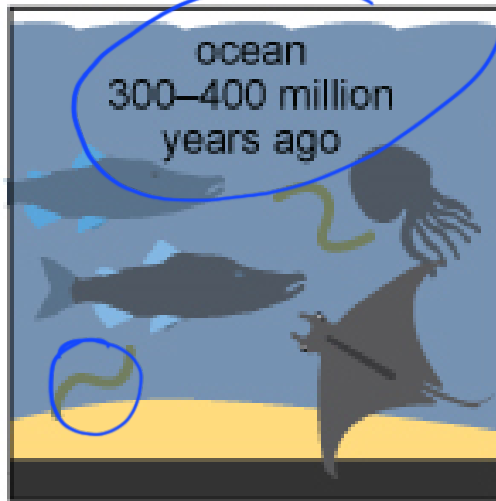
# Natural Gas

- Natural gas is primarily methane
  - CH<sub>4</sub>
- Produced by the same process of oil but at temperatures that occur at greater than 15,000 ft
- All carbon bonds are broken

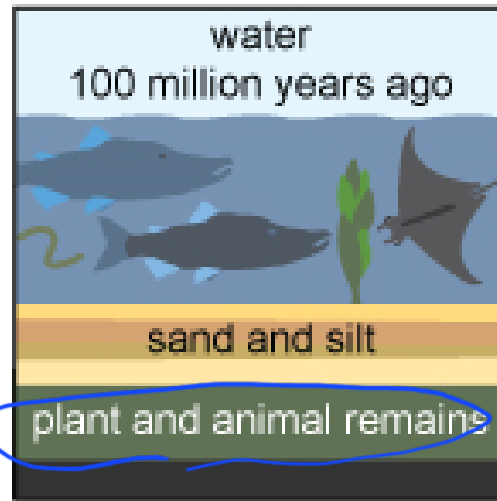


# Petroleum and natural gas formation

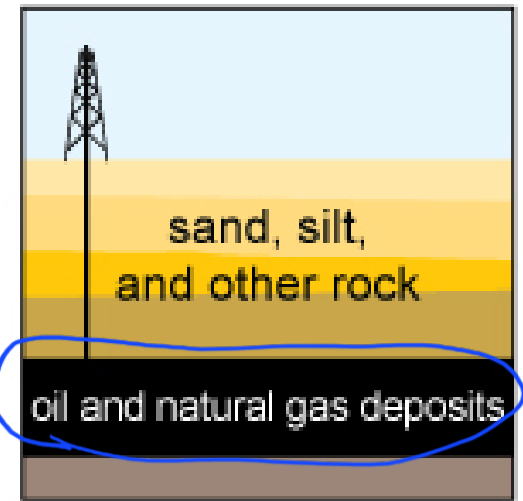
Tiny marine plants and animals died and were buried on the ocean floor. Over time, the marine plants and animals were covered by layers of silt and sand



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



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



Source: Adapted from National Energy Education Development Project (public domain)

# Energy Content

- Specific Energy Density: energy content in 1 kg
- Approximate ranges:
  - Coal (anthracite): ~30 MJ/kg
  - Oil (Diesel) ~ 45 MJ/kg
  - Oil (Gasoline): ~ 45 MJ/kg
  - Natural Gas: ~ 45-55 MJ/kg