Biofuels

***Mains**: GS3 - Science and Technology: Developments and their applications and effects in everyday life | Infrastructure - Energy*

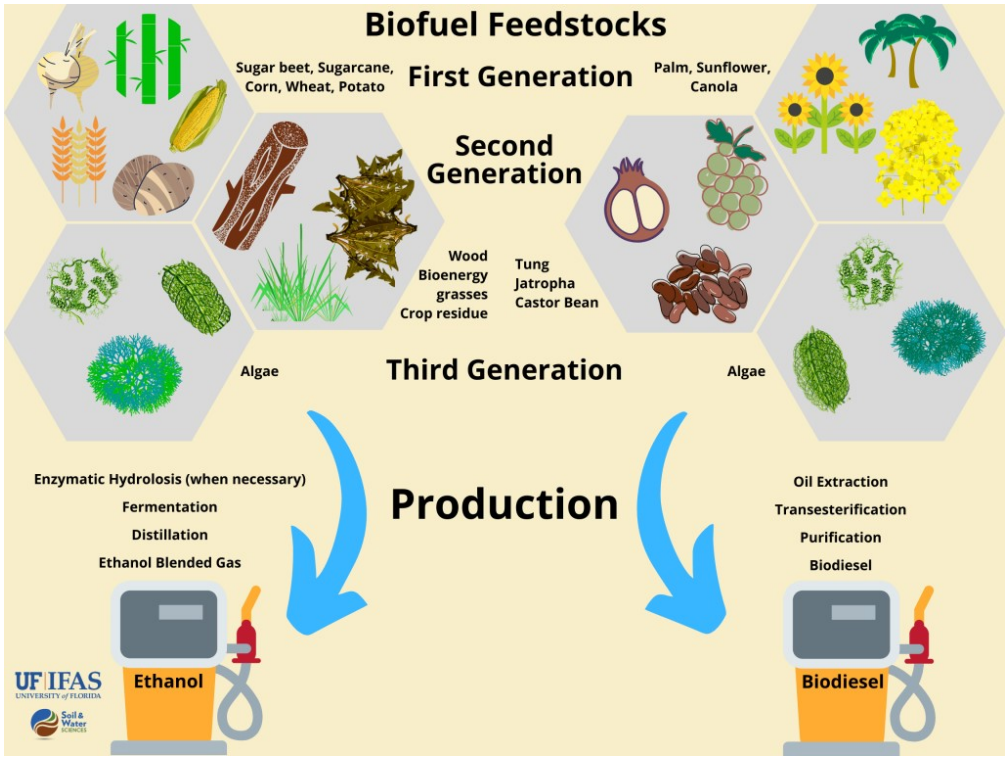
Why in news?

The recent global shift towards renewable energy sources, Biofuels have emerged as a promising alternative to fossil fuels, leaving the questions about its efficiency in net energy consumption.

What are biofuels?

- **Biofuels** – Fuel produced from organic matter, or biomass which can be used as a replacement for fossil fuels like gasoline and diesel.
- They can be ***solid, liquid, or gaseous***, with liquid biofuels like ethanol and biodiesel being the most common.
- They are considered *renewable because the biomass used to produce them can be replenished.*
- **Types of Biofuels**

Generation	Source	Example
First generation (1G)	Food sources - corn, sugarcane, and vegetable oils.	Bioethanol, biodiesel, biogas
Second generation (2G)	Non-food sources and the waste left from the food resources - Municipal solid waste, wood chips etc.,	Cellulose ethanol, biodiesel
Third generation (3G)	Algae - It consists of 40% of lipids which can be converted to biodiesel or synthetic petroleum.	Butanol, Gasoline, Jet fuel
Fourth generation (4G)	Produced from genetically engineered bio algae	



- **Ethanol** – A liquid biofuel made by fermenting sugars from crops like corn and sugarcane.
- **Biodiesel** – Another liquid biofuel made from vegetable oils, animal fats, or recycled greases.
- **Production process**
  - *Thermochemical methods* like pyrolysis and gasification, producing fuel materials with low moisture content.
  - *Biochemical method utilize microorganisms* to break down high-moisture organic matter, generating biogas or bioethanol through processes of anaerobic digestion or fermentation.
  - *Agrochemical method* involves conversion of biomass using chemical processes i.e. transesterification to produce fuels like biodiesel from plant oils or animal fats.

How plant waste are turned into fuel?

- **Enzymatic cellulose breakdown –** Cellulase enzymes can break down plant waste into glucose, but slow reactions, instability, and cellulose variability hinder efficiency.
- **Fermentation process –** *Yeast and bacteria ferment sugars* to ethanol, but ethanol above 10% inhibits these microbes, demanding extra purification,
  - Moreover, different microbes leave some sugars unfermented.
- **Process optimization –** *Co-fermentation and immobilized enzymes* optimize sugar conversion, the full process includes biomass selection, pretreatment, saccharification, fermentation, distillation, and by-product recovery.
- **Biochemical engineering –** It now uses immobilized enzymes instead of live microbes, allowing continuous reactions without cell growth.
- This reduces sugar loss and improves biofuel efficiency.

What is the role of biomass in the carbon cycle?

- **Carbon cycle** – The carbon is managed via vital processes like photosynthesis, respiration, feeding, and consumption.
    - Each year, about 250 gigatonnes (Gt) of dry organic material circulate through the biosphere, with 100 Gt of this being carbon.
- **Role of photosynthesis** – The carbon fixed during photosynthesis, which annually captures roughly 2×10^{21} Joules of solar energy across the planet, crucial in maintaining the natural carbon cycle.

Humans directly manage around 0.5 % of global biomass, mostly as food crops.

- **Carbon released from energy** – For over 10 % of the world's energy needs, especially in developing regions, biomass remains the primary energy source, much of which is used directly for heating.
    - This in turn release carbon into the atmosphere
- **Carbon cycle and sustainability –** Biomass energy keeps the carbon cycle balanced, the carbon taken in during photosynthesis is equal to what is released through respiration and decay.
- **Climate impact –** Biofuels recycle existing carbon, fossil fuels add new carbon which increases warming and threatening biodiversity.

What are the concerns of the biofuel usage?

- **Food security –** First Generation Biofuels raising concerns about food shortages, particularly for poorer populations.
- **Production constraints** – Ethanol production by microbes *requires acidic conditions* through either aerobic respiration or anaerobic respiration.

Aerobic Respiration *uses oxygen to fully extract energy from glucose, releasing* CO_2 *and water for cellular work.* ***Anaerobic Respiration*** *is faster but less efficient, producing energy-rich byproducts like ethanol and lactic acid.*

- **High treatment costs** – Second generation biofuels aim to convert waste biomass into fermentable sugars.
    - Extracting sugar from complex biofibers incurs high costs due to pretreatment processes.
- **Biofuel environmental impact** – Expansion of biofuel requires large quantity of biomass, which in turn changes land use patterns and fertilizer use.
- This excess usage release potent greenhouse gases like nitrous oxide and methane

Sugarcane ethanol *reduces greenhouse gas emissions, but most biofuels do not.*

- **Societal impacts** – The proposals to clear large swathes of Amazon rainforest for energy crop cultivation requires displacement of indigenous populations
- **Ecological risks –** Worsening of erratic weather and climate patterns due to large scale soil disturbance and deforestation.
- Monoculture farming reduces biodiversity and depletes scarce freshwater resources, posing long-term ecological risks.

Quick Facts

Biofuel-Ethanol
• **Properties** – Azeotropic ethanol contains ~4.4% water and remains liquid from -114°C to 78°C. • Flash point (lowest temperature at which the vapor above the oil will ignite momentarily when exposed to an ignition source) is 9°C, self-ignites at ~423°C. • *Lower energy density than petrol* (24 GJ/m^3 vs 39 GJ/m^3), but better combustion compensates. • **Engine compatibility** – 5% ethanol blend works in standard vehicles without tuning (modification). • E10 and E15 can be used with minor or no engine modifications. • Ethanol's anti-knock properties improve engine smoothness. • **Limitations** – Water in ethanol blends dissolves in petrol, causing sludge buildup in tanks and harm to unmodified engines. • **Ethanol market** – The *US leads ethanol* production followed by Brazil. - US - Mainly corn-based - Brazil - Sugarcane-based • **India** – It had produced over 1 billion gallons in 2022, now *contributing about 5% to global output*. • The *use of maize for biofuel* has turned India from exporter to net importer of the feed grains. • Production now allowed from sugarcane, B-molasses, C-molasses, and surplus rice (up to 2.3 million tonnes from FCI). • It targets 20% ethanol blending, like US, Brazil, and EU.

Reference

Indian express| Biofuels as an Alternative to Fossil Fuels