



The Shirpur Education Society's

R. C. Patel College of Engineering and Polytechnic, Shirpur

Department of Mechanical Engineering

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Unit - 1 Green Fuels 10 Marks

SUBJECT TEACHER

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Unit-1 - Green Fuels

1.1] Introduction to Green fuels.

10 Marks

Conventional fuels like coal, petrol, diesel, compressed natural gas i.e. fossil fuels emit harmful gases while burning. These fuels increase the greenhouse gases & are very harmful to the environment.

Green fuels are providing a better solution to reduce pollution. Green fuels are ecofriendly, low greenhouse gas emissions, less carbon emissions.

Types of green fuels =

- i) Biofuels (Biogas, Biomethane)
- ii) Green hydrogen, Blue hydrogen
- iii) Synthetic E-fuels (Green methanol or Green ammonia)
- iv) Sustainable aviation fuels
- v) Algal biofuel

Characteristics of Green fuels =

- i) Low carbon emission = They emit less or zero carbon greenhouse gases like CO_2 , NO_x & others as compared with petroleum based fuels. They are a good source of energy for cleaner & less carbon footprints.
- ii) Eco-friendly = They release very less particulates i.e. SO_2 , NO_x , Carbon soot etc. It can lower the chances of smog formation.
- iii) Renewable = These fuels can be extracted from natural sources of energy like plants, organic waste and from synthetic processes. All the above sources are get renewed.

- iv) High energy
- iv) Toxicity = They are free from heavy metals like sulfur, crude oil (carbon), Hence they are Non-Toxic in nature. They are very safe for transportation, handling & storing due to non-toxicity.
- v) Biodegradable in nature = They can be broken down naturally, causing minimal harm to environment if got spilled.
- vi) Compatibility with existing infrastructure =
They are highly compatible with present technology (Petroleum based), with minimal changes required. Eg. Ethanol mixed with petrol. (E10, E20, E85 fuel).
- vii) High energy content = Hydrogen & synthetic fuel has high energy density. It can provide a large amount of energy when compared to its volume.
- viii) Best from waste = Green fuels utilise waste raw material to produce energy. It can also help economy as they use waste material or byproducts from industry.

Benefits & advantages =

- i) Eco-friendly, less carbon footprint =

Many green fuels emit ~~green~~ very less gases like CO_2 , NO_x , SO_2 etc. Hydrogen & methanol produces zero carbon while their use, hydrogen fuel ~~can also~~ emit water vapour as byproduct. Low emissions can help to increase quality of air & increases the quality of environment.

ii) Health benefits = They emit very less amount of harmful gases like CO_2 , NO_x , SO_2 . Also their emission contains very less amount of particulates ~~at~~ like SO_2 , Carbon particles unlike fossil fuels. This leads to increase quality of air in cities & environment. Clean environment tends to increase quality life & reduces the various illnesses related to respiratory system.

iii) Energy security & non-dependancy =
India can only produce 15% of petroleum products & remaining 85% are imported from international market. Due to wars or any other reason if supply chain got disturbed we can face serious consequences. Use of green fuels can reduce the dependence from other countries.

iv) Renewables unlimited source of energy =
These fuels are made from renewable sources hence unlimited in nature. Eg. Bioethanol made from agricultural byproducts, Hydrogen made from sunlight via electrolysis process.

v) Highly compatible =
Many green fuels are compatible with their alternatives from petroleum products. Eg = Ethanol can be good alternative with petrol, only small changes required. Biodiesel is best alternative for diesels with small changes. etc.

vi) Best from waste (Energy value generation) =
As byproducts from agriculture, Industries are used to generate green fuels they add economic benefit to society.

vii) Support industries to achieve their carbon emission goals =
Less emission can tend to lift up industries' reputation, strengthening investor relations etc.

1.2) Classes of Green fuels =

On basis of feedstock & processing technology for extraction, green fuels are divided into four generations.

- i) 1st generation of green fuels. (1G)
- ii) 2nd generation of green fuels. (2G)
- iii) 3rd generation of green fuels. (3G)
- iv) 4th generation of green fuels. (4G)

General production process of biofuel.

Fermentation



Distillation



Purification



Blending



Biofuel

i) 1st generation of green fuels = (1G)

Types of 1G fuels =

Raw material

- Bioalcohols. - Sugarcane, corn, wheat, sugar beet etc
- Biodiesel - Vegetable oil (Soya, palm), animal fats
- Vegetable oil - Sunflower, soya oil, palm oil, etc
- Bioethers - Derived from biomass etc
- Biogas. - Organic waste, animal manure, sewage sludge, food waste, etc.

1G fuel

Production process

Bio-ethanol

- Fermentation process

Bio-diesel

- Transesterification process

Biogas

- Anaerobic digestion

Drawbacks -

- i) Food-fuel conflict. = - Increases food prices.
- Threatens food security.
- Land usage

- ii) Environment related = - Deforestation
- High water consumption,
- Chemical pollution (through chemical fertilizers).

- iii) Energy content - Low energy density,
= low Land efficiency.
- Weather dependant.

ii) 2nd generation of green fuels (2G) =

Types

Cellulosic ethanol
Bio-butanol
Synthetic fuels
Biogas

Raw material

- Agri. waste - Corn stover, sugarcane bagasse.
- Biomass feedstocks like corn, wheat, etc.
- Captured carbon dioxide combined with hydrogen.
- Animal manure, agri waste, household waste etc.

- Unlike 1G fuels, 2G fuels did not use food for production instead they use non-food biomass like agri. waste, wood, grass, algae etc.

- Benefits =
- Drastic reduction in gas emissions.
 - Enhanced energy security.
 - Utilises waste material.
 - High energy content.

iii) 3rd generation of green fuels (3G) =

These green fuels are produced from microorganisms like algae.

Eg - Butanol - Derived from algae.

Unlike 1G & 2G green fuels these fuels did not required food, agri waste or large land or fresh water for production. Instead they require salt water (sea water) for their cultivation. These algae's can be cultivated in open pond, Closed, highly controlled system called Photobioreactors or municipal wastewater,

Benefits =

- i) High yield = Algae produce large crop than conventional producers.
- ii) Rapid growth.
- iii) Carbon captured = Algae consume more CO_2 via photosynthesis process.
- iv) Less land usage = Land requirement for its cultivation is very less.

Drawback = i) Use of chemical fertilizers tends to pollute environment.

- ii) For producing on large scale can requires large capital investment.

iv) Fourth generation green fuels (4G) =

These fuels ~~are~~ are produced by engineered microbes/synthetic biofuels, these fuels can absorb carbon dioxide directly. Artificially crop is produced that contains maximum oil. This oil is then processed to max. amount of 4G fuel extracted.

Types - Engineered algae based fuels

- Carbon negative fuels,
- Bio-hydrogen
- Synthetic fuel from waste.

Benefits =

- i) Direct absorption of CO_2 tends to reduce pollution.
- ii) High energy yield.
- iii) Renewable energy.
- iv) Minimal Land requirement for production.

Drawback = i) Biological contamination.

- ii) Metabolic stress.

1.3) Types & Applications of green fuels =

A] Biofuels =

Types =

- i) Ethanol = It can be extracted from sugarcane, corn or wheat. It can be blended with petrol (gasoline) as substitute in IC engine with small changes in existing mechanism.
- ii) Biodiesel = It is extracted from vegetable oil eg. soya oil, palm oil, ~~etc~~ animal fat, cooking oil (waste). It can be blend with diesel & can be used in IC engines with minor changes.
- iii) Cellulosic ethanol = It is produced from non-edible parts of plants eg. agri waste, wood chips, and grasses, corn stover & wheat straw.
- iv) Algal biodiesel = ~~There~~ It can be produced by extracting oils from micro algae & then chemically treating them & converting to useful form. Good replacement to diesel.
- v) Algal bioethanol = It is produced by fermentation process. Sugar or starch is fermented as content of microalgae. Algal biodiesel uses oils while algal bioethanol utilizes the structural & storage sugars of the biomass. eg- wood, cotton, fibers in agri. stalks.
- vi) Sustainable aviation fuels = Algae oils chemically processed to produce fuel used for aviation fuel.
- vii) Biogas = By anaerobic digestion of waste like food, agri. waste, waste from home, cow dung. biogas can produce natural gas.

viii) Green diesel = It can be produced by same raw material as biodiesel, only the difference is - it can be processed by hydrotreating process that can result in higher quality fuel. It can be used in diesel engine without modification.

Application of biofuels =

i) Transportation =

- Best alternative for passenger cars working on petrol.

- Best suited for heavy transportation vehicles like trucks, bus etc.

- Sustainable aviation fuel

- Fuel for marine transportation with lower emissions.

ii) Electricity & Power generation =

- Useful in backup generators.

- Chemically treated to generate clean hydrogen

- Biogas produces sufficient energy to fulfill industrial energy demand from industrial waste itself.

iii) Thermal energy & heating =

Domestic use = Instead of natural gas biofuel can be used to heat house. In very cold regions like European countries.

Industrial use = Can be applied to heat feed-water required to generate steam.

Cooking = Biogas can be used as fuel for cooking purpose.

iv) Strengthening economy = Biofuels can be produced from agri. waste, so it can help to create economy in rural areas. Also reduces import of petroleum fuels from other countries.

v) Environmental benefits =

Help to reduce greenhouse gases, Reduction in carbon emission help to maintain good quality environment.

vi) Reduction in carbon footprint in industries.

vii) Health benefits =

Reduction in pollution can improve the quality of life.

B) Hydrogen fuels =

Types =

i) Green Hydrogen = Produced via electrolysis of water & electricity from renewable sources like solar, wind etc.

ii) Blue hydrogen = Produced from natural gas through steam methane reforming (SMR).

iii) Gray hydrogen = Produced from natural gas through SMR except it doesn't capture greenhouse gases.

iv) Brown / Black hydrogen = Produced from coal through gasification process.

v) Pink / Red hydrogen = Produced via electrolysis process by water. Nuclear power is used to split water in electrolysis process.

vi) White hydrogen = It found in nature as geological hydrogen. It can be extracted by mining.

Applications of hydrogen fuel =

i) Industrial applications =

a) steel production = Hydrogen is best alternate for production of steel as compared with coal.

b) Ammonia production = Industries use hydrogen to mfg. ammonia for agricultural use. For producing fertilizers.

e) Petroleum refining = To remove sulfur from crude oil refineries utilise hydrogen.

d) Fuel for furnaces = Industries use hydrogen as fuel to achieve very high heat for production of different parts.

2) Transportation =

a) Heavy transport vehicles = Trucks, buses etc utilise hydrogen as energy source. It provides less refueling time & less payload as compared with EVs.

b) Marine applications = Hydrogen can be a best alternative to heavy fuels used on large ships.

c) Aviation = It has potential to be used as commercial aviation fuel with very less carbon emission. Many industries are doing research on it.

d) Railway = Recently India developed a rail which runs on hydrogen fuel. It reduces pollution & is best suited for heavy transportation.

3) Power generation = Green storage, Gas turbine, blending, Stationary fuel cell, remote microgrids are best examples for power generation.

c) Synthetic fuels = Ethanol, Methanol, Butanol, propane, Ammonia, non-fossil methane.

Synthetic fuels can be produced through chemical processes & are best alternatives to fossil fuels. They can be produced from carbon-rich feedstock like biomass, coal, natural gas converted to petroleum, diesel, gasoline alternative.

Application of synthetic fuels =

- a) Transportation = Heavy vehicles like truck, bus, trailer, earth moving equipments.
- b) Aviation fuel = Sustainable aviation fuel, e-kerosene replaces conventional jet fuels.
- c) Marine fuel = E-Methanol is best alternative for marine applications, to handle large vessels.
- d) Sport-cars = Synthetic fuel is used by sport-car brands to get high performance from sport car. They mfg IC engine for synthetic fuels.
- e) Industrial fuel = For chemical processes, high heat generation, to store energy generated by solar power, wind power in the form of e-fuels.
- f) Defence = Supply chain independence.

D) Algae fuels =

- Types = Algae fuels contains high yield & sustainability & has carbon neutral,
- i) Bio-diesel, ii) Green diesel, iii) Biojet fuel, iv) Biogasoline are some types of algal fuels which are in the liquid form.
 - Biomethane, Biohydrogen, are the forms of algae fuels in gaseous form.
 - Biomass pellets is type of algae fuel in the solid state.

Applications of algae fuel =

- a) Transportation = Hydrotreated algal diesel is used as fuel in trucks. They have advantage as the less dead load of fuel ~~comp~~

areed with conventional fuel, batteries in EVs.

b) Railways = Trains use algal biodiesel to reduce particulate matter & greenhouse gases.

c) Agricultural use = Heavy machinery like tractors, excavators, earth moving equipments ~~used~~ use algal diesel to get high torque.

d) Power generation = Power plants burn leftover algae biomass pellets instead of coal to heat feed water for generating electricity.

In peak hours, liquid algae biofuels can use to provide electric backup to hospitals, data centers & emergency services.

e) Industrial use = Algal cultivation area is planned to be install near industrial area to absorb more & more carbon. Also wastewater from same industries can be utilised for it.

E) Biodiesel from plants =

Types =

1) 1G biodiesels =

i) Soybean methyl ester.

ii) Rapeseed methyl ester.

iii) Palm oil methyl ester

iv) Sunflower & Sunflower blends.

v) Coconut & corn oils.

2) 2G biodiesels =

i) Jatropha curcas oil,

ii) Pongamia oil.

iii) Camelina & field pennycress

3) 3G biodiesels =

i) Algal methyl ester.

Applications of biodiesel from plants:

1) Transportation:

i) Public transport = Used in urban areas for transportation, as it will help to reduce pollution.

ii) Heavy transportation = It can be used in heavy duty vehicles like trucks, bus etc. B20 $\rightarrow$ means 20% biodiesel & remaining 80% diesel.

iii) It is also helpful in transporting goods, parcels, in school buses etc.

iv) Earth moving vehicles = It can be best suitable alternative to diesel. Can be used in tractors, harvesters, irrigation pumps, excavators etc.

2) Marine applications = For providing fuel to cargo ships, ferries, boats it can be employed.

3) Railways = It can be blend with diesel to be used for railway locomotive. Reduce the dependency from petroleum products.

4) Power generation = It can generate power through running of power generators. Energy can be supplied to hospitals, data centers, universities etc.

5) Industrial application = They can be used as solvents & cleaners to clean up the grease or oil spills. Also can be use with low sulphur diesel at low percentage to restore lubrication to all parts of diesel engine.

6) Aviation fuel = To reduce carbon emission more & more airlines take initiative to use biodiesel as it is eco friendly & emits very less carbon.

- Many airlines use 40% to 5% plant biofuel which is mixed with diesel with 50% to 60%.
- Unmanned aerial vehicles can use plant based biodiesel on small scale. Highly refined plant oils are used for weather monitoring drones.

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