**Content:**

- **Engineering materials and Polymer Chemistry**: Glass, ceramics, refractory, composites, magnetic materials, Polymer, Properties, Polymer processing, Industrial polymers, conducting polymers
- **Natural Products and Biomolecules:** Amino acids/nucleic acids/proteins/lipids, Enzymes, Vitamins, Biomacromolecules, and Solid phase synthesis.
- **Fuels and Combustion**: Properties of fuels, Calorific value, Petroleum and petrochemicals, biofuels.
- **Electrochemical Systems:** Electrochemical cells and EMF, Applications of EMF measurements, Nernst Equation, Batteries, Fuel cell, corrosion and its control.

**Textbook books:**


1. P. Atkins and J. Paula, Physical Chemistry, 10th Edition, Oxford University Press, Oxford.

2. F. A. Cotton, and G. Wilkinson, Advanced Inorganic Chemistry, 5rd Ed., Wiley.

4. H.D. Gesser, Applied Chemistry - A Textbook for Engineers and Technologists, Springer


**Reference books:**


1. Fred W. Billmeyer, Text Book Polymer Science, Wiley India Pvt. Ltd.

2. D. J. Shriver, P. W. Atkins, and C. H. Langford, Inorganic Chemistry, 3rd Ed., ELBS.

# Bomb calorimeter

- ***Formula for Higher Calorific Value (HCV) & Lower Calorific Value (LCV)***

$$\mathrm{HHV} = 32,796\,\mathrm{C} + 141,886\,(\mathrm{H} - \mathrm{O}/8) + 9300\,\mathrm{S} \quad (\mathrm{kJ/kg})$$

$$\mathrm{LHV} = \mathrm{HHV} - 2440(\mathrm{W} + 9\mathrm{H}) \quad (\mathrm{kJ/kg})$$

- In these relations, the letters C, H, O, S, and W are percent weights of carbon, hydrogen, oxygen, sulfur, and water vapor in the coal composition, respectively.

# Calorific value

❖ ***Lower and higher heating values of some fuels***

| Fuel type | | Unit | Lower heating value | | Higher heating value | |
|---|---|---|---|---|---|---|
| | | | kcal | kWh | kcal | kWh |
| Wood | | kg | 2500 | 2.90 | 2800 | 3.25 |
| Coal | Lignite | kg | 3000 | 3.50 | 3300 | 3.84 |
| | Export | kg | 6000 | 6.98 | 6500 | 6.96 |
| Diesel | | kg | 10200 | 11.86 | 10,800 | 12.58 |
| Natural gas | | $m^3$ | 8250 | 9.59 | 9155 | 10.62 |
| Heater fuel | | kg | 9700 | 11.28 | 10,500 | 12.18 |
| LPG (30% propane, 70% butane) | | $m^3$ | 26,000 | 30.16 | 28,200 | 32.71 |
| | | kg | 11,000 | 12.76 | 11,900 | 13.80 |
| Propane | | $m^3$ | 21,200 | 23.95 | 23,000 | 25.93 |
| | | kg | 11,100 | 12.87 | 12,000 | 13.98 |
| Electric | | kWh | 860 | 1 | 860 | 1 |
| Fuel oil | | kg | 9700 | 11.28 | 10,500 | 12.18 |

# Calorific value

❖ ***Heating (calorific) values of some fuels***

| Fuel | Heating value (MJ/kg) | Fuel | Heating value (MJ/kg) |
|---|---|---|---|
| Animal/plant waste | 9.62 | Propane | 42.70 |
| Asphaltites | 18.00 | Fuel gas | 43.96 |
| Briquette | 20.93 | Acetylene | 59.57 |
| Coal | 23.02 | Coke gas | 16.85 |
| Coke dust (powder) | 25.12 | Natural gas | 34.54 |
| Crude oil | 43.96 | LPG | 45.63 |
| Graphite | 33.49 | Naphtha | 43.54 |
| Industrial lignite | 12.56 | Fuel oil No: 5 | 41.97 |
| Lignite plant | 8.37 | Fuel oil No: 6 | 41.28 |
| Petro-coke | 31.81 | Gasoline | 43.54 |
| Prina (Olive pomace) | 18.00 | Gas oil | 34.70 |
| Sawdust | 12.56 | Black liquor | 12.56 |
| Wood | 12.56 | Diesel fuel | 42.70 |

# Petroleum and petrochemicals

***The role of innovation and technology in sustaining the petroleum and petrochemical industry***

- Petroleum, the New “Black Gold”

- The word "petroleum" means "rock oil" or "oil from the earth" (EIA, 2005). Mankind has known petroleum or crude oil since the dawn of civilisation.

- It was used in ancient Persia and Burma, particularly as fuel for lamps. Burning of the natural gas (escaping from petroleum underground) gave the 'perpetual fire' at Baba Gurgur in Iraq (Arene and Kitwood, 1979).

- Innovation and Technology go hand in hand within the petroleum and petrochemical industry.

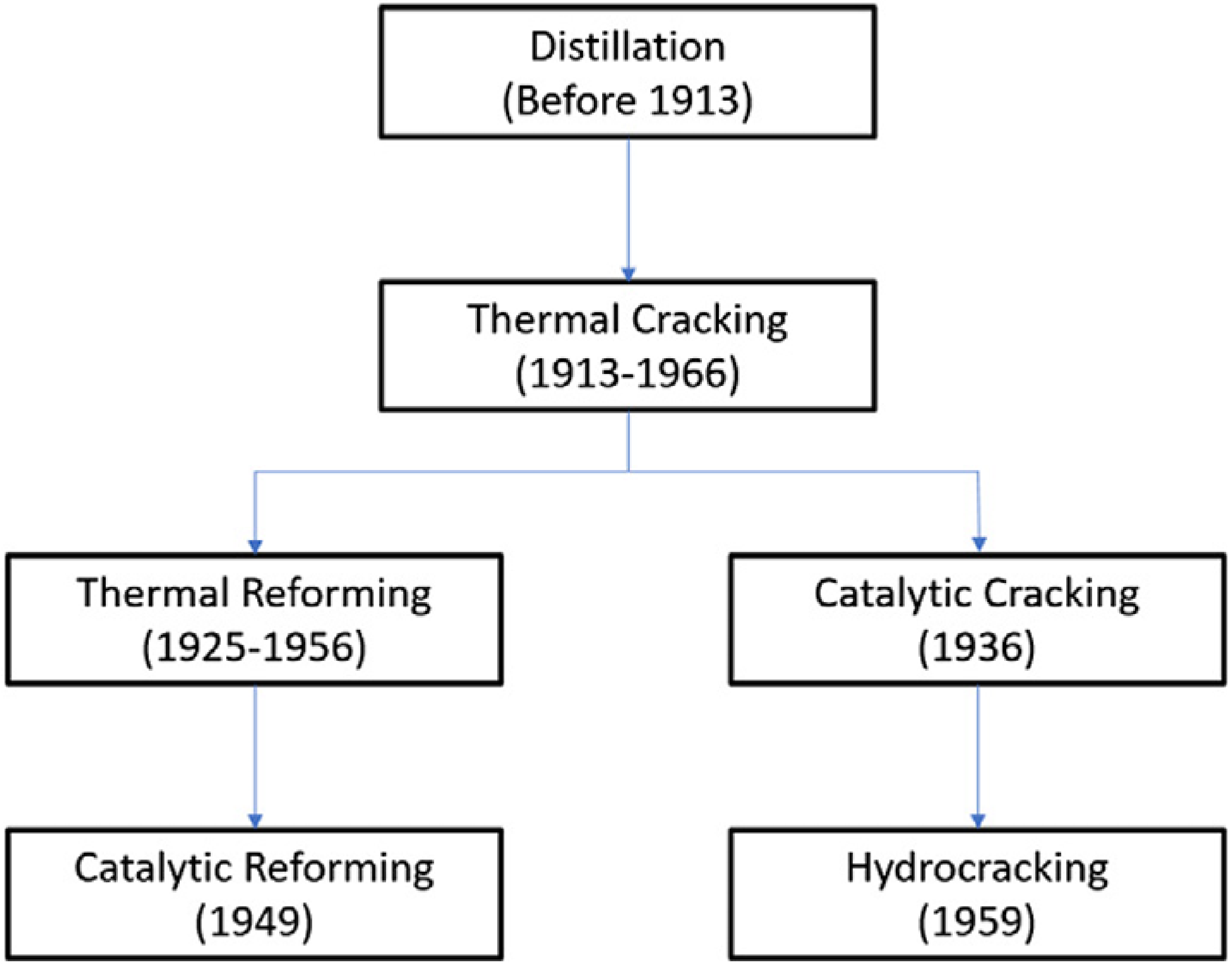
- Oil price volatility, geopolitics, and economic uncertainty, all contribute towards the continued need to innovate and technologically advance if petroleum and petrochemical companies are to survive in this highly competitive industry.

- Thereafter, the focus shifts towards identifying both quantifiable and non-quantifiable impacts of technology and innovation within the petroleum and petrochemical industry.

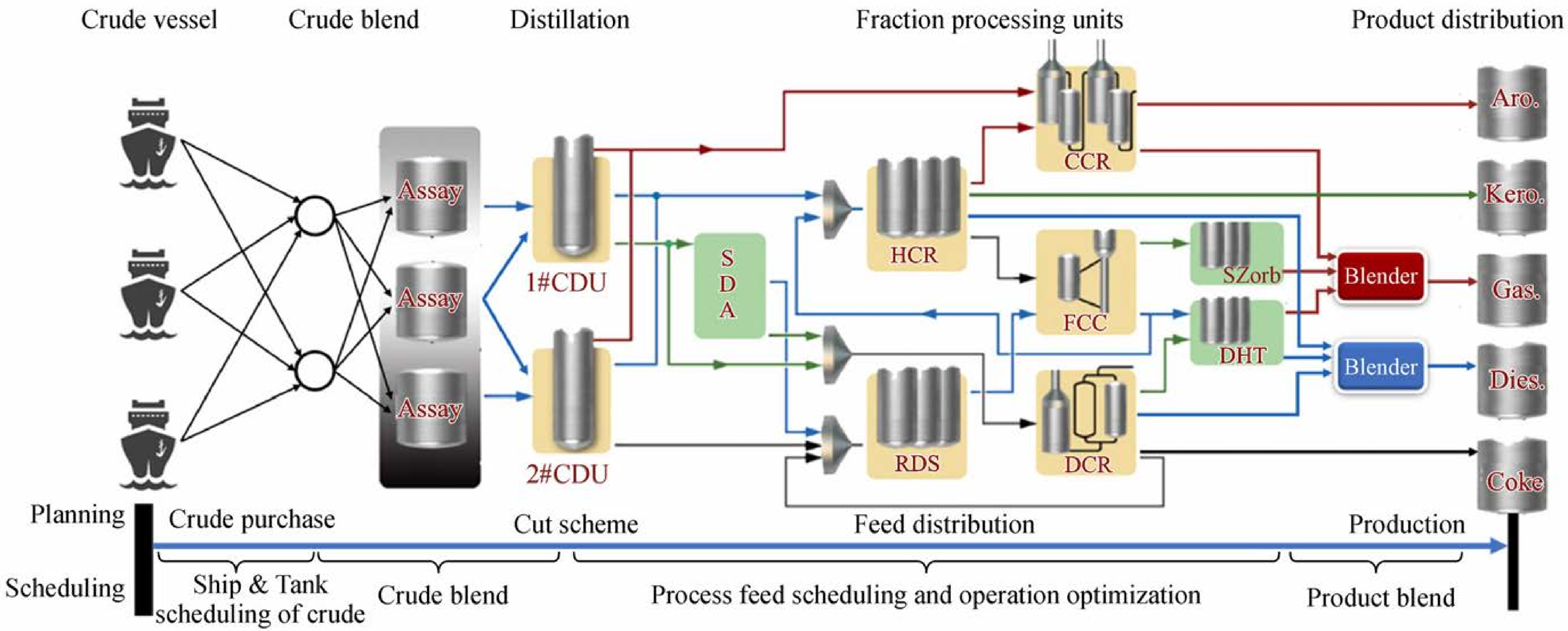
*J. Applied Sci*., 11 (12): 2084-2091, **2011**

*Technological Forecasting & Social Change* 119 **(2017)** 1–17

# Historical innovations in petroleum refining processes



# Production planning and scheduling optimization




*Front. Eng. Manag.* **2020**, 7(3): 373–383

# The Origin of Petroleum

The formation of petroleum has long been debated, but two main theories are generally discussed:

❖ **1. Biogenic Theory (widely accepted):**

- Petroleum originates from the slow decomposition of marine plant and animal remains, especially plankton, that settled in ancient seas.
- Over hundreds of millions of years, these organic deposits were buried under layers of mud and sand.
- With increasing temperature, pressure, and time, the organic matter was converted into kerogen (a waxy substance).
- Further thermal decomposition of kerogen produced liquid petroleum and natural gas.
- The petroleum then migrated through porous rocks until it became trapped beneath impermeable layers, forming oil and gas reservoirs.

❖ **2.Abiogenic or Atmospheric/Chemical Theory (minority view):**

- Suggests that petroleum could have been generated by purely chemical processes within the Earth's mantle.
- Hydrocarbons might have been formed from carbon present in the early atmosphere and later trapped underground.
- This theory, however, faces challenges, especially in explaining how such petroleum could accumulate in the vast quantities found in commercial reservoirs.

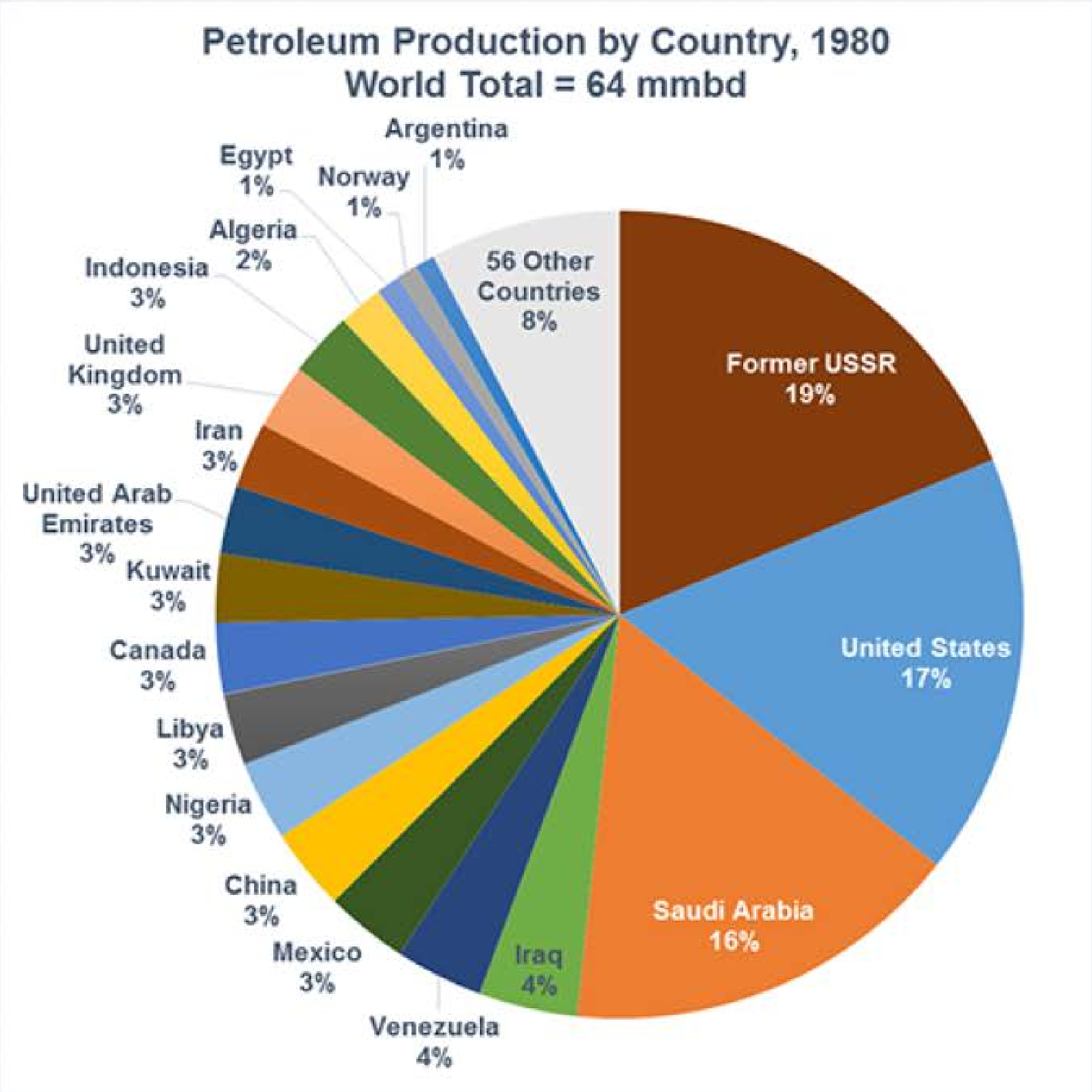
*J. Applied Sci.*, 11 (12): 2084-2091, **2011**

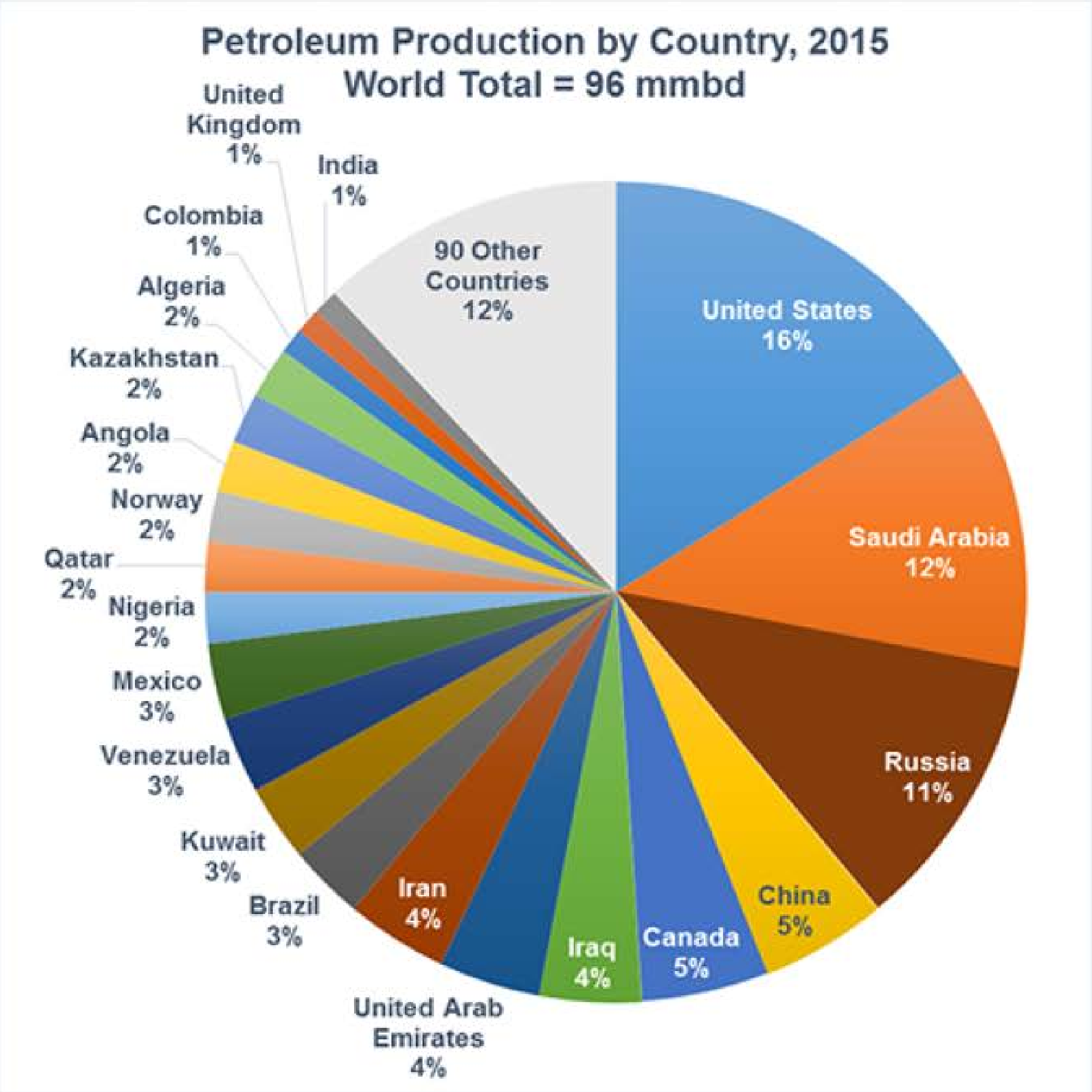
# Petroleum Exploration

- Petroleum exploration is the process of locating underground oil and gas reserves.
- It requires specialized knowledge of geology, geophysics, and geochemistry to identify potential source rocks, reservoir rocks, and structural traps.
- Modern exploration techniques include:
- Seismic surveys (2-D, 3-D, and even 4-D) to map subsurface structures.
- Drilling exploratory wells to confirm the presence of hydrocarbons.
- Geological modeling to estimate the size and quality of reserves.
- Successful exploration results in proven reserves, which can then be developed for commercial production.

*J. Applied Sci.*, 11 (12): 2084-2091, **2011**

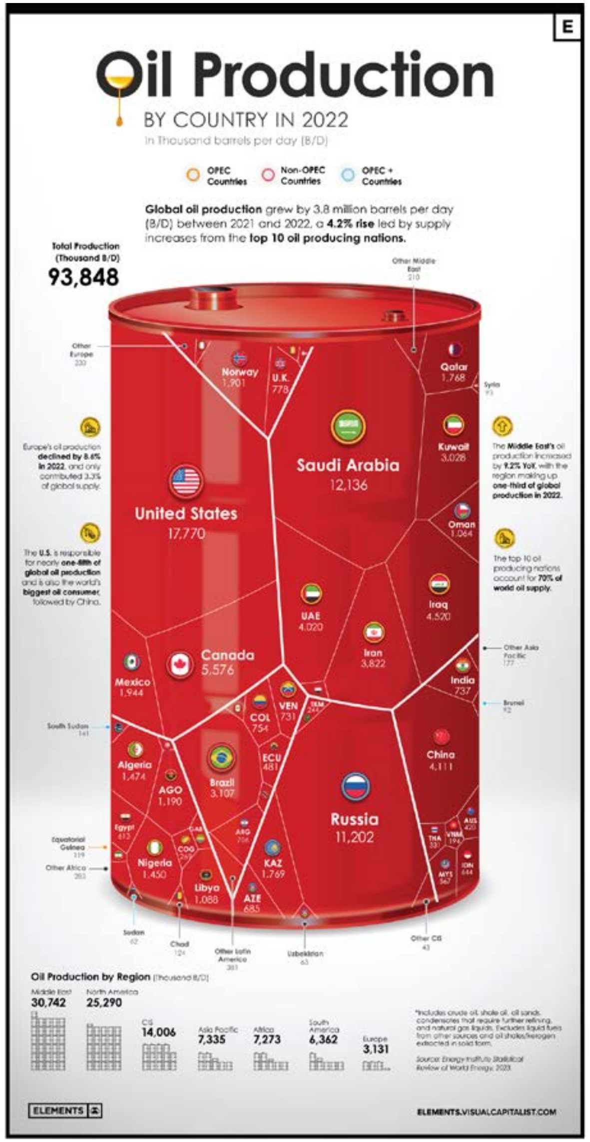
# Major Petroleum Producing Countries

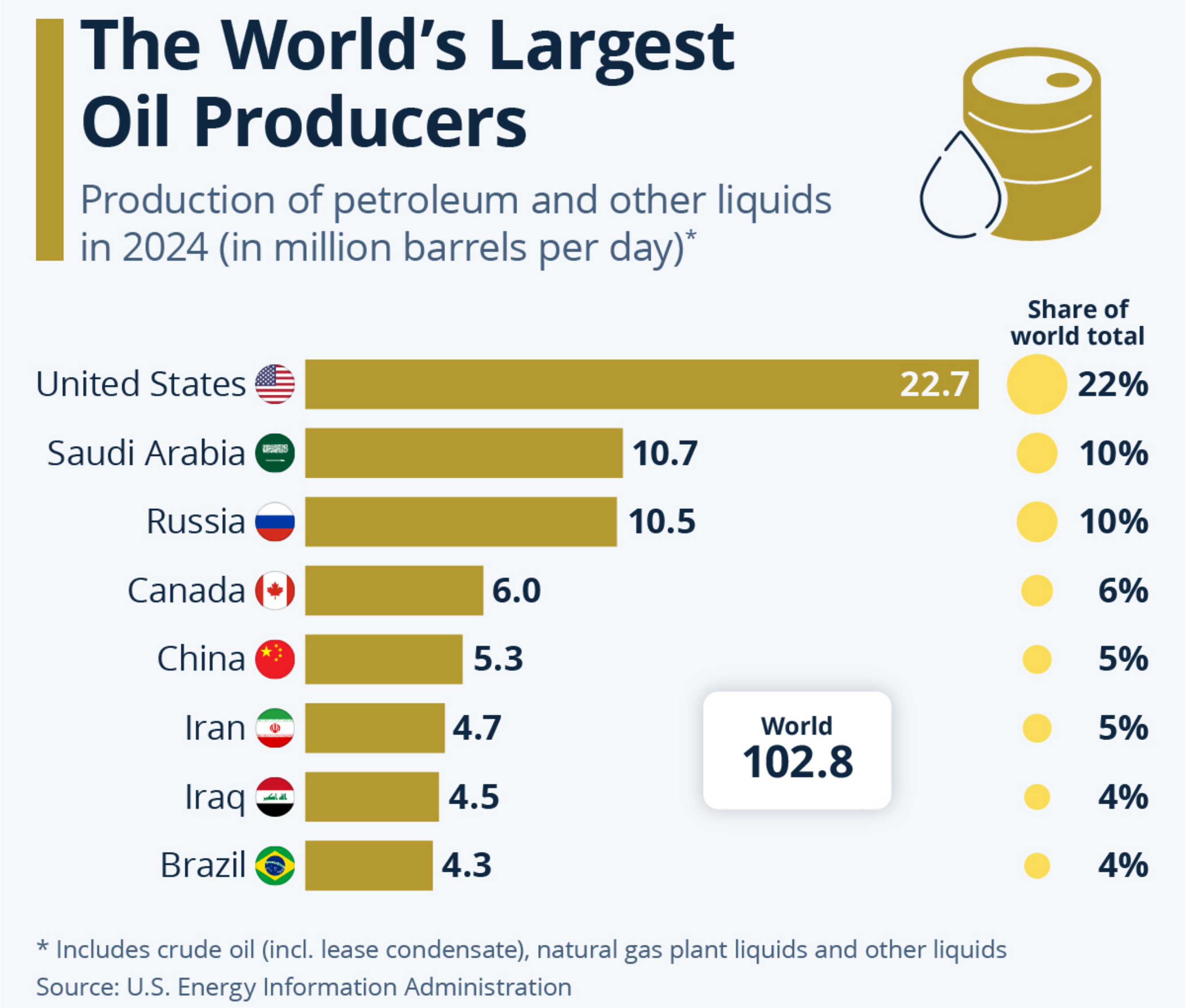



https://www.energy.gov/eere/vehicles/fact-965-february-20-2017-united-states-produced-more-petroleum-any-other-country

# Major Petroleum Producing Countries




https://elements.visualcapitalist.com/ranked-the-worlds-biggest-oil-producers/ https://www.statista.com/chart/16274/oil-producing-countries/

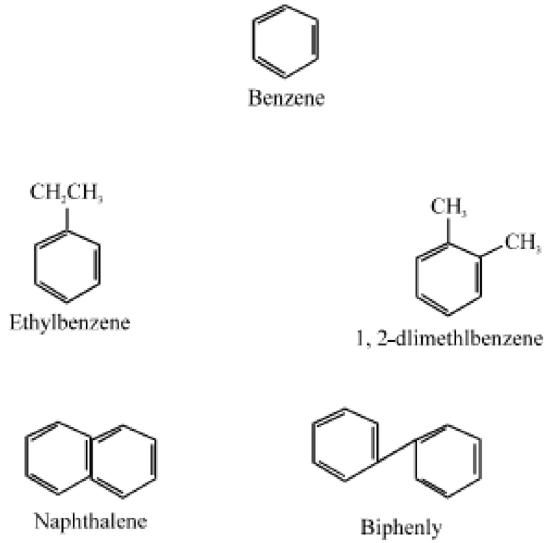
## ❖ The Nature of Petroleum

- ❑ Petroleum is a naturally occurring, flammable, oily liquid found beneath the Earth's surface.
- ❑ It consists mainly of hydrocarbons but also contains small amounts of sulfur, nitrogen, and oxygen compounds.
- ❑ Physically, crude oil is usually brown to black in color, sometimes greenish, with a characteristic odor.
- ❑ It is less dense than water and insoluble in water, but soluble in organic solvents.
- ❑ Petroleum occurs in nature within porous sedimentary rocks, sealed by impermeable layers that trap it in reservoirs.

## ❖ *Composition of Petroleum*

**Elemental Composition (approximate ranges):**

- ➢ **Carbon (C):** 83–87%
- ➢ **Hydrogen (H):** 11–15%
- ➢ **Sulfur (S):** 0.05–6%
- ➢ **Nitrogen (N):** 0.1–2%
- ➢ **Oxygen (O):** up to 1.5%



# The Nature and Composition of Petroleum

❖ **Hydrocarbon Types:**

- **Paraffins (Alkanes):**
  - Straight- or branched-chain hydrocarbons (e.g., methane, hexane).
  - Major component of petroleum.
  - Important for fuels, but straight chains knock easily in engines, while branched chains give smoother combustion.

- **Naphthenes (Cycloalkanes):**
  - Saturated ring compounds (e.g., cyclohexane).
  - Contribute to fuel stability.

- **Aromatics:**
  - Ring hydrocarbons with delocalized electrons (e.g., benzene, toluene, xylene).
  - Higher energy content but also linked to health hazards.

❖ **Non-Hydrocarbon Compounds:**

- **Sulfur compounds:**
  - ➢ $H_2S$, mercaptans, thiophenes (cause corrosion, pollution).

- **Nitrogen compounds:**
  - ➢ pyridines, carbazoles (can poison refining catalysts).

- **Oxygen compounds:**
  - ➢ phenols, naphthenic acids (affect acidity and stability).

- **Trace metals:**
  - ➢ vanadium, nickel, etc., present in heavy crude.

*J. Applied Sci.*, 11 (12): 2084-2091, **2011**

# PETROLEUM PROCESSING AND PRODUCTS

Table 1: Petroleum fractions

| Boiling range (°C) | Composition (No. of carbon atoms per molecule) | Name | Main uses |
|---|---|---|---|
| <20 | $C_1$ to $C_4$ | Natural gas (gaseous compounds) | Fuel, chemical synthesis (i.e. raw material for chemical industry) |
| 0-30 | - | Natural gas (Zymogene and Rhigolene) | Liquid zymogene is used in the manufacture of ice. Rhigolene is used in medicine as local anaesthesia. |
| 20-90 | $C_5$ to $C_7$ | Light petroleum (petroleum ether) | Solvent |
| 30-150 | $C_5$ to $C_{14}$ | Crude naphtha | Solvent |
| 70-90 | $C_6$ to $C_{18}$ | Gasoline of petrol | Motor fuel, solvent in dry cleaning |
| 70-200 | $C_6$ to $C_{10}$ | Petrol (gasoline) | Motor fuel |
| 90-120 | $C_7$ to $C_8$ | Ligroin (high b.p. petroleum ether or light petroleum) | Solvent in dry cleaning |
| 100-200 | $C_5$ to $C_{10}$ | Fuel | Automobiles |
| 120-160 | $C_5$ to $C_{10}$ | Benzene | Solvent (in dry cleaning and in oil and paint industry) |
| 150-300 | $C_{10}$ to $C_{38}$ | Kerosine | Fuel, illuminant, making oil gas |
| 175-300 | $C_{10}$ to $C_{18}$ | Kerosine (paraffin) | Fuel for jet engines or central heating systems |
| 200-300 | $C_{12}$ to $C_{18}$ | Kerosine (paraffin) | Fuel (lamps and stoves) |
| >275 | $C_{12}$ to $C_{20}$ | Gas oil | Fuel for diesel engines |
| >300 | $C_{18}$ to $C_{38}$ | Gas oil or heavy oil | |
| 300-400 | $C_{15}$ to $C_{25}$ | Diesel oil | Fuel (locomotive) |
| | $C_{20}$ to $C_{24}$ | Lubricating oil | Lubricant (making candle, shoe polish, etc.) |
| >400 | $C_{21}$ to $C_{30}$ | Paraffin wax | Various |
| Non-volatile oil | $> C_{20}$ | Lubricating oils, waxes, etc. | Lubricant candles |
| Solid residue | $> C_{40}$ | Asphalt, bitumen | Road surfaces, roofing |
| | | Vaseline | Lubricant |
| | | Pitch | In toilet goods and ointment |
| | | Petroleum coke (on redistillation of tar) | In paints and varnish. As fuel. |

# Octane Number

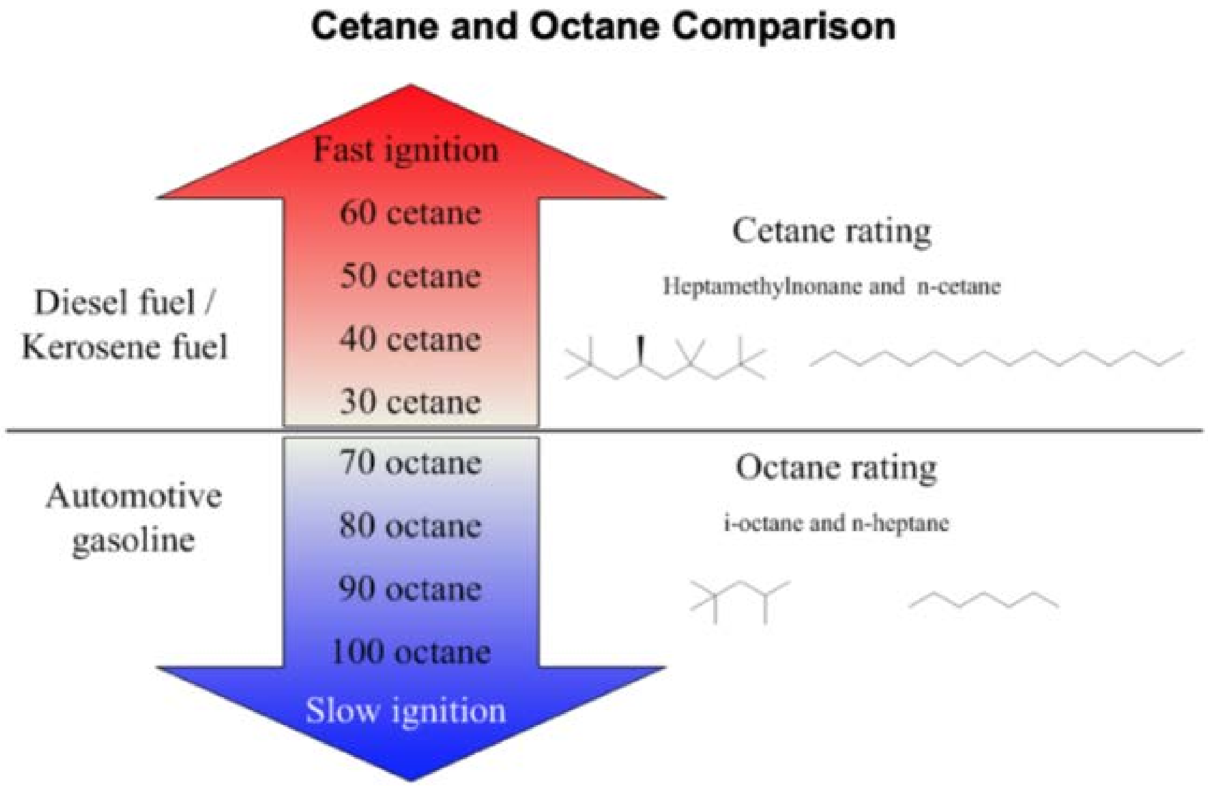
❖ **Definition**

- The octane number (or octane rating) is a measure of a fuel's resistance to knocking (auto-ignition) in a spark-ignition engine.
- Knocking occurs when the air–fuel mixture in the cylinder ignites prematurely due to compression, causing a metallic "pinging" sound and engine damage.
- Fuels with higher octane numbers resist knocking better and allow for smoother engine operation.

| Hydrocarbon | Motor method | Research method |
|---|---|---|
| Methane | 110.0 | 107.5 |
| Ethane | 108.0 | 107.1 |
| Propane | 100.0 | 105.7 |
| *n*-Butane | 91.0 | 93.6 |
| *n*-Pentane | 61.7 | 61.7 |
| *n*-Hexane | 26.0 | 24.8 |
| *n*-Heptane | 0.0 | 0.0 |
| *n*-Octane | –17.0* | –19.0* |
| Naphtha | 41.0—56.0 | 43.0—58.0 |

*J. Applied Sci.*, 11 (12): 2084-2091, **2011**

# Octane Number




❖ **Reference Scale**

- The octane rating is defined by comparing the fuel to a mixture of two reference hydrocarbons:
  - **n-Heptane** → assigned an octane number of 0 (knocks very easily).
  - **Iso-octane (2,2,4-trimethylpentane)** → assigned an octane number of 100 (very resistant to knocking).
- ***Example:*** A gasoline with an octane number of 90 behaves the same, in terms of knocking tendency, as a mixture of 90% iso-octane and 10% n-heptane.

# Octane Number

❖ **Improvement of Octane Number**

- In the past, the octane number was improved using tetraethyl lead (TEL) as an anti-knock additive.
- Due to environmental and health hazards, TEL has been phased out.

- Today, octane enhancement is achieved by:
  - Oxygenates such as ethanol and methanol.
  - Aromatic hydrocarbons (e.g., toluene, xylene).
  - Isomerization and reforming processes in refineries to produce branched hydrocarbons with higher octane.

❖ **Significance**

- A higher octane fuel allows:
  - Higher compression ratios in engines.
  - Greater efficiency and power output.
  - Reduced knocking and smoother performance.

- Common commercial gasoline grades:
  - Regular (≈ 87 octane)
  - Mid-grade (≈ 89 octane)
  - Premium (91–98 octane, depending on country).

*J. Applied Sci.*, 11 (12): 2084-2091, **2011**

# USES OF PETROLEUM

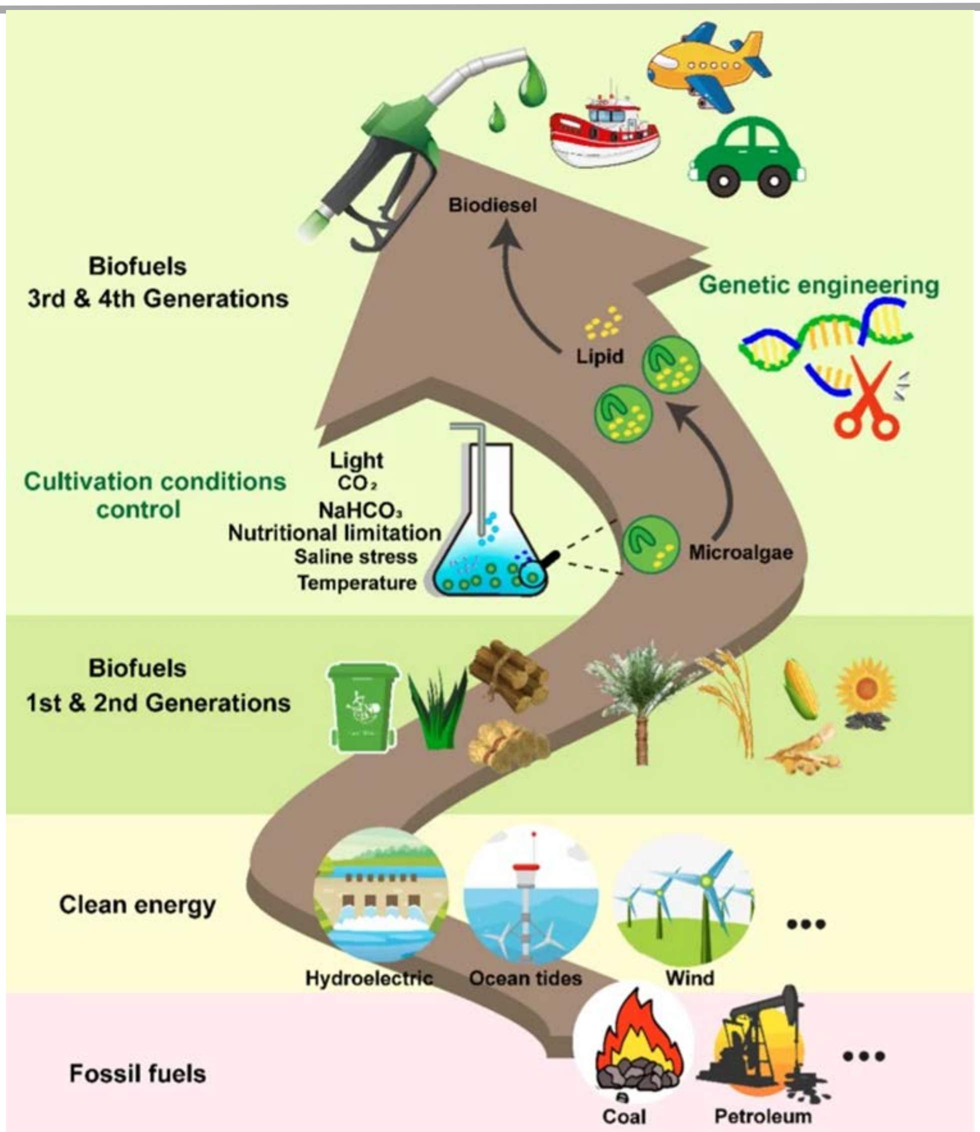
- ***Petroleum has two main uses.***

- The first is as a fuel The combustion of crude oil gave in-road to derivation of various energies from petroleum. Petroleum has been a source of energy for heating, lighting and locomotion and particularly the most convenient fuel for the internal combustion engine. This use has increased rapidly in importance with the coming of the motor car and a wide range of other applications of internal combustion engine (Bankole and Ogunkoya, 1978).

- The second use of petroleum is the synthesis of organic compounds. By 1965, about 80% of the world organic chemicals were synthesized from petroleum. This figure rose to 98% in 1980 and 99% in the year 2000. Thus, petroleum chemicals (petrochemicals) are a wide variety of chemicals. Commercially important ones include gasoline and kerosine. Petroleum jelly is a greasy gelatinous substance sourced from petroleum and used as ointment base, lubricant and protective covering (Arene and Kitwood, 1979).

*J. Applied Sci.*, 11 (12): 2084-2091, **2011**

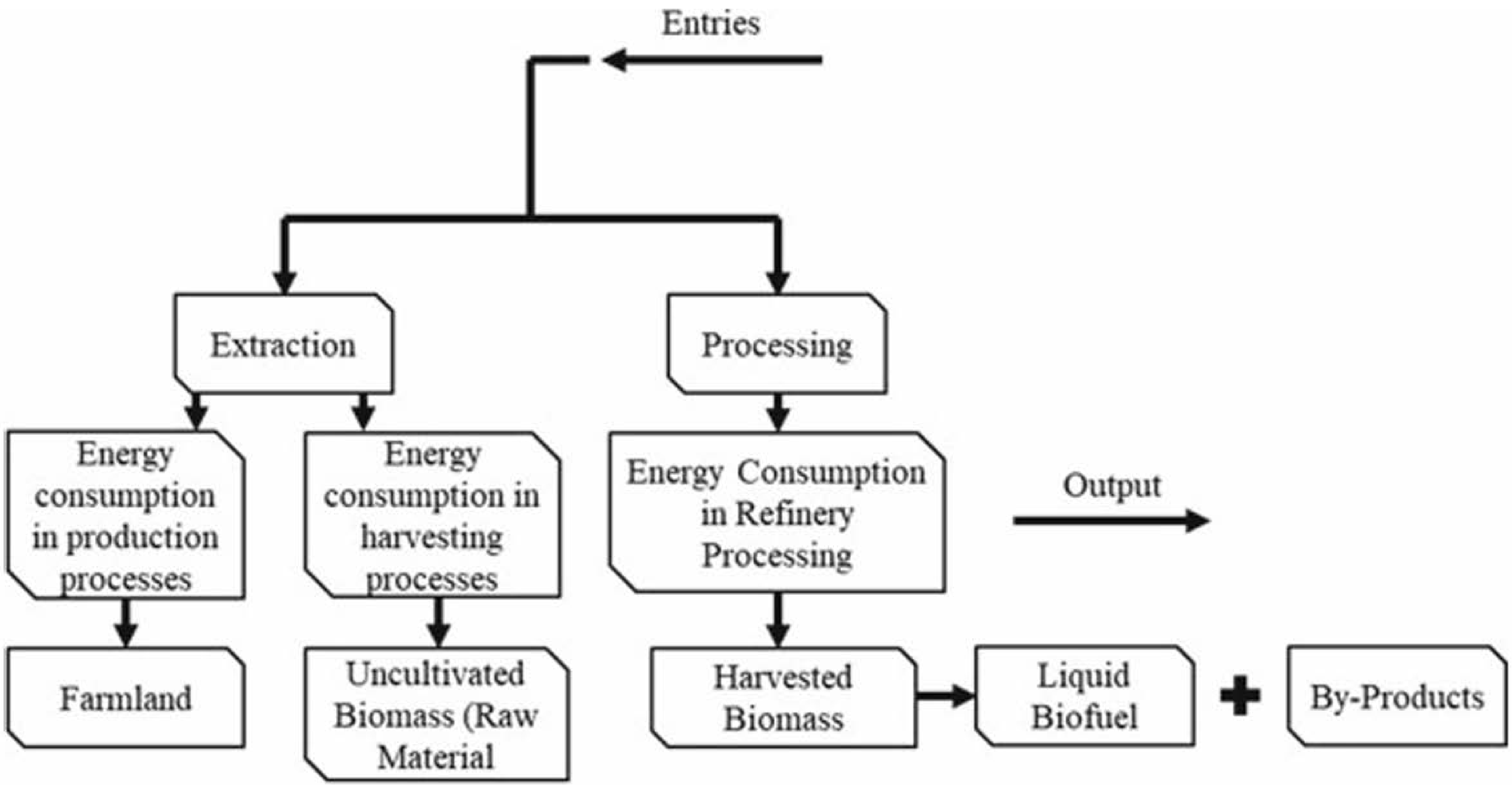
# Biofuels



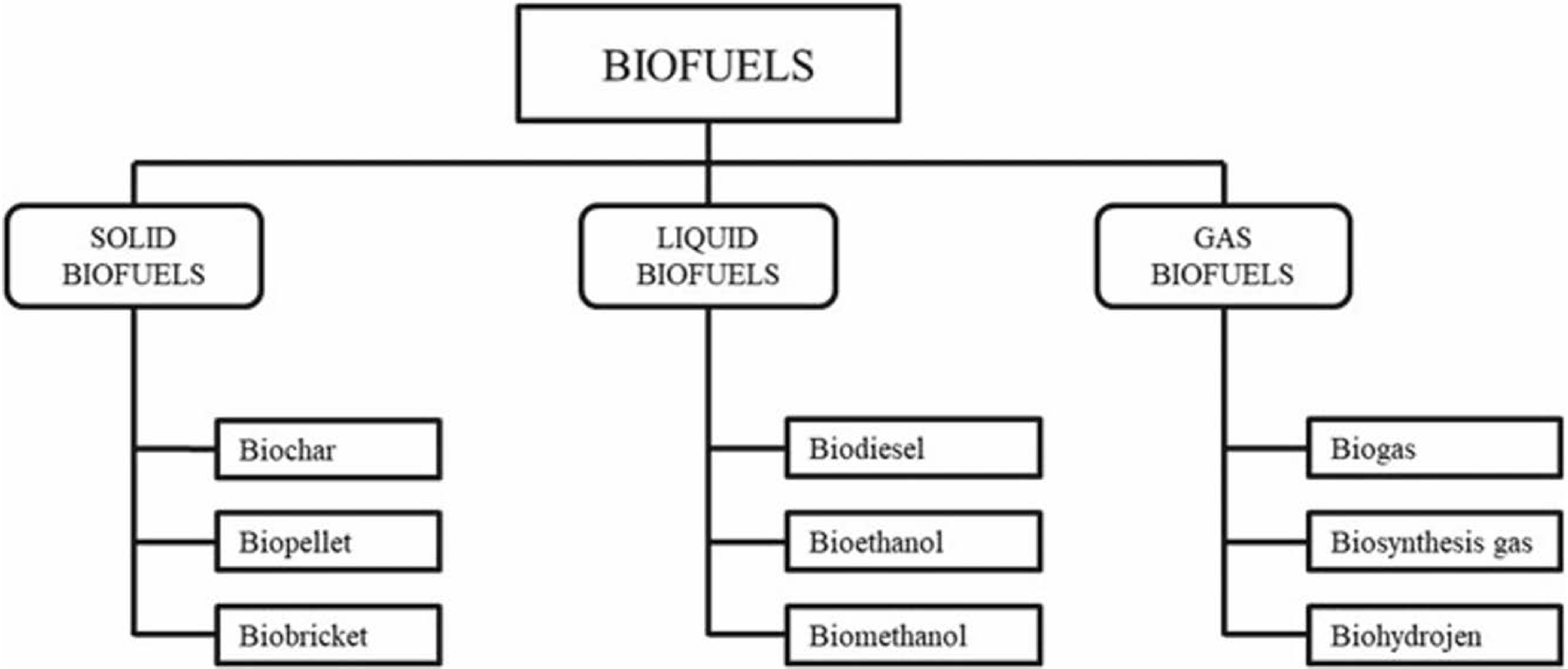

*Biotechnol Biofuels* **17**, 10 (2024)

- ❑ The rapidly increasing world population, industrialization, and the environmental problems caused by the excessive use of fossil resources have gradually changed from a regional and national dimension to a global problem. Countries that do not want to be dependent on external energy and have problems in energy supply are trying to increase and diversify their alternative energy sources due to increasing environmental problems due to fossil resources. It can be said that alternative energy sources, which are unwanted in the past due to high costs, have become more attrac tive today due to technological developments. New and renewable energy sources are an important opportunity especially for countries that are dependent on foreign sources of energy.

# Biofuel Production Processes



# Classification of fuels of biological origin




Book : Energy Management and Energy Efficiency in Industry by Durmuş Kaya , Fatma Çanka Kılıç , Hasan Hüseyin Öztürk

# Solid Biofuels




- Biofuels can be classified in different ways according to their sources and types. Biofuels that can be produced from forests, agricultural and fishery products or municipal wastes, agro-industry, food sector, and food sector products and wastes maybeinthe form of solid, ethanol, biodiesel, and pyrolysis fuels such as firewood, charcoal, and wood chips, or gas such as biogas. Biofuels:

  - Primary (unprocessed)

  - secondary (processed) biofuels.

# Biofuels

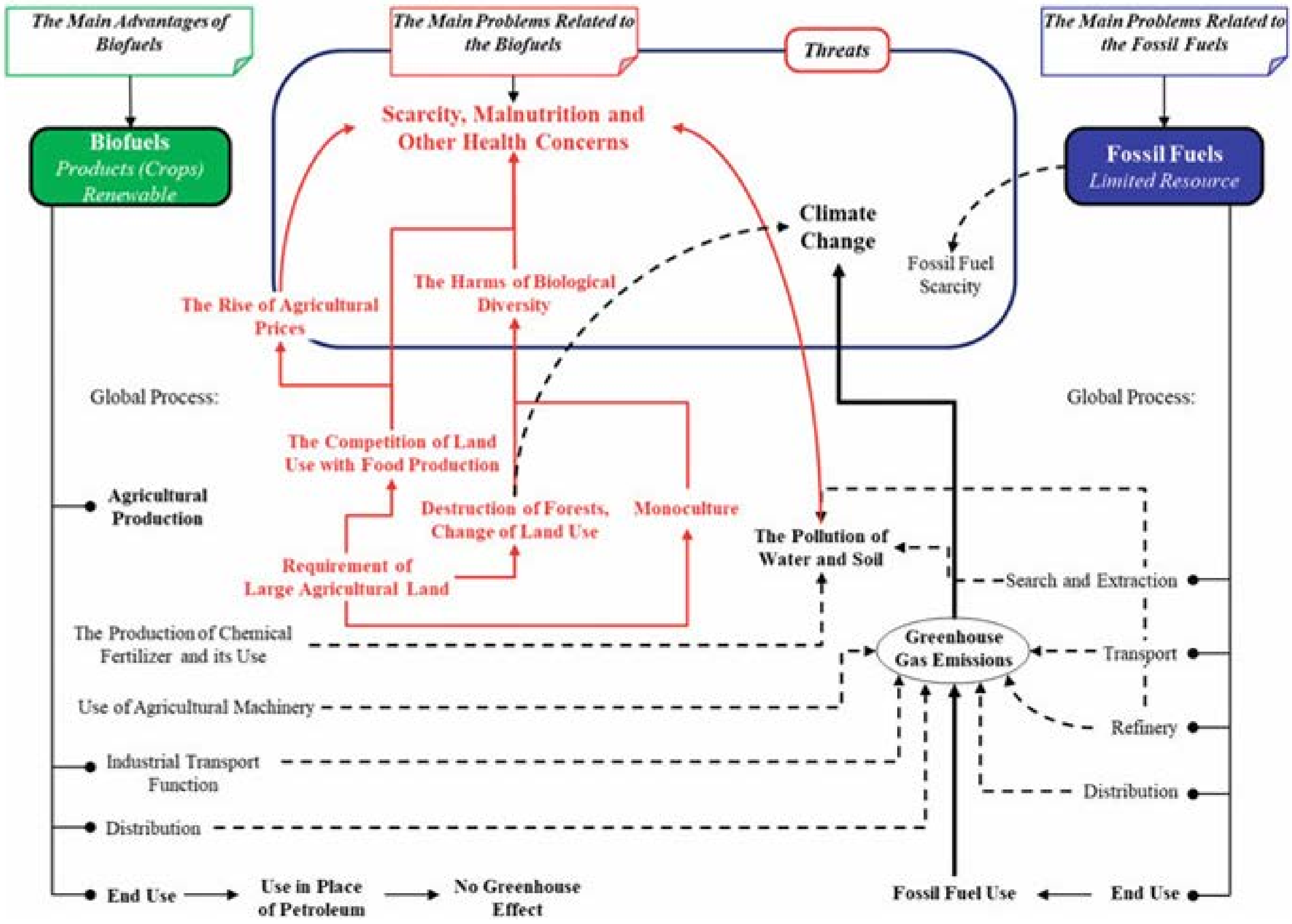
- ***Primary biofuels:***

firewood, wood shavings, and parts thereof are organic mate rials used in their natural state. Burnt fuels are sources of energy that are often used for energy for cooking, heating, and energy production.

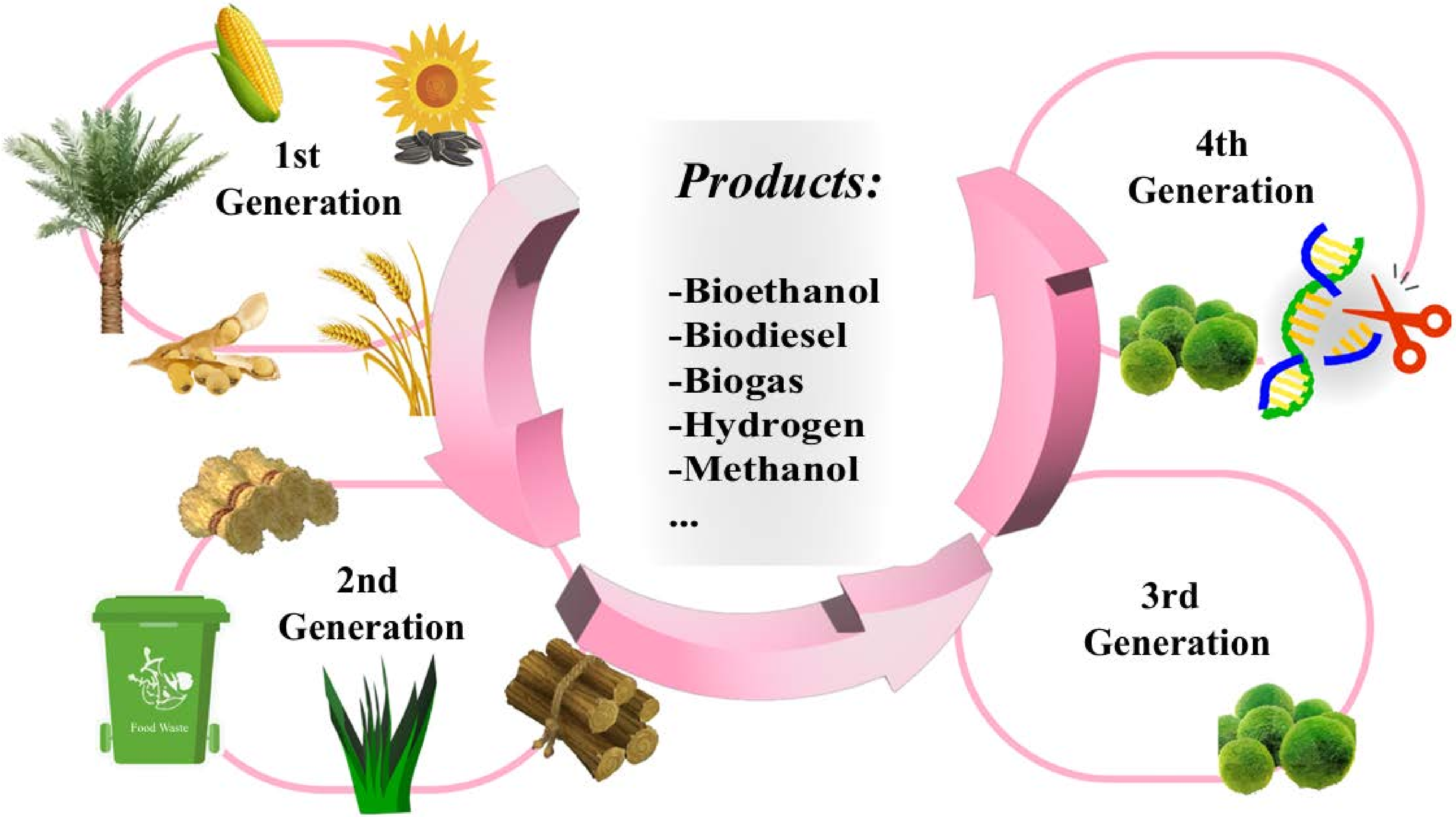
- ***Secondary biofuels:***

solid (charcoal), liquid (ethanol, biodiesel, and other biofuels), and gases (biogas, synthetic gas, and hydrogen).

# Main features of fossil and biofuel use



# Productions of different generations Biofuel




Wang et al. Biotechnology for Biofuels and Bioproducts