

BIOENERGY ESE 404

Resources, Production
Applications, & Economics



Prof. Dr. Khairy Hussein
Assoc. Prof. Dr. Hanaa Abulmagd
Energy Department
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Course Overview

- ✓ Course code: ESE404
- ✓ Pre-requisite: EMP301
- ✓ Credit hours: 3 hrs
- ✓ Contact hours: Tuesday 9:00 am-11:00 am
- ✓ Tutorial : Tuesday from 11:00 am-1:00 pm
- ✓ Marks: 100 (60+40)
- ✓ Marks distribution: 30% mid 1 + 20% mid 2 + 10% attendance + 40 % final



Course Topics

- Bio-energy: Origin – Types- characteristics- technology of production and cost.
- Biomass resources: agriculture energy crops, woody crops (trees) – crops residues – forest residues – animal wastes
- Advantages and disadvantages of different biomass resources
- Thermal, chemical and biochemical conversion
- Uses and markets of biofuels
- Technology for producing Bio-power: combustion and gasification – steam or gas turbines, fuel cells, anaerobic digestion of manures to produce methane

Course Objectives

- To understand the basic principles of Bioenergy.
- To differentiate between non-renewable and renewable energy resources.
- To differentiate between the different biomass resources.
- To learn how to produce biofuels from biomass.
- To compare between the characteristics of each biofuel.
- To be familiar with Thermal, chemical and biochemical conversion taken place in the biofuels production.
- To understand the basics of combustion and gasification
- To relate the cost of biofuel production to its benefits.

Four Main Parts to be Covered

Bioenergy Resources

Production of Biofuels

Applications of Bioenergy

Bioenergy Economics Concerns

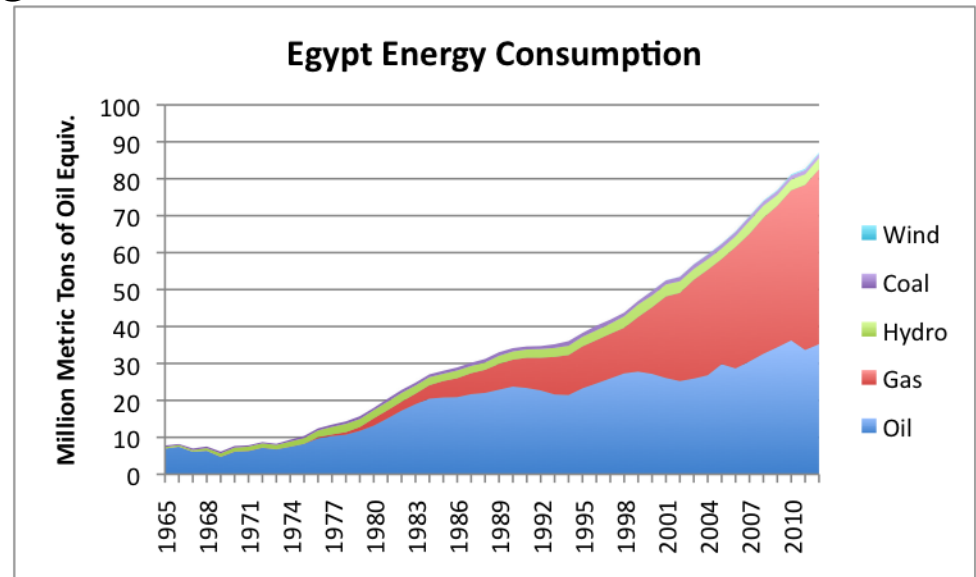
World Energy Picture

Our Needs: electricity, transport, heat

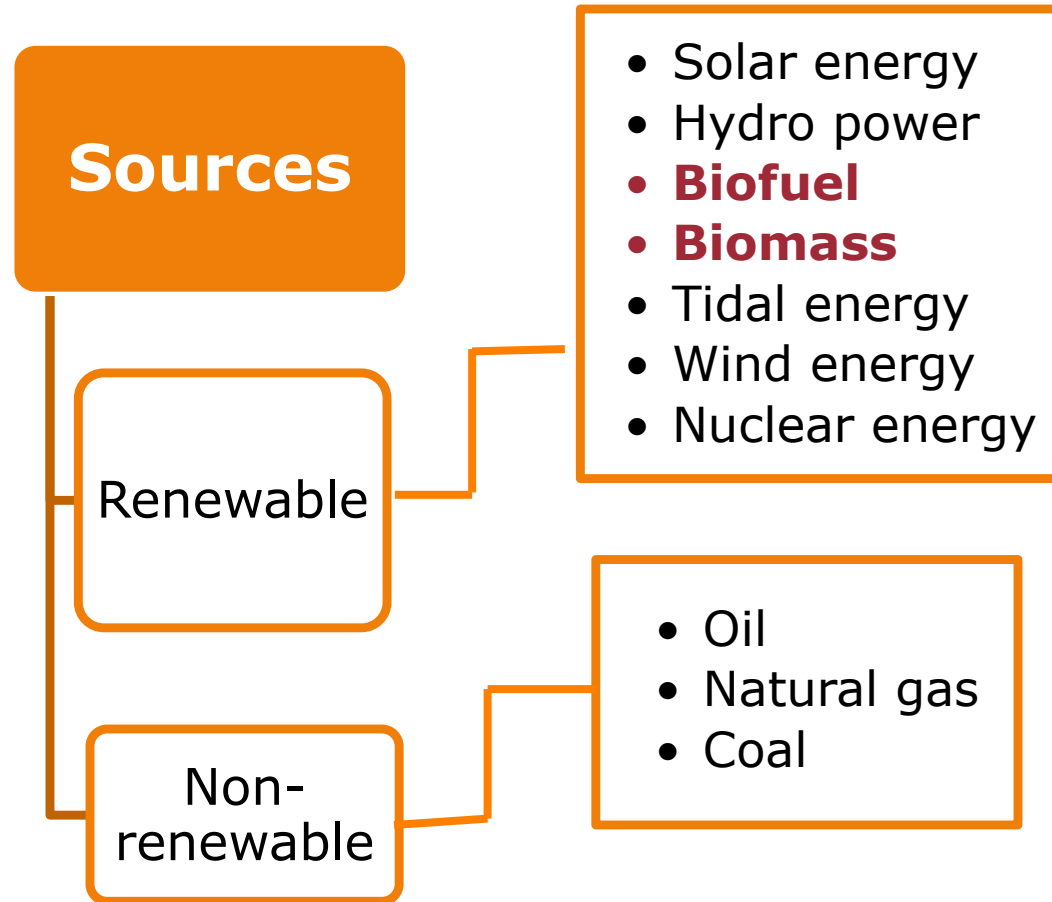
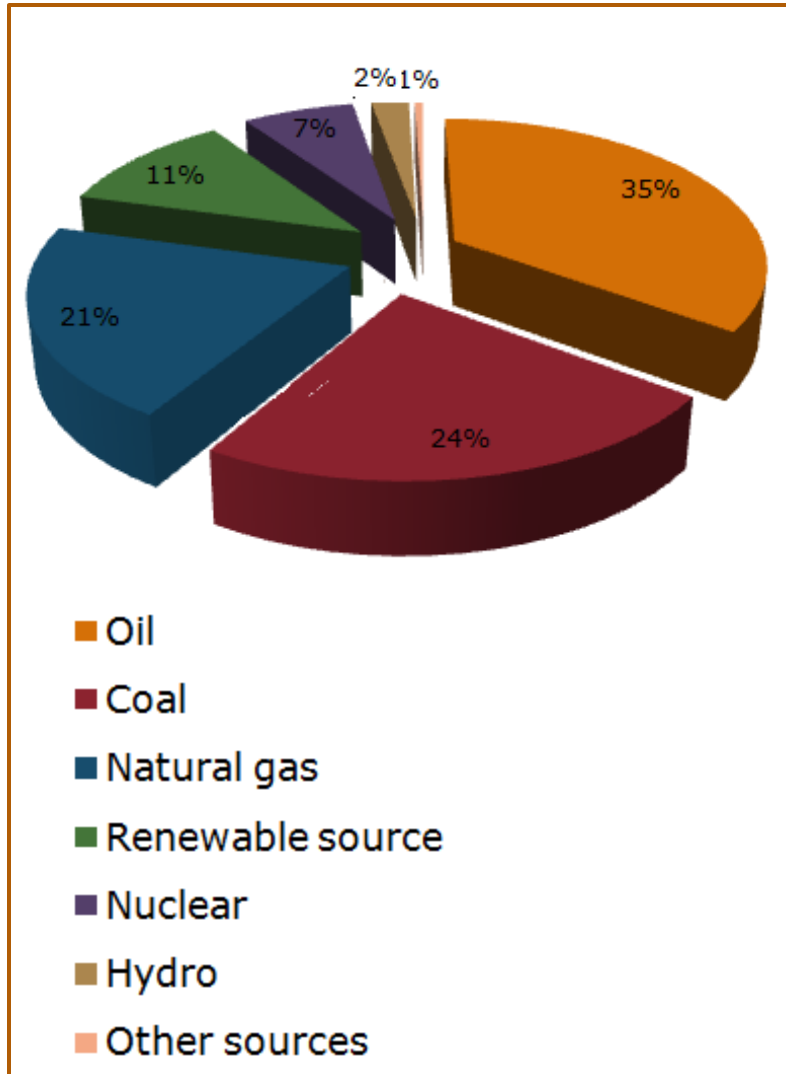
Requirements: coal, oil, gas

Challenges and Concerns:

- Pollution & Climate Change .
- Resource Depletion, Security.
- Rapid increase in population, increase in energy demand.
- Price: people can't afford the energy they want.



Types of Energy Resources



WHY RENEWABLE ENERGY?

- ❖ The fast growing population, and industrialization have increased the demand of energy in developing countries.
- ❖ The current demand of energy depend on sources are non-renewable in nature such as fossil fuels.
- ❖ Up to 2040, all the resources of fossil fuels will be finished.
- ❖ So, for this reason scientists are focus their view on the alternative renewable energy resource such as solar energy, biogas, biodiesel, wind power, tidal energy etc.

Fuels

Types, Resources, Uses and applications



What is fuel?, Can you imagine life without it?

- ❖ **Fuels** are any material that stores potential energy in forms that can be released and used as heat.
- ❖ They are required for a variety of purposes such as:
 - 1) Transportation: it accounts for 25% of energy demand and nearly 62% of oil consumed.
 - 2) Electricity Generation:
 - The generation of electricity is the single largest use of fuel in the world.
 - More than 60 % of electricity generated comes from fossil fuels.

Chemical composition of fuel

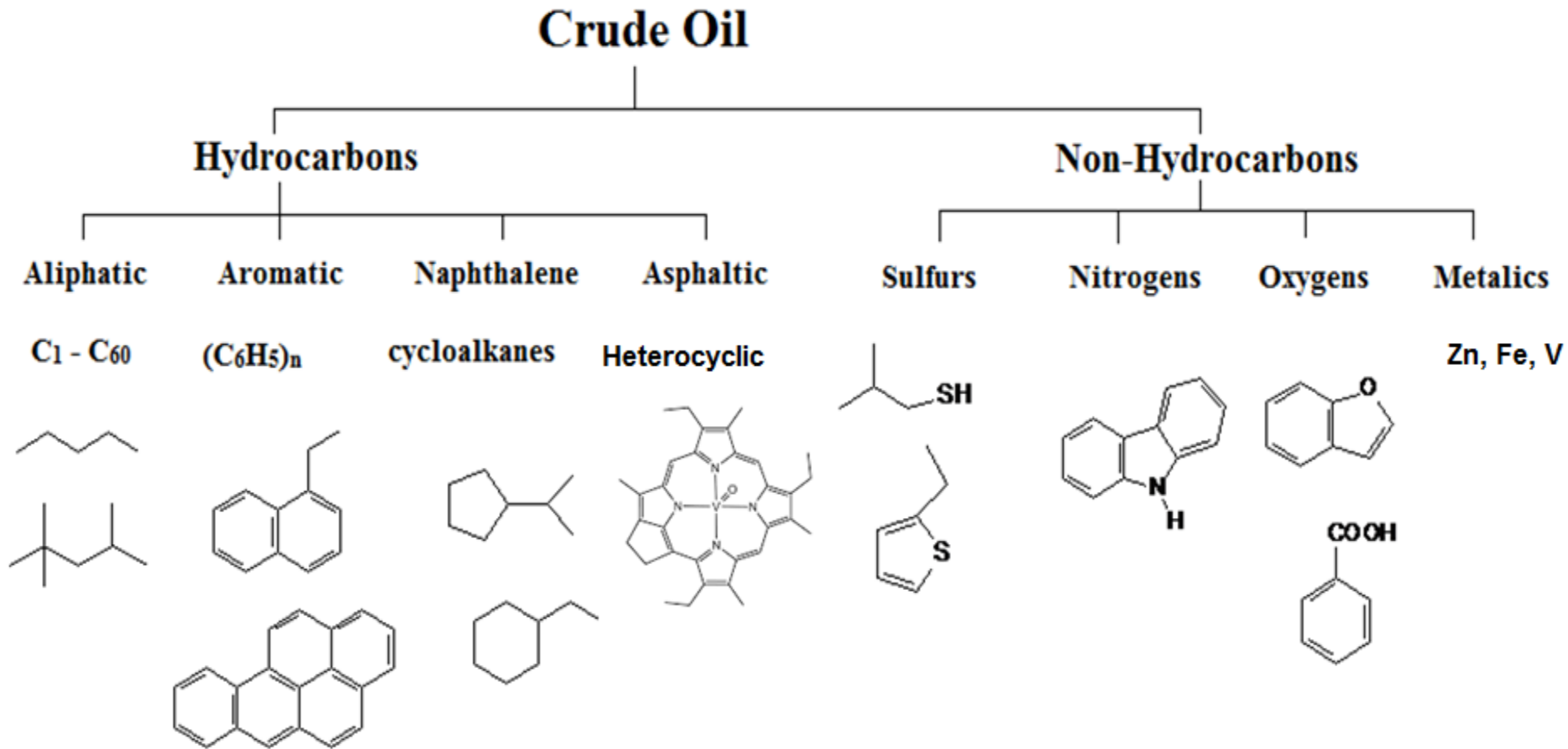


- ❖ Petroleum (black gold) is a complex, naturally occurring liquid, and in usages it includes crude oil and natural gas also.
- ❖ It is a mixture of hydrocarbons, and some compounds of oxygen, nitrogen and sulfur.
- ❖ It contains four different forms of hydrocarbons with different molecular weights, chemical properties, and organic structures.
- ❖ Most of the world's petroleum is to be found in the Middle East.

❖ Natural gas contains hydrocarbons in gaseous forms, and methane (CH_4) is the major component.

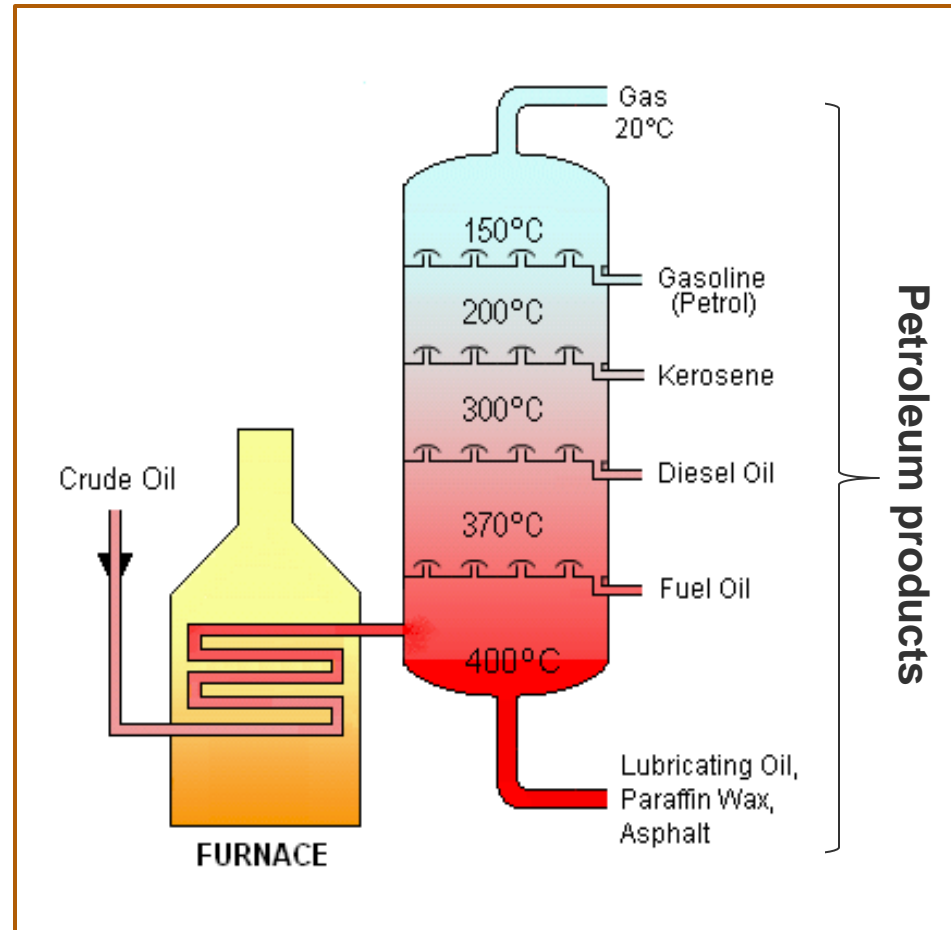
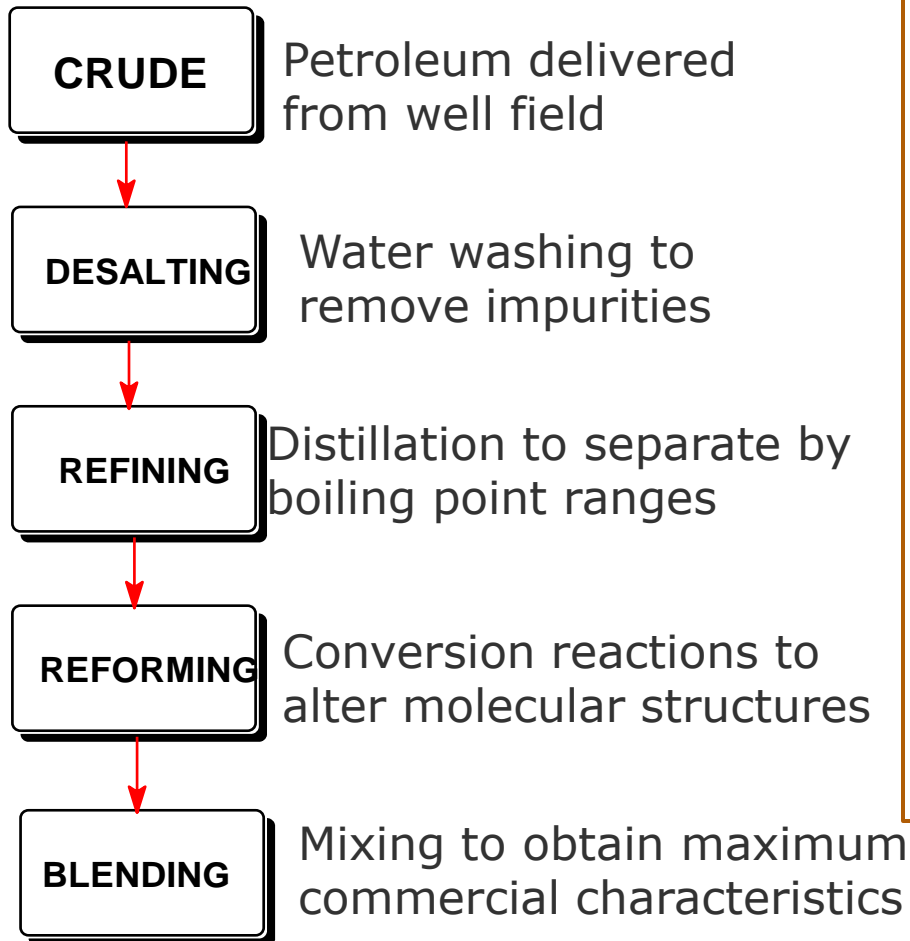
Element	Wt. %	Hydrocarbons	Wt. %
Carbon	83-87	Alkane	30
Hydrogen	10-14	Naphthalene	49
Nitrogen	0.1-2	Aromatics	15
Oxygen	0.1-1.5	Asphaltic	6
Sulfur	0.5-6		
Metals	< 0.1		

Composition of Crude Oil

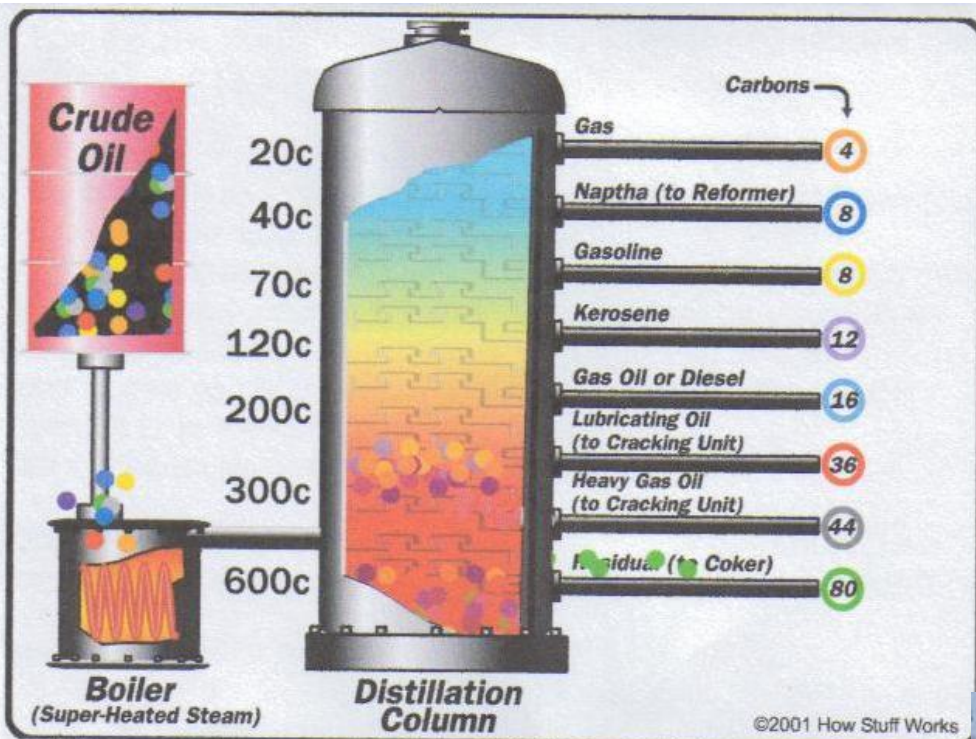


Refining of Crude Oil

During refining of crude oil, the lighter hydrocarbons (gases) move up in the distillation tower.



Schematic representation of distillation towers

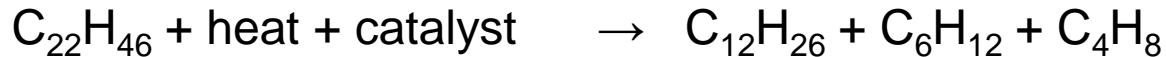


The oil refining process starts with a fractional distillation colu



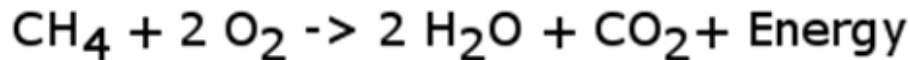
Important Chemical Reactions in Petroleum

➤ Cracking processes take place in petroleum refining to break down heavy hydrocarbons into lighter products. The catalyst used is often silica or alumina

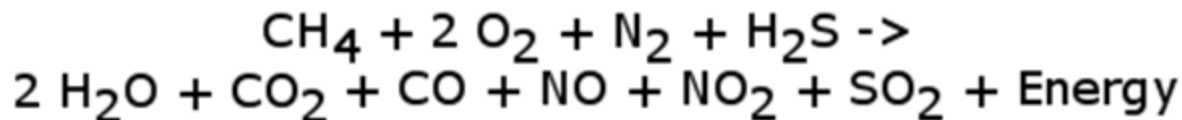


➤ **Combustion of some petroleum products**

1- Combustion of clean products such as natural gas and gasoline:



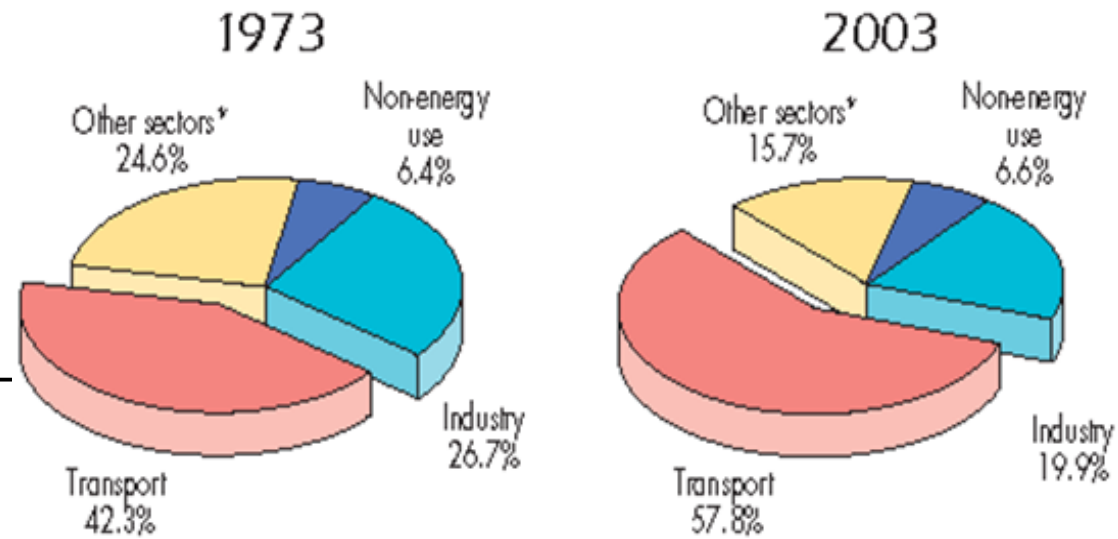
2- Combustion of Petroleum Contaminants:



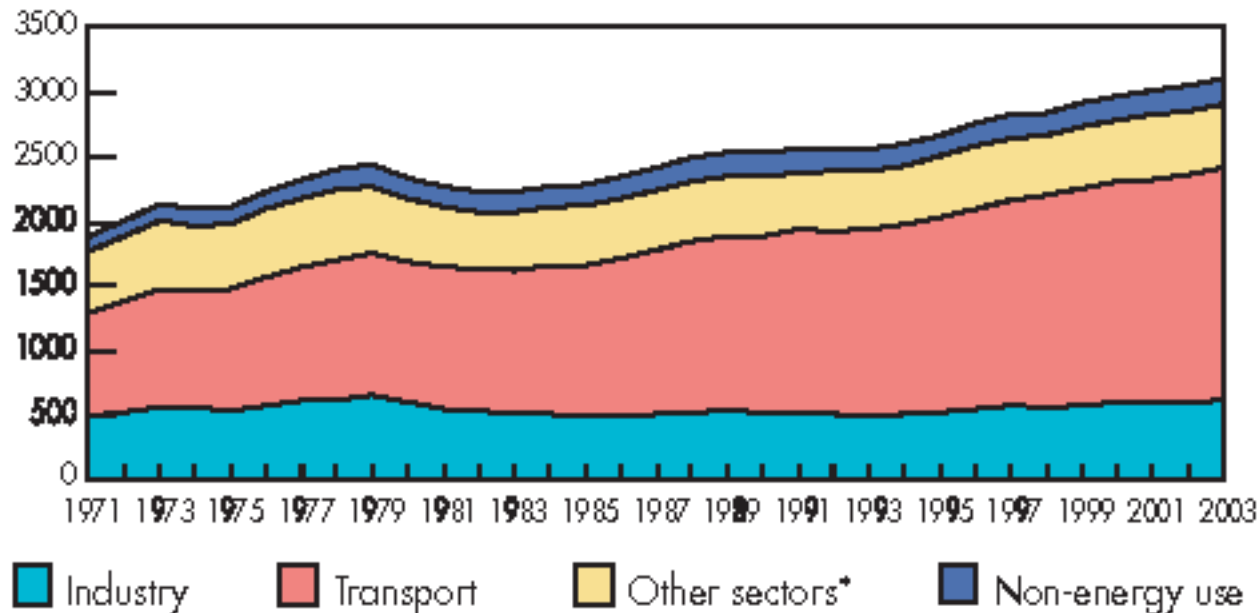
Acid rains

Use of Oil

Mainly in transportation –
industry – power production –
synthesis of plastics



**Other sectors comprises agriculture, commercial & public service, residential and non-specified.*

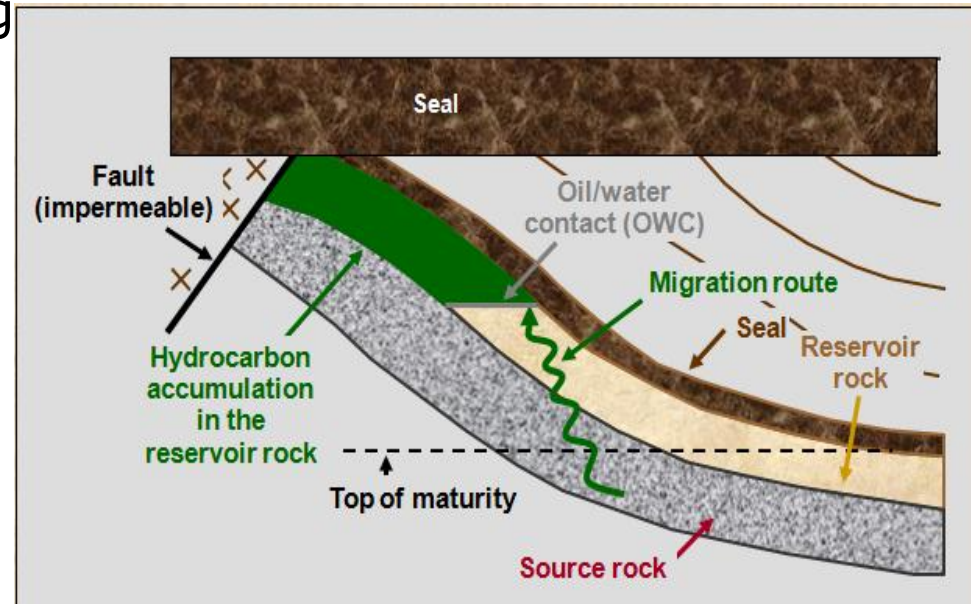


Problems and disadvantages of fossil fuel

Fossil fuels: They are hydrocarbon fuels that take millions years to be formed.

- They are nonrenewable (once used it is no longer available)
- They are very hazardous and cause environmental pollution because their burning releases CO₂ or CO.
- Their prices are always in rising
- Power stations consume lots of fuel and effort to generate electricity, they will be stopped if there is reduction in fuel.

What is the solution !!!!



Alternative energy – Bioenergy

Bioenergy: energy produced from recently living organic matters called biomass

These matters can be :

burned directly for heat (traditional biomass) or

converted to **biofuels** such as **biodiesel** or **bio-ethanol**.

➤ Sources of bioenergy :

• Biofuels

- ❖ Liquids: Methanol, Ethanol, Butanol, Biodiesel
- ❖ Gases: Methane, Hydrogen

• Bioheat

- ❖ Wood burning

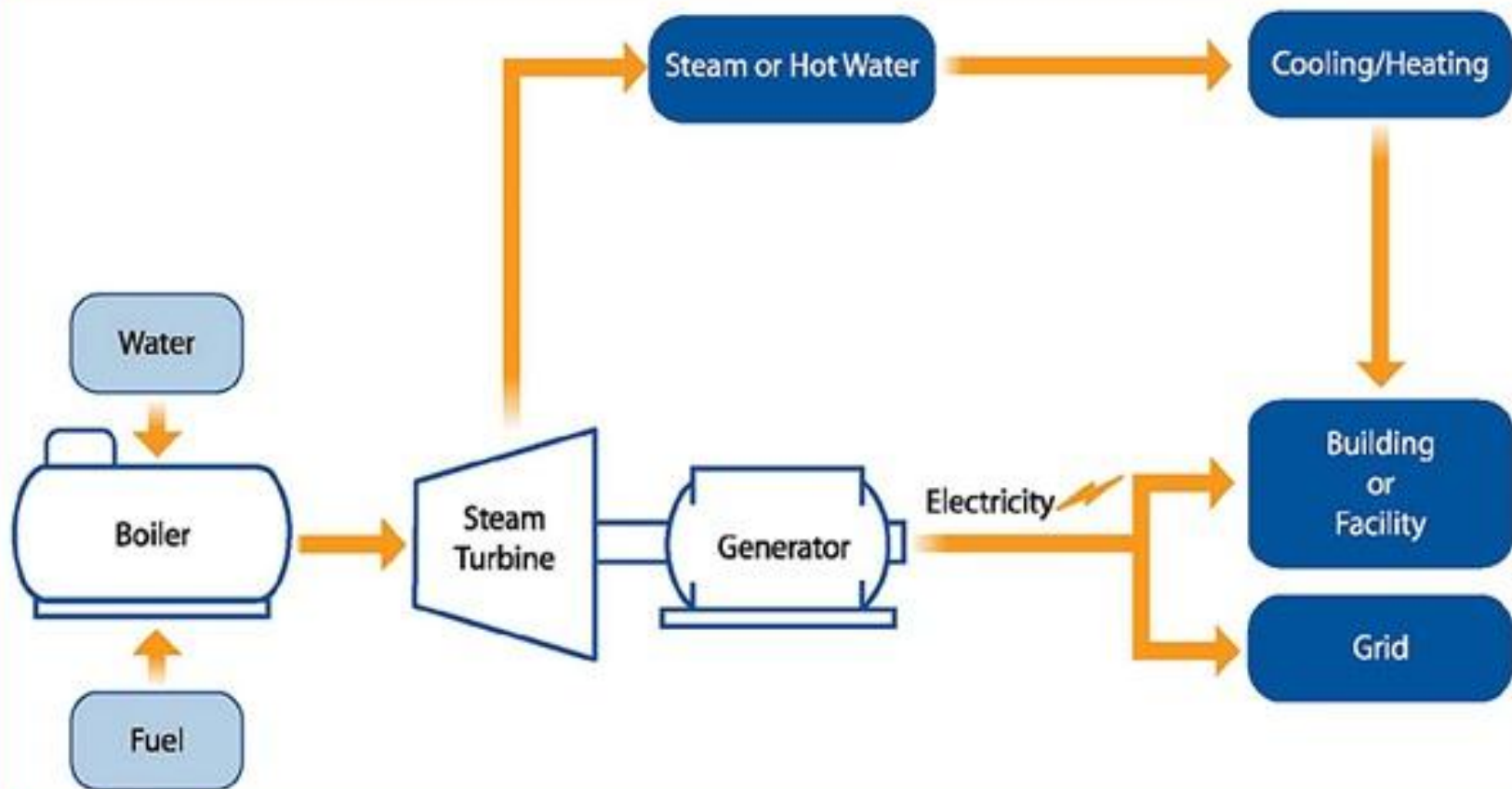


• Bioelectricity

- ❖ Combustion in Boiler to Turbine
- ❖ Microbial Fuel Cells (MFCs)



Steam boiler with steam turbine



History of Bioenergy

Bioenergy is not new!!!!

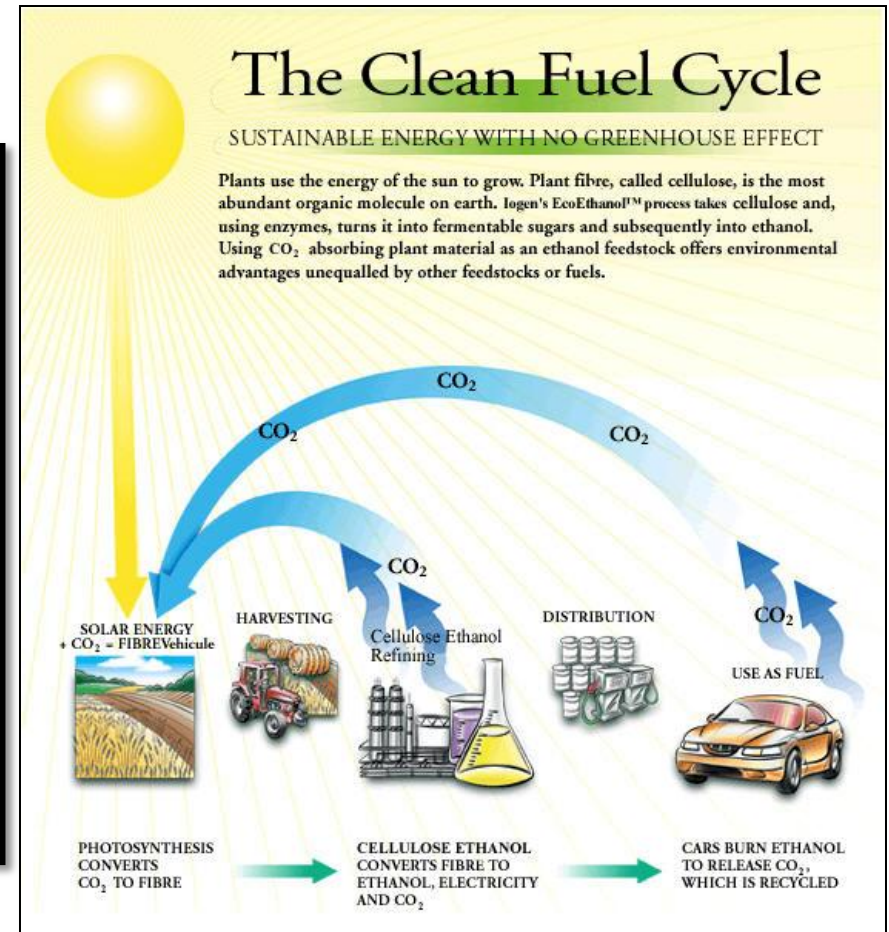
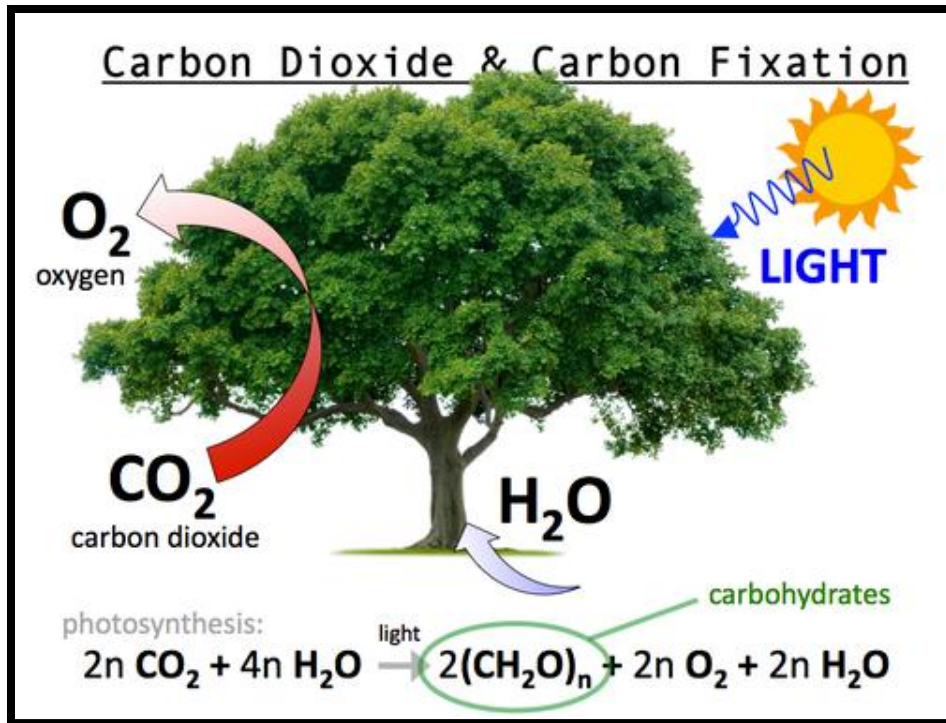
- Biomass such as wood & crops are used to burn for heat and lightning long time ago.
- 1850s: Ethanol used for lighting.
- 1896: 1st ethanol-fueled automobile, the Ford Quadricycle.
- 1908: 1st Ford Model T working with ethanol
- WWI and WWII: Ethanol used due to high oil costs.
- 1990s: Ethanol was the most recent biofuel popularity



Increased in response to high emissions standards & increasing demands for enhanced fuel economy.

Bioenergy cycles

Lessons from Nature

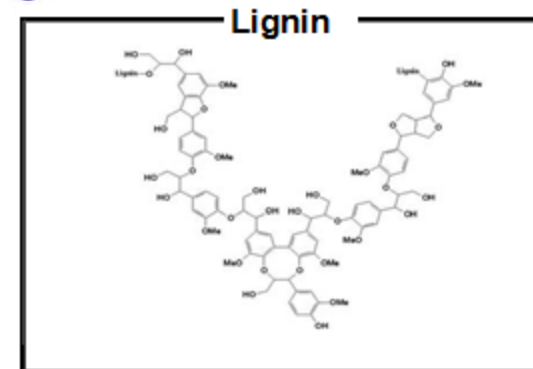
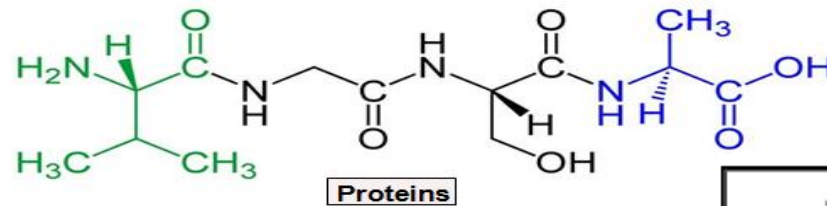
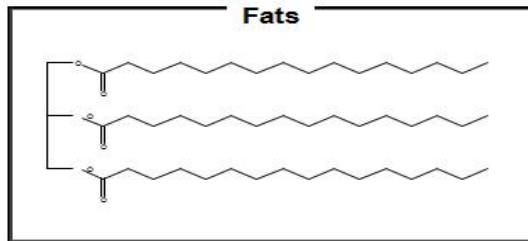
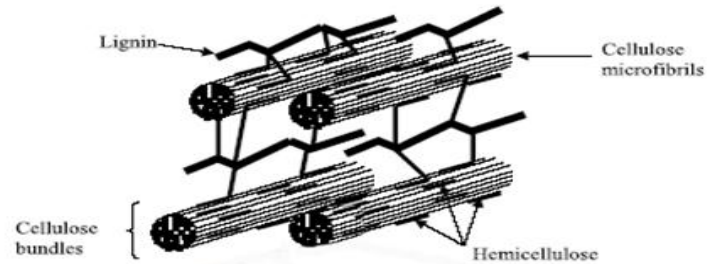
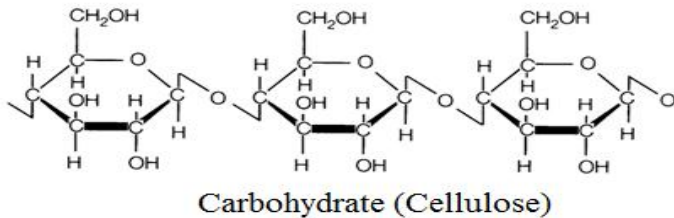
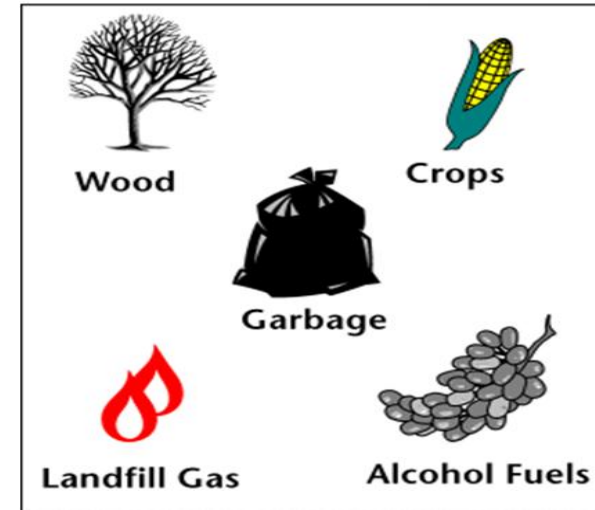


Photosynthesis is a biological carbon fixation process utilized by plants to obtain energy in the form of carbohydrates.

Biomass Resources and Biofuel Production

Origin of Biomass

- They are all living or recently living organisms, animal/plant waste, industrial and municipal waste
- The main components of biomass are: carbohydrates & lignin (+proteins, lipids)



- Biomass can be classified into two categories: Woody and non-woody Biomass.

Woody Biomass

- **Coconut** - In areas common with coconut trees. Their hulls burn efficiently with very little residue. They are used for cooking and heating specifically in undeveloped countries.



- **Oil Palm** - The oil palm provides biomass in two ways: direct and indirect biomass. The fruit produces oil, which can be chemically converted to biodiesel.



- The hulls can be burned directly.
- **Poplar** - The poplar family includes trees like the Aspen and Cottonwood. These trees are valued for their rapid growth and ability to be cultivated from sprouts cut from adult trees.



- **Pine** - Pine likes poplar is so valued, it grows fast, it's easy to cultivate, and is relatively inexpensive to grow.



Uses of woody biomass:

- Generally burned to heat space or heat water (direct biomass).
- To produce steam to generate electricity via a turbine generator

Non-Woody Biomass

- Such as corn, sugar cane, soybeans, grass, algae.
- It is used as indirect biomass, or to produce different liquid biofuels.
- The most commonly used non-woody biomass is Switchgrass.
- It becomes more attractive to generate ethanol from cellulosic.

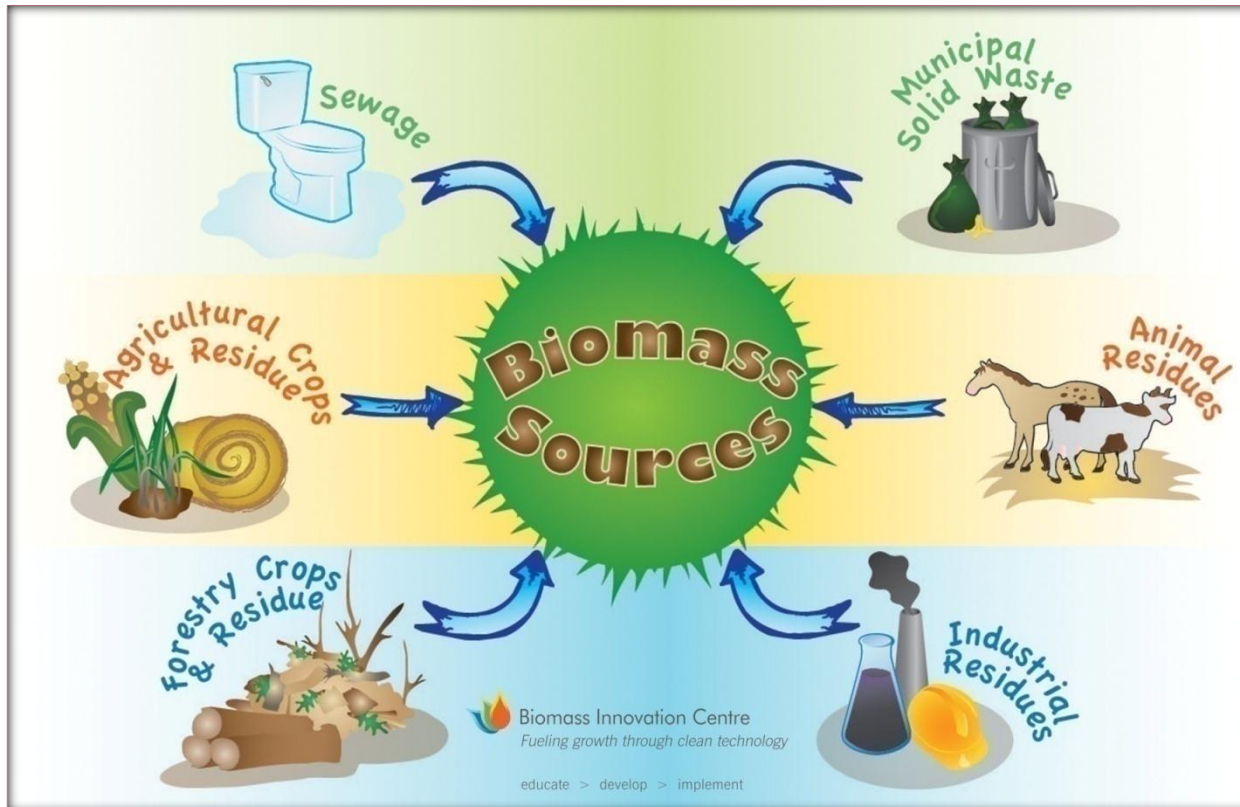
The benefits of switch grass over other biomass include:

- It has high cellulose content that makes it an ideal direct biomass.
- It is also mechanically converted into pellets for easy transportation.
- Perennial (lowers costs) محصول معمر
- Improved soil quality from not plowing each year
- Relatively high yield even in bad lands انتاجية عالية
- Drought and pest resistant مقاوم للجفاف و اللافات
- Low water and fertilizer needs لا يحتاج لماء و سماد بكمية كبيرة



Other agricultural wastes and biomass

- Crop and forestry residues, animal manure, food processing waste, yard waste, municipal wastes, sewage, industrial waste.
- Wood processing mill residues
- Paper & pulping waste slurries



Biomass is an eco-friendly power source

Energy contents of Biomass

Average heat energy content of fuels

Fuel	Energy content		Fuel	Energy content	
	GJ t ⁻¹	GJ m ⁻³		GJ t ⁻¹	GJ m ⁻³
Wood (green, 60% moisture)	6	7	Straw (as harvested, baled)	15	1.5
Wood (air-dried, 20% moisture)	15	9	Sugar cane residues	17	10
Wood (oven-dried, 0% moisture)	18	9	Domestic refuse (as collected)	9	1.5
Charcoal	30	*	Commercial wastes (UK average)	16	*
Paper (stacked newspapers)	17	9	Oil (petroleum)	42	34
Dung (dried)	16	4	Coal (UK average)	28	50
Grass (fresh-cut)	4	3	Natural gas (at supply pressure)	55	0.04

Note that the composition of coal and most biofuels is variable and the energy content per kg can differ significantly from the above averages. The energy *per cubic metre* depends on the density and can vary even more widely. (* Indicates dependence on specific types of material.)

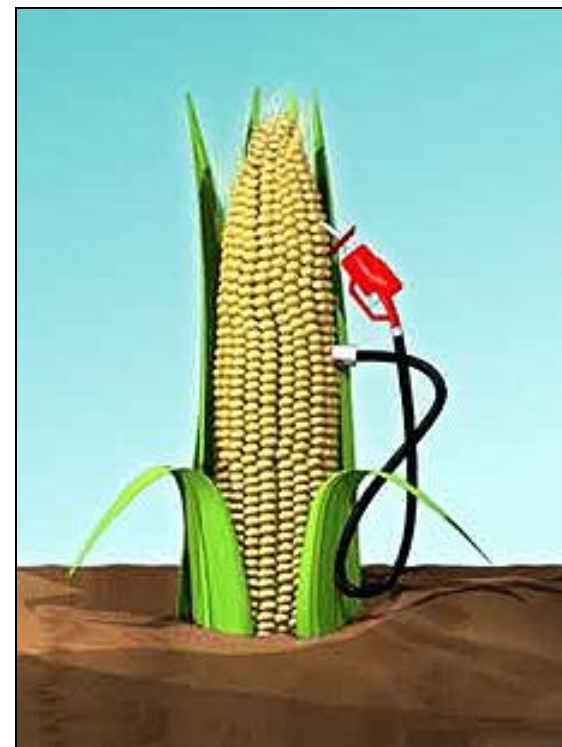
Uses of Biomass

Many important non-energy uses

- Food for humans
- Animal feed (a major and growing use)
- Lumber & other construction materials
- Clothing (cotton, wool, linen, leather)
- Paper, packaging, etc.

Energy uses:

- To produce heat or electricity
- Convert to Gas (CH_4 or CO/H_2)
- Convert to Liquid Fuels to be used in transportation.



Alternative and renewable fuel



Biofuels:

- Any hydrocarbon fuel that is produced from living organic matter in a short period of time (days, weeks, or months).
- They are alternative of fossil fuels, so they are ways of energy security.
- They burn cleaner than fossil fuels, resulting in fewer emissions of greenhouse gases or substances that cause acid rain such as sulfur.
- They are biodegradable, so when spill, less harm is done compared to when fossil fuels spill.

Why biofuels?

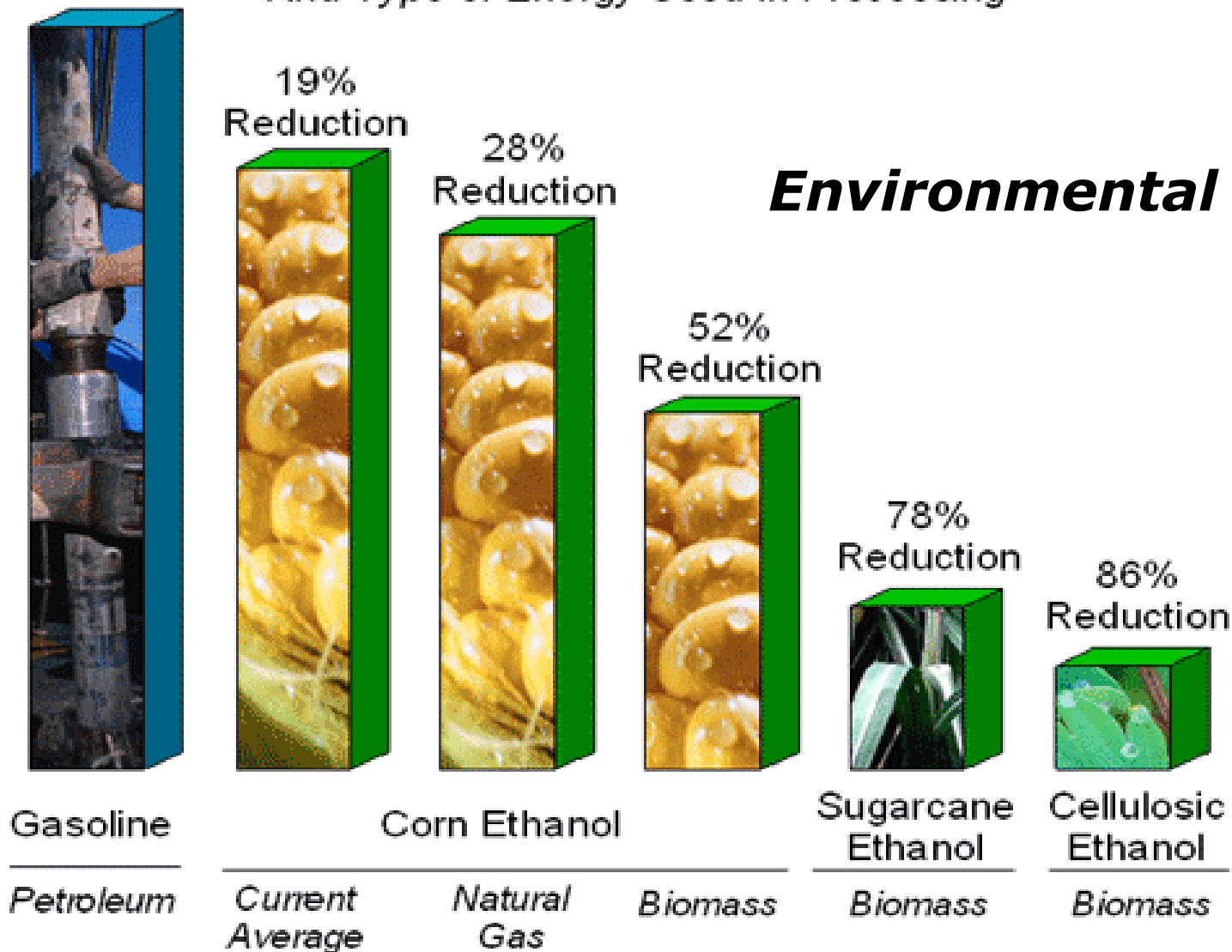
There are many reasons forced us to use biofuels:

1. To reduce our dependence on fossil fuels
2. To reduce reliance on foreign oil
3. To lower emissions of green house gases
4. To bring business to rural economics

Advantages of biofuels

1. Locally available in every region of the world.
2. Friendly with the environment: do not cause global warming – do not emit any hazardous gas
3. Highly energetic: the energy release per unit mass of biofuel is greater than that of fossil fuels.

Greenhouse Gas Emissions by Transportation Fuel And Type of Energy Used in Processing



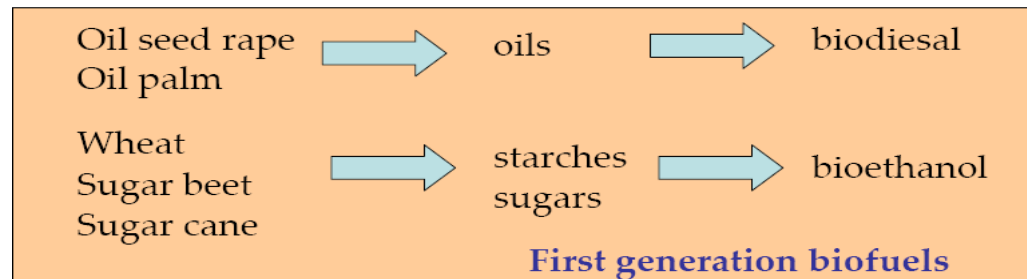
Sources: Wang et al, *Environ. Research Letters*, May 2007; Wang et al, *Life-Cycle Energy Use and GHG Implications of Brazilian Sugarcane Ethanol Simulated with GREET Model*, Dec. 2007

Converting Biomass to biofuels

According to the production method, there are three Generations of biofuels:

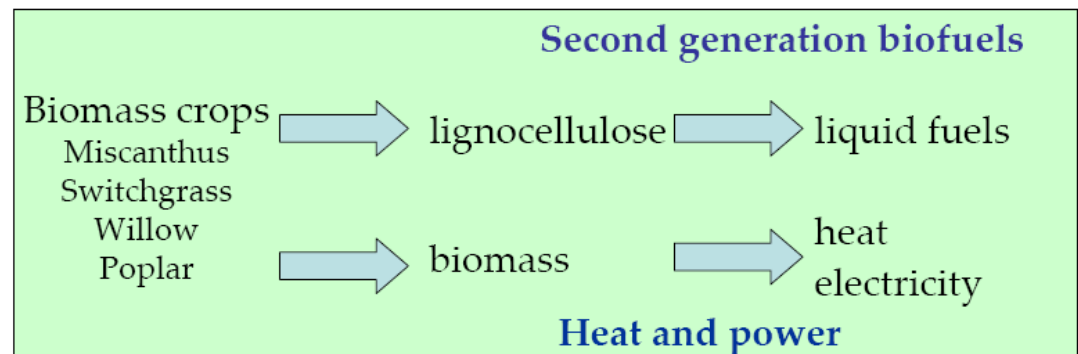
1- First generation: called Conventional Biofuels, made from sugar, starch, and vegetable oil.

i.e produced from edible Stuffs, this will affect the feed security ☹️👎



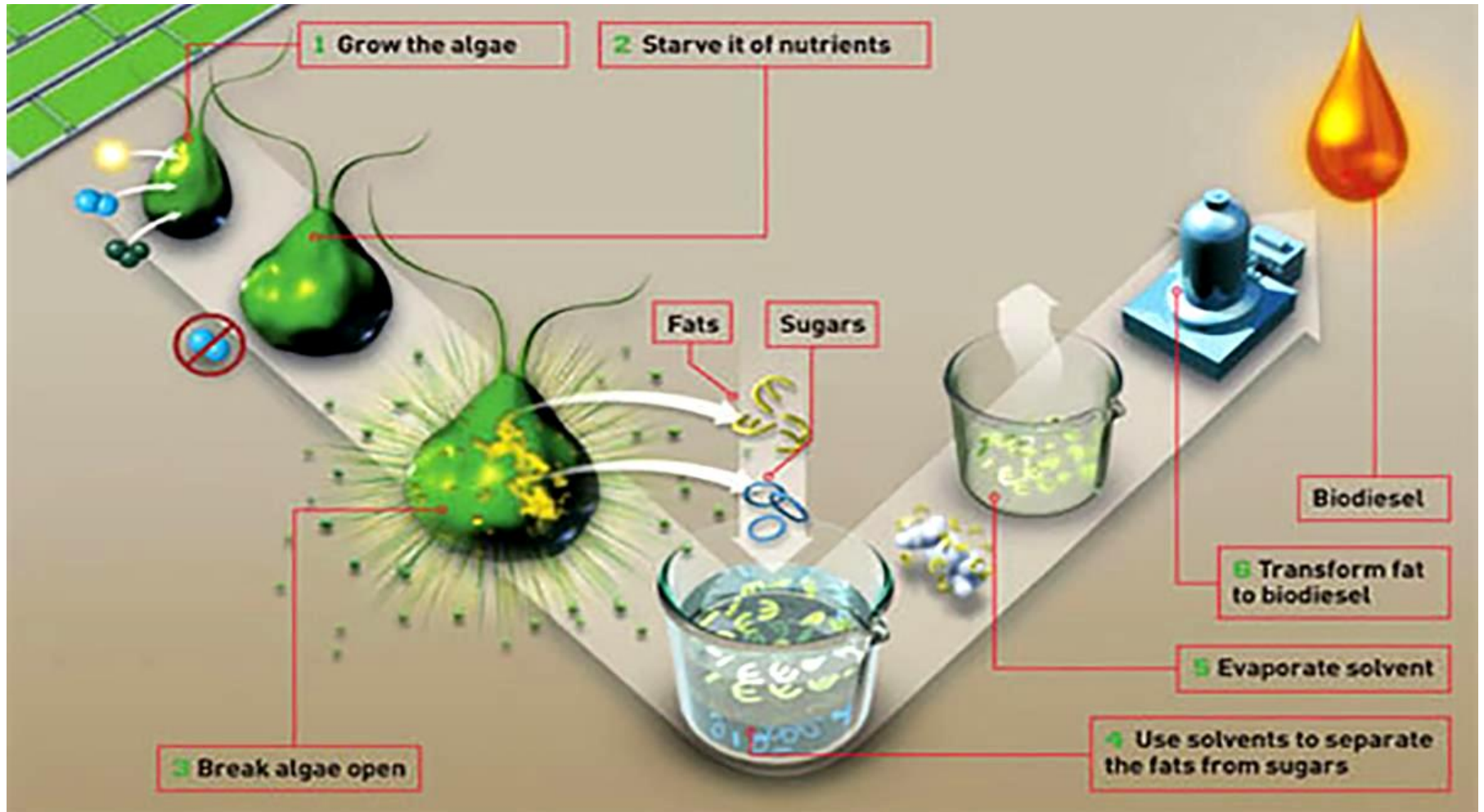
2- Second generation Biofuel: called advanced biofuels, made from non edible plants.

Feed Security



3- Third generation Biofuel: made from algae and microbes.

Converting Biomass to biofuels



Production of biofuel from algae