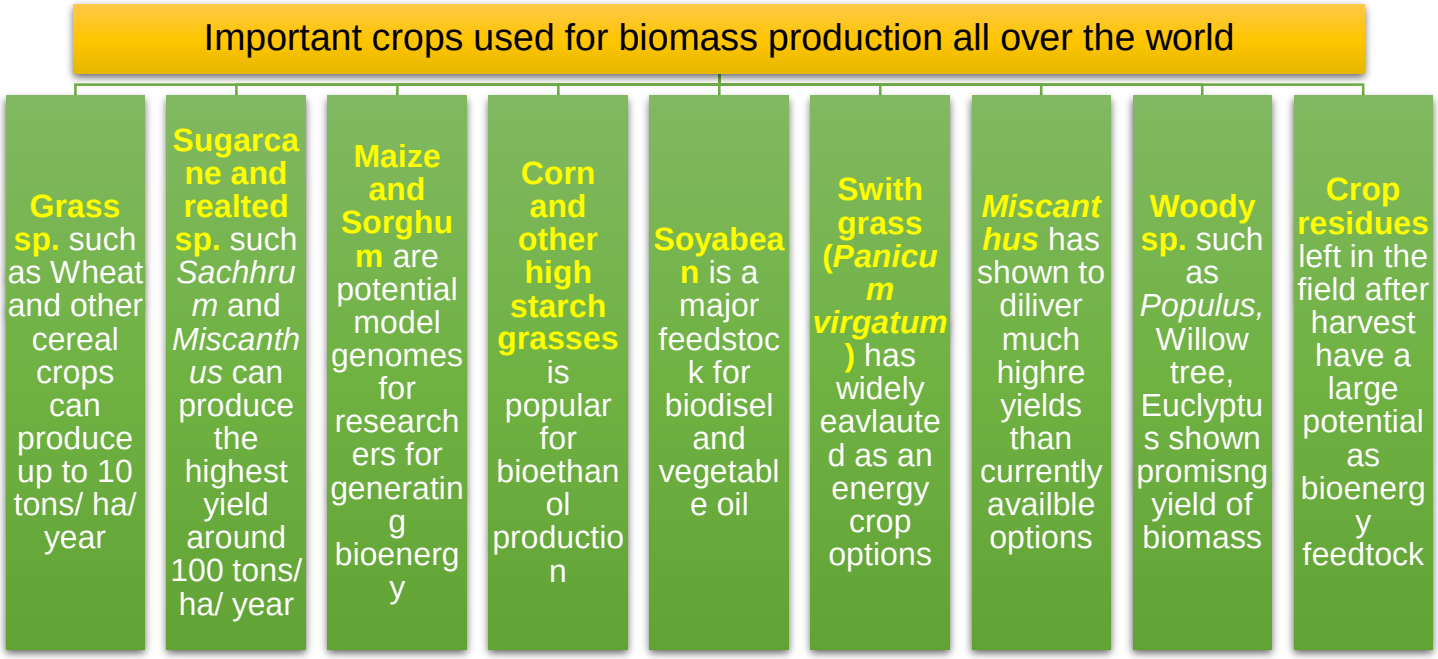
Plants as Renewable Energy Sources

Energy is a vital component of any society, playing a pivotal role in economic growth, human well-being, and environmental sustainability. Among natural sources, plants have long served as a renewable energy resource, mainly through biomass production. Early civilizations recognized the potential of plants for providing energy, utilizing materials like wood, and later developing bioethanol, biodiesel, and biogas technologies. Plants act as natural potential biomass materials because they accumulate solar energy through photosynthesis, storing it in chemical bonds. Biomass (stems, leaves, seeds, roots) is considered renewable because plants can be regrown annually or within short periods. Historically, this potential was realized through the widespread use of plant biomass, particularly wood burning, as a primary source of fuel.

Certain crops are specifically cultivated for high biomass or energy content:

- Sugarcane, Sorghum, Maize for ethanol production.
- Oilseeds like Jatropha, Soybean, and Mustard for biodiesel production.
- *Miscanthus* and Switchgrass for bioenergy biomass.

Plant-based energy also promotes carbon neutrality: the CO_2 released during bioenergy use is reabsorbed by growing plants. Using plants for energy reduces dependence on fossil fuels, lowers greenhouse gas emissions, and supports energy security.



Main Products Derived from Plant Biomass

Type of Renewable Fuel	Produced From	Remarks
Bioethanol	Sugary crops (Sugarcane, Maize, Sorghum)	Fermentation of sugars
Biodiesel	Oilseeds (Soybean, Mustard, Jatropha)	Transesterification of oils
Biogas	Organic waste, crop residues	Anaerobic digestion
Biochar	Agricultural residues	Pyrolysis (carbon-rich product)
Butanol, Methanol	Lignocellulosic biomass	Advanced biofuels

🌱Bio-based products as renewable energy sources🌱

Bio-based products are materials, chemicals, or energy derived from renewable biological resources mainly plants, animals, and microorganisms. Unlike fossil fuels (which are non-renewable), bio-based products offer sustainable alternatives and help reduce carbon emissions. They contribute to energy security, environmental sustainability, and economic development.

1. **Bioethanol**
   Ethanol can be produced through the **fermentation** of **Starch-based** products such as Maize and Sorghum, **Sugar-based** products like Sugarcane and Sweet potatoes or **Cellulose** by the action of **microbes** and **enzymes**. It reduces the dependence on gasoline and can be used either independently or blended in any proportion with gasoline in petrol-based engines (e.g., E10, E85 blends).

2. **Biodiesel**
   A renewable diesel substitute made from vegetable oils or animal fats produce from **Oilseeds-crops** (e.g., *Jatropha*, Soybean, Mustard, Palm and even waste cooking oil) by **transesterification**. Sugarcane residues (bagasse) are also considered for bioethanol and other biofuels. Used in diesel engines, either pure (B100) or blended (B20). Europe is the leader in making biodiesel.

3. **Biogas**
   A mixture of methane and carbon dioxide produced by **microbial anaerobic breakdown** of **organic matter** such as plant residues, animal manure, food waste and sewage. Biogas used for electricity generation, cooking gas and heating.

4. **Biohydrogen**
   A promising renewable fuel alternative, H_2 gas produced from **biological processes** (like dark fermentation, photolysis and photofermentation), mainly by **microalgae, cyanobacteria** and **organic waste fermentation**. Used as clean energy for fuel cells and transportation as it reduced carbon emissions.

5. **Biochar**
   Biochar is black Charcoal-like material produced by **biomass pyrolysis** from biomass sources such as wood chips, plant residues, manure or other agricultural waste products) for the purpose of transforming the biomass carbon into a more stable form (carbon sequestration). Biochar enhances soil fertility and carbon sequestration, and can be used as a low-grade fuel.

6. **Biomethanol and Biobutanol**
   Produced from **lignocellulosic biomass** such as wood biomass, agricultural residues and algae through **fermentation** or different **chemical processes** like gasification and pyrolysis (for biomethanol). Biobutanol is produced via ABE (acetone-butanol-ethanol) fermentation, a dual-phase process where microorganisms like *Clostridium* convert sugars into solvents. Used as alternative fuels for cars, solvents and chemical feedstock.

Bio-based Product	Source	Process
Bioethanol	Sugarcane, Maize	Fermentation
Biodiesel	Soybean oil, Jatropha oil	Transesterification
Biogas	Animal waste, food scraps	Microbial anaerobic digrstion
Biohydrogen	Microalgae, bacteria	Dark fermentation, photolysis and photo-fermentation
Biochar	Crop residues, sawdust	Biomass pyrolysis
Biomethanol/ Biobutanol	Agricultural and wood biomass	Fermentation/ Gasification and Pyrolysis

Second-Generation Biofuels (Advanced Biofuels)

Second-generation biofuels are advanced biofuels produced from non-food biomass sources, mainly agricultural residues, woody crops, waste biomass, and algae. These biofuels are designed to overcome the limitations of first-generation biofuels, which compete with food production. They aim to provide sustainable, low-carbon, and renewable energy without harming food security.

Feedstocks (Raw Materials) for Second-Generation Biofuels:

1. **Lignocellulosic biomass**: Crop residues (wheat straw, rice husk, corn stover) and Forestry waste (wood chips, sawdust).
2. **Non-edible oilseeds**: *Jatropha curcas* (oil-bearing, drought-resistant shrub)
3. **Algae**: Microalgae and macroalgae with high oil content.
4. **Fungi and Microorganisms**: Used in new innovations like **Mycodiesel** (diesel from fungi).

Major Types of Second-Generation Biofuels

1. **Cellulosic Ethanol:**
   Produced from: Cellulose-rich biomass (e.g., wheat straw, sugarcane bagasse, switchgrass).
   Process: Pretreatment → Enzymatic hydrolysis (from fungus) → Fermentation → Distillation.
   Use: Blended with petrol or used as independent fuel.

2. **Mycodiesel**
   Produced from: Lipid (oil) accumulation by specific fungi (e.g., *Gliocladium roseum*).
   Process: Fungal cultivation (*Gliocladium roseum*) → Oil extraction → Conversion into biodiesel-like fuel.
   Use: Can be used in diesel engines similar to traditional biodiesel.

3. **Algal Biofuels**
   Produced from: Oil extracted from fast-growing algae species.
   Process: Algae → Extraction of biofuels liquid → Reaction
   Use: Biodiesel, bioethanol, biogas, jet fuels.

4. **Jatropha-based Biodiesel**
   Produced from: Oil extracted from seeds of ***Jatropha curcas***.
   Advantages: Grows on poor soils, drought-tolerant, non-edible.
   Use: Diesel engines (pure or blended biodiesel).

Examples of Second-Generation Biofuels

Biofuel Type	Source Material	Example
Cellulosic Ethanol	Wheat straw, Sugarcane bagasse	Ethanol from non-food biomass
Mycodiesel	Fungal lipids (*Gliocladium roseum*)	Diesel-like fuel from fungi
Algal Biofuels	Microalgae, Macroalgae	Biodiesel and jet fuel from algae
Jatropha Biodiesel	Jatropha seeds	Diesel alternative from Jatropha oil