Exploring Bio fuel Technologies and Trends

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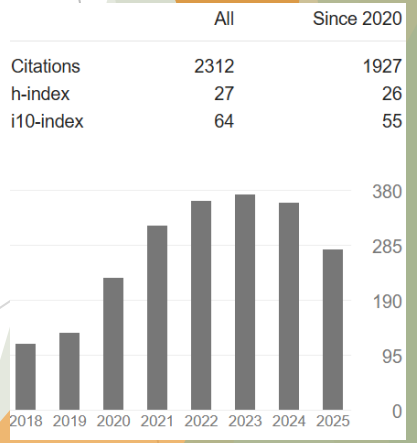
International Islamic University

SAARC ENERGY CENTRE

Energy for Peace & Prosperity

Introduction

- Director Institute of Professional Development IIUI
- Former Dean Faculty of Engineering & Technology at IIU
- Professor of sustainable energy and data engineering in thermal systems
- Author of more than 100 International Journal articles with combined Impact factor of more than 250
- Areas of research
  - Data driven modelling, multi-objective optimization in thermal systems and fluid mechanics
  - Biofuels, waste to energy conversion, Bio refineries and distributed energy and heat systems



Presentation Outline

- What are Biofuels?
- Statistics related to Biofuels
- Biofuels - Generations
- Common Biofuels pathways
- Next Generation Biofuels and applications
- Challenges in Adoption
- Used Oils/Fats to Biodiesel: A case study
- Life cycle assessment and Way forward

Partners

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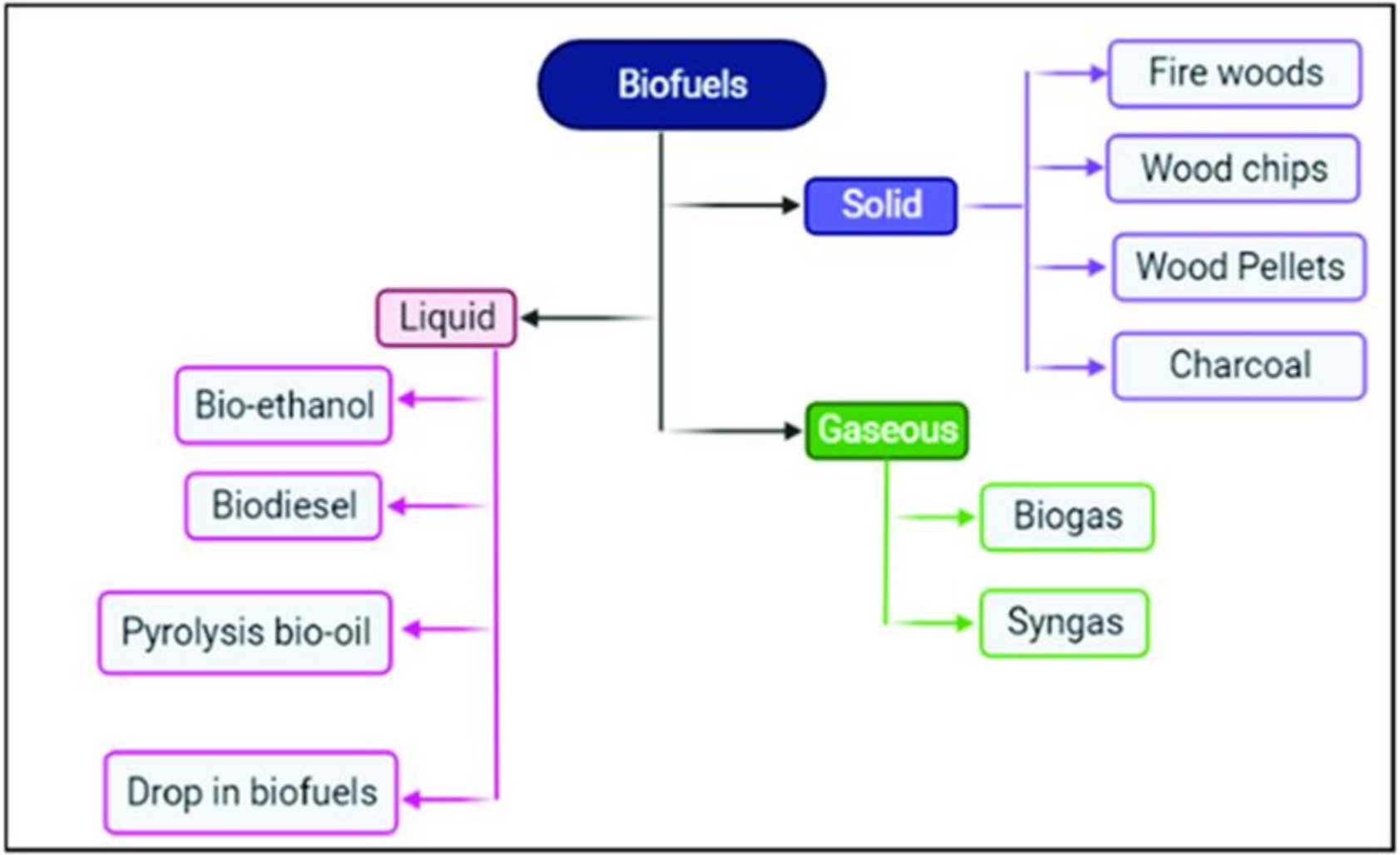
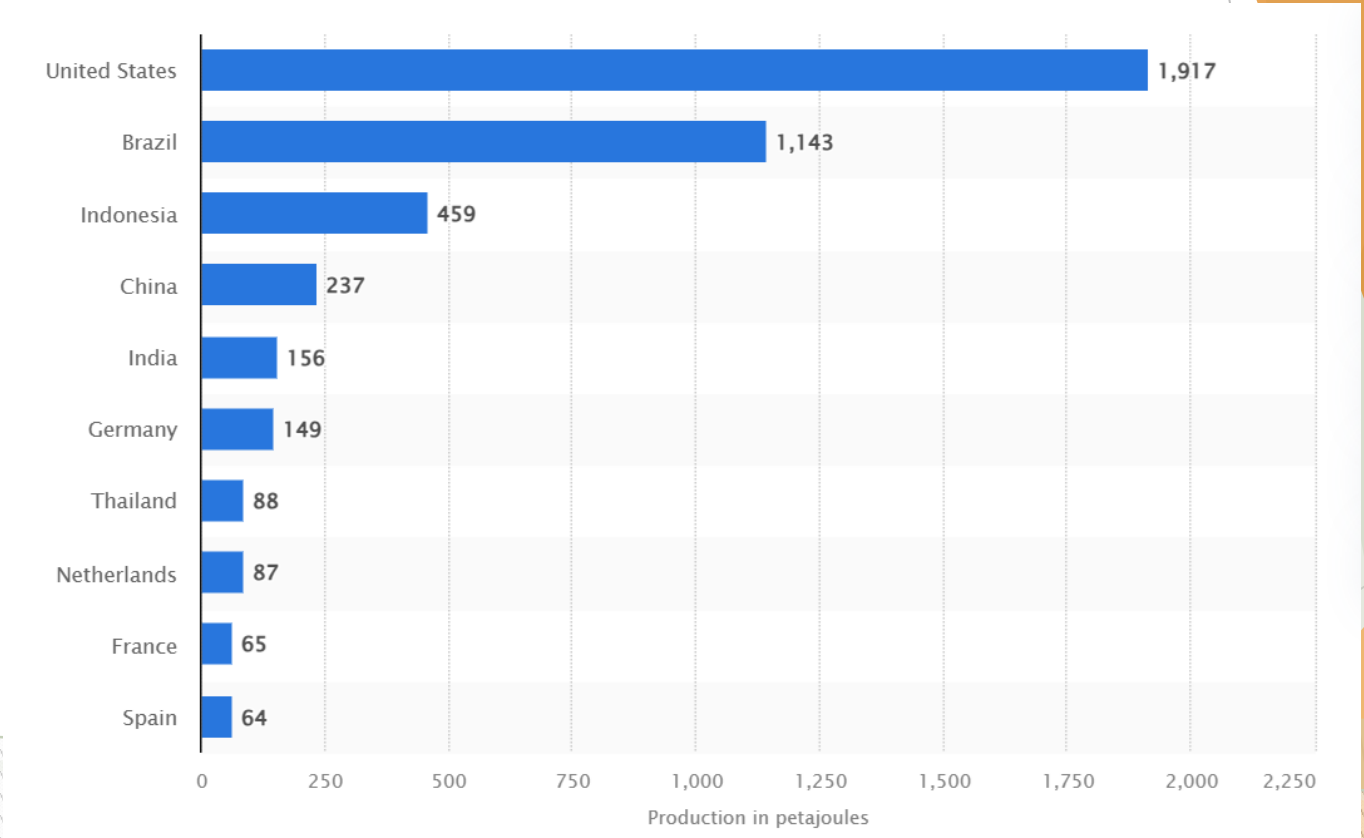
Biofuels
An Introduction

What are commonly known Biofuels?

- Biofuel can be described as "any fuel made from organic materials or their processing and conversion derivatives"
- Biofuels are combustible fuels derived from **recently produced biomass**, as opposed to **ancient biomass**, which is the source of petroleum products.
- The term biofuel usually refers to liquid fuels used as replacements for or additives to petroleum-based liquid fuel. (Bio-gas is also there but less commonly categorized as biofuels)
- In the literature, the term bioenergy has been used interchangeably with biofuel, though it is more commonly used to describe any energy source based on recently produced biomass—everything from food, fiber, wood, grasses, crop residues, and even industrial and municipal wastes.


Biofuels
Solid
Fire woods
Wood chips
Wood Pellets
Charcoal
Liquid
Bio-ethanol
Biodiesel
Pyrolysis bio-oil
Drop in biofuels
Gaseous
Biogas
Syngas

World Biofuel production 2024



BioFuel Target Canvas: Ethanol + BioDiesel

India

Current Mandate

- **Ethanol – 5%**

Planned Targets or Voluntary Blending

- **Ethanol/Biodiesel – Target of 20%**

Source:
Global Renewable Fuel Alliance

Biofuel Feedstocks

Sugar beet, Sugarcane, Corn, Wheat, Potato

First Generation

Palm, Sunflower, Canola

Second Generation

Wood
Bioenergy grasses
Crop residue

Tung
Jatropha
Castor Bean

Algae

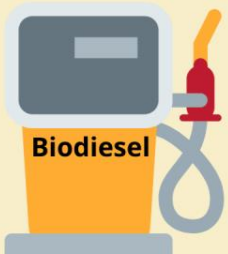
Third Generation

Algae

Production

Enzymatic Hydrolosis (when necessary)
Fermentation
Distillation
Ethanol Blended Gas

Oil Extraction
Transesterification
Purification
Biodiesel



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Biofuels - Generations

First Generation

Ethanol/biodiesel is produced directly from biomass that is generally a food source.

Ethanol is produced by fermenting sugar or starch in food-crop sources that are biochemically categorized as carbohydrates. The major source of sugar is sugarcane, while corn is the major source of starch. Besides cane and corn, first-generation ethanol is produced from but not limited to other less popular sources like wheat, barley, and sugar beet

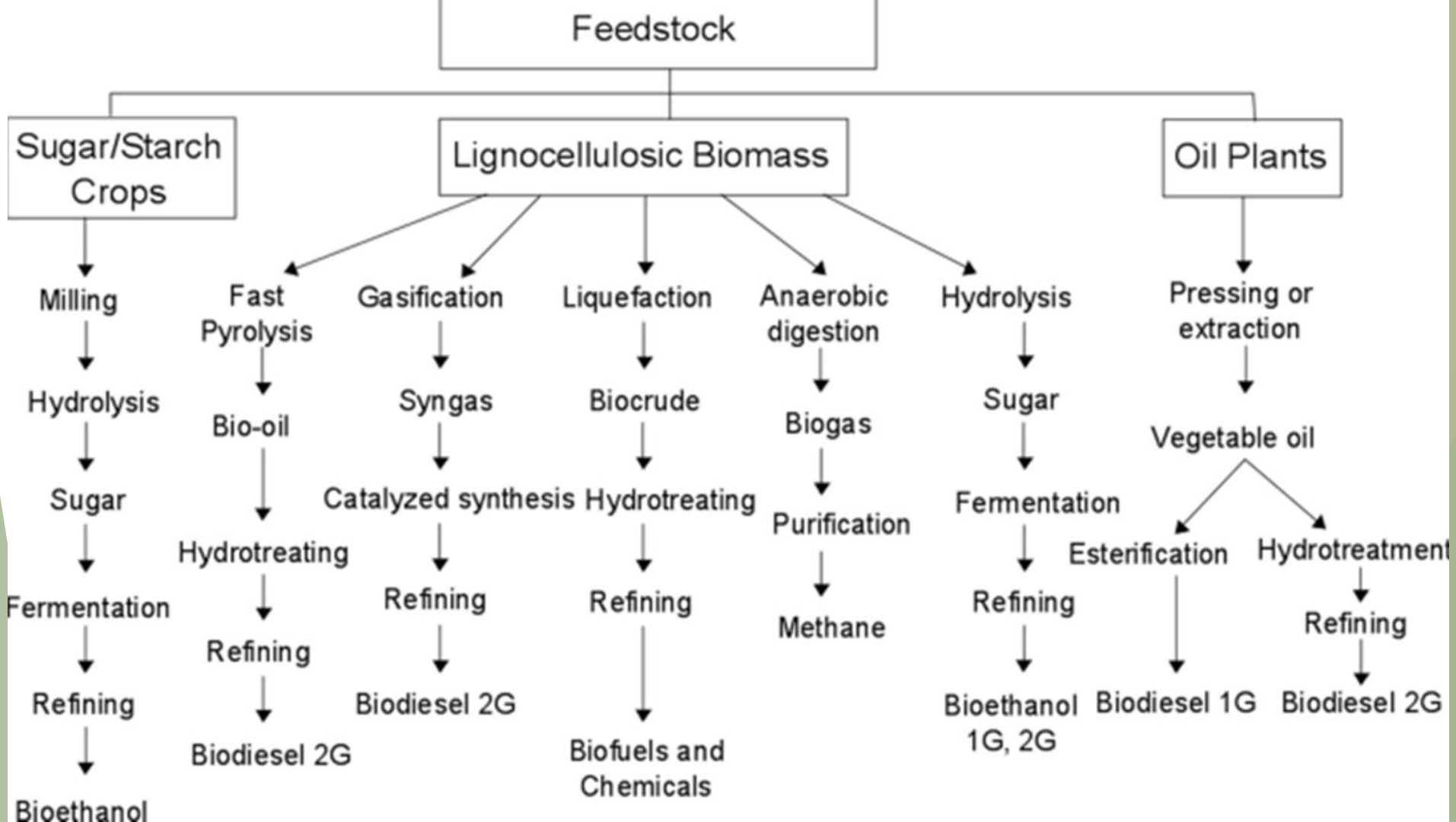
Second Generation

Ethanol/biodiesel is produced from non-edible biomass sources. The sources of second-generation ethanol include dedicated biofuel grasses, crop residues, and wood chips, which are biochemically categorized as lignocellulosic materials.

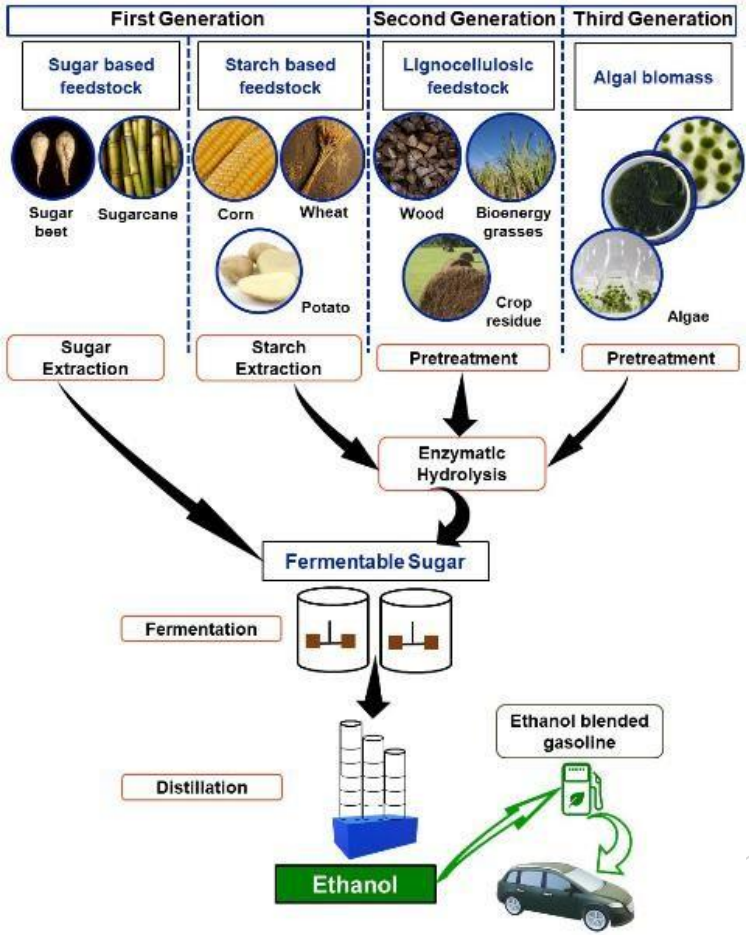
Second-generation biodiesel is produced from non-edible oils, and most comes from jatropha (Bhuiya et al. 2014).

Third Generation

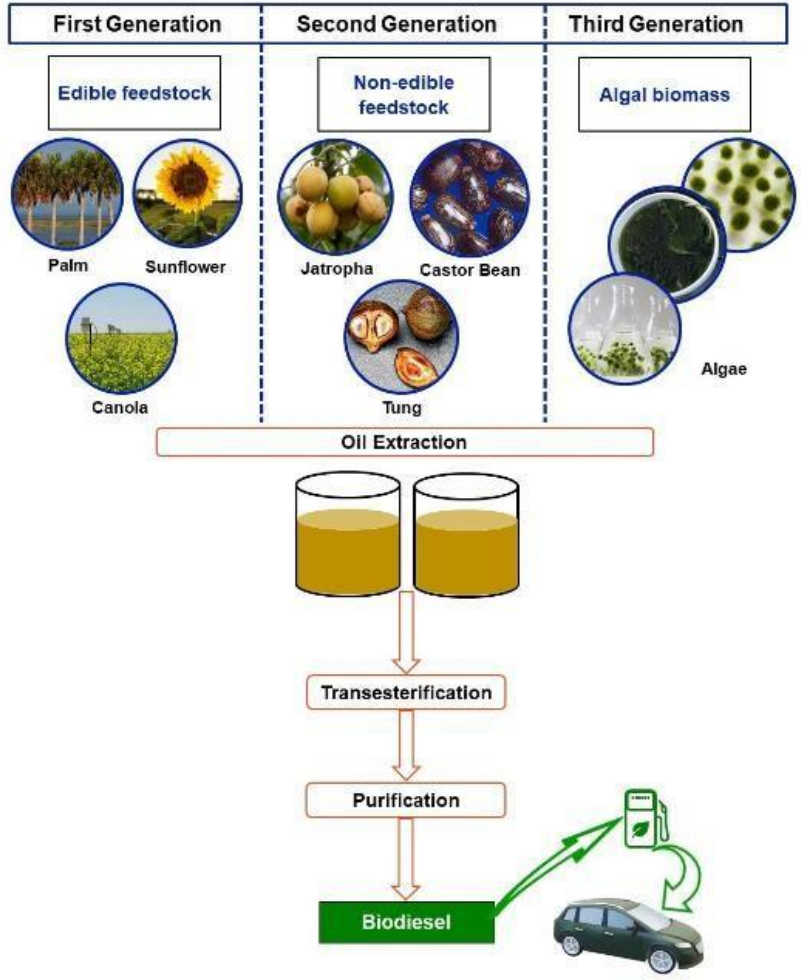
Ethanol/biodiesel is commonly produced from algae, a single-cell organism. Generally, algae are categorized based on their habitat, such as freshwater algae, marine algae, or wastewater algae. Based on its characteristics, a specific alga is chosen for either ethanol or biodiesel production (Wilkie et al. 2011)


Feedstock
Sugar/Starch Crops
Lignocellulosic Biomass
Oil Plants
Milling
Hydrolysis
Sugar
Fermentation
Refining
Bioethanol
Fast Pyrolysis
Bio-oil
Hydrotreating
Refining
Biodiesel 2G
Gasification
Syngas
Catalyzed synthesis
Refining
Biodiesel 2G
Liquefaction
Biocrude
Hydrotreating
Refining
Biofuels and Chemicals
Anaerobic digestion
Biogas
Purification
Methane
Hydrolysis
Sugar
Fermentation
Refining
Bioethanol 1G, 2G
Pressing or extraction
Vegetable oil
Esterification
Biodiesel 1G
Hydrotreatment
Refining
Biodiesel 2G

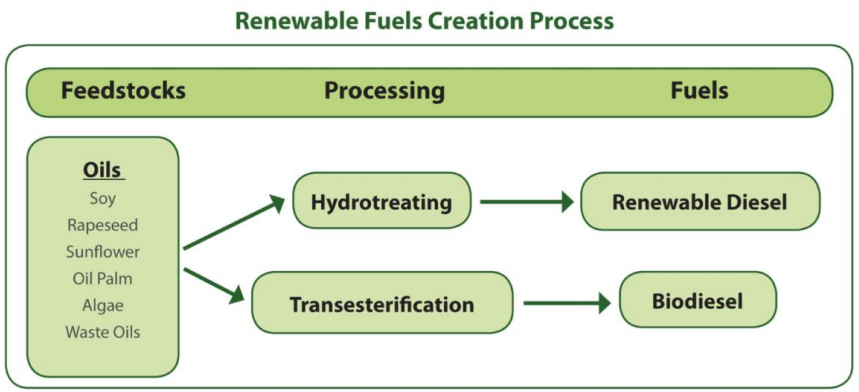
Ethanol Common Production Pathway

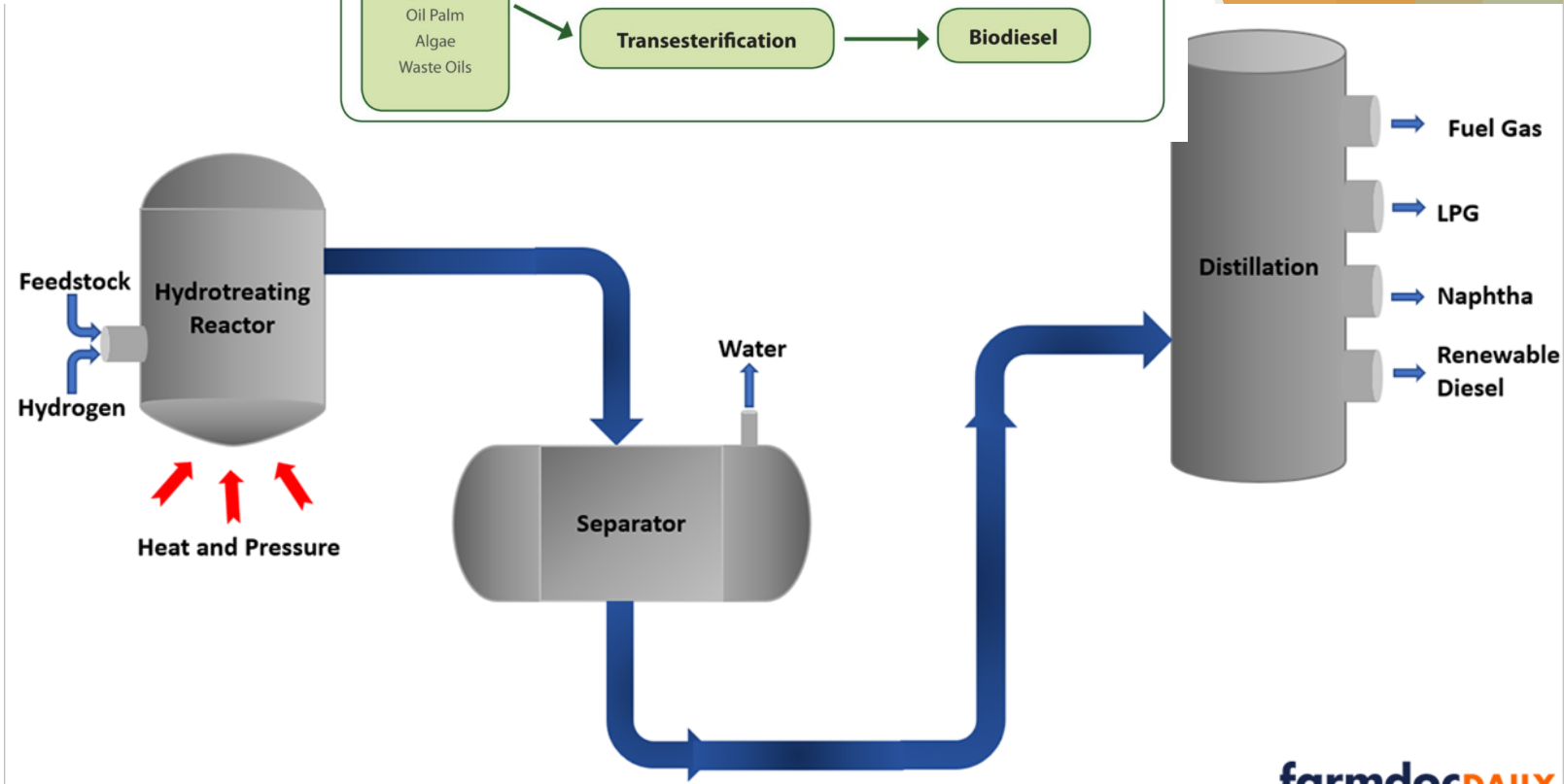


Biodiesel Common Production Pathway

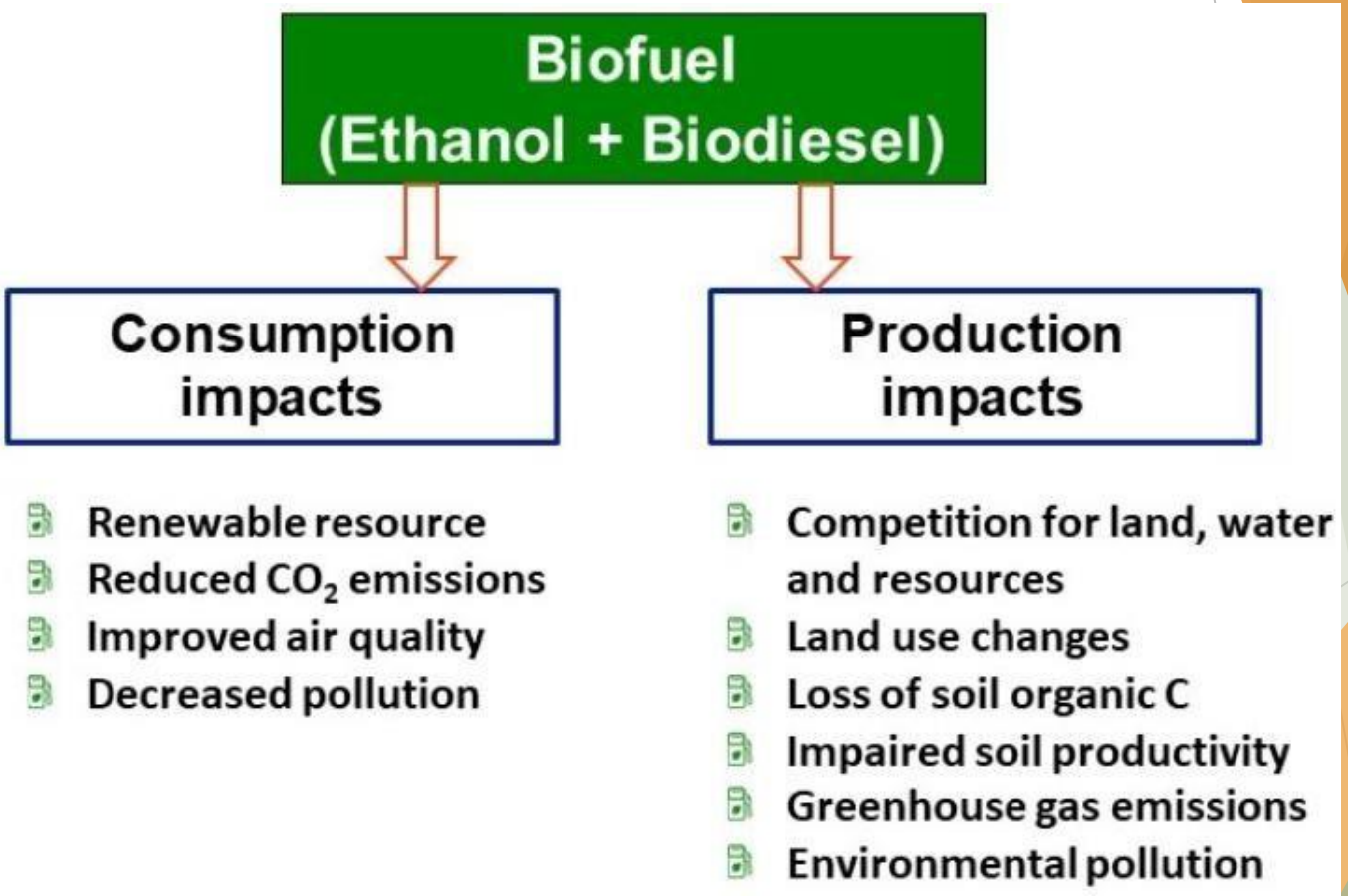


Renewable Diesel: A drop in fuel





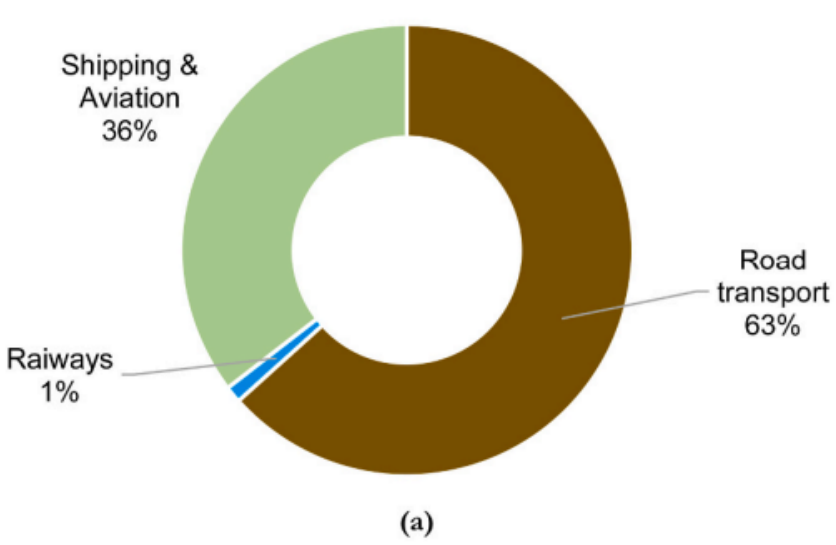
Pros and Cons

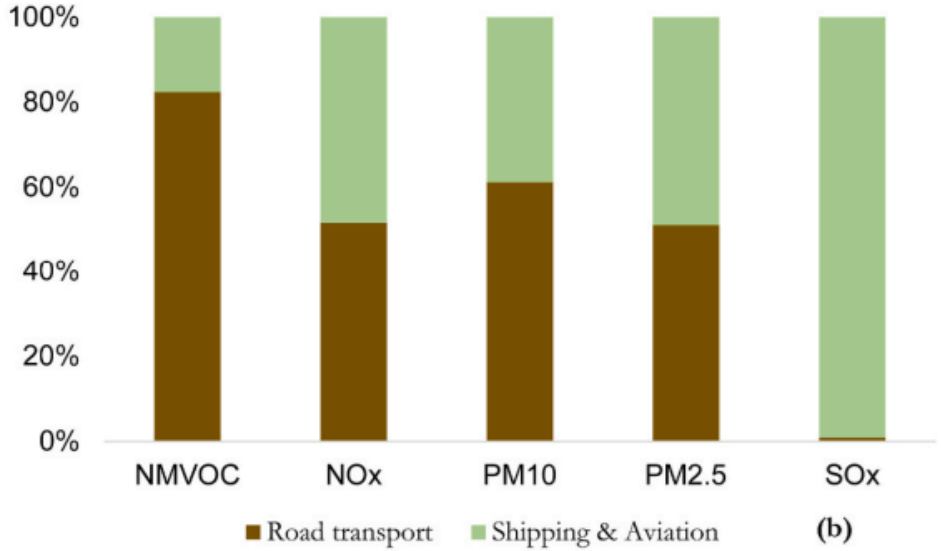


Other Biofuels

- **Biogas and Biomethane**: Produced from organic waste through anaerobic digestion, biogas serves as a versatile fuel for transportation and heating.
- **Advanced Bioalcohols/Hydrocarbons**: Derived from lignocellulosic biomass such as agricultural residues and wood waste, advanced bioalcohols offer higher energy density compared to traditional ethanol. E.g. Dimethyl ether (DME), Methanol etc.

Fueling the Economy: Challenges





Source: European Environmental Agency, Eurostat (2020)

Next Generation Biofuels - Prospects and Challenges

Expanding Applications Beyond Automotive: Biofuels have transcended their traditional role in automotive fuel to become pivotal in addressing various hard-to-abate sectors

- **Aviation and marine:**
  - **Renewable** diesel derived from hydrotreated vegetable oil (HVO) is gaining momentum. United Airlines uses renewable diesel from HVO to reduce carbon emissions in their flights.
  - **Alcohol-to-Jet Technology** is an innovative process that converts ethanol into jet fuel, offering a greener alternative. Alaska Airlines has successfully tested Alcohol-to-Jet fuel
- **Industrial Uses**: Steel manufacturing companies like India's iconic aluminium producer Bharat Aluminium Company Limited (BALCO) utilize **biodiesel** for smelter operations, showcasing the versatility of biofuels.

Challenges in Biofuel Adoption

Despite their promise, biofuels encounter significant challenges, primarily centered around feedstock availability. With escalating demand for bio-based fuels, concerns arise regarding the sustainability and adequacy of feedstock sources.

Currently, **over 70% of biodiesel feedstock originates from first-generation sources like palm oil**, which not only competes with food production but also raises ethical concerns. Second-generation feedstocks, such as used cooking oil, while promising, face limitations in supply and potential export restrictions.

Innovative solutions are imperative to ensure biofuels evolve into a sustainable long-term energy solution. Exploration into non-edible feedstocks and Algae is underway, with companies increasingly involved in developing and scaling these resources to enhance sustainability.

SAF - A new horizon for Biofuels

The aviation sector is under increasing pressure to adopt sustainable practices, leading to the growing use of aviation biofuels or Sustainable Aviation Fuel (SAF). These fuels, derived from renewable biomass feedstocks like plant oils, waste oils, and agricultural residues, significantly reduce greenhouse gas emissions compared to conventional jet fuels.

Key drivers for SAF adoption include environmental regulations, sustainability targets, technological advancements, and governmental incentives. The market is bolstered by partnerships, substantial investments in research, integration with existing infrastructure, and life cycle analysis.

Waste/Used Cooking oil to Biofuels

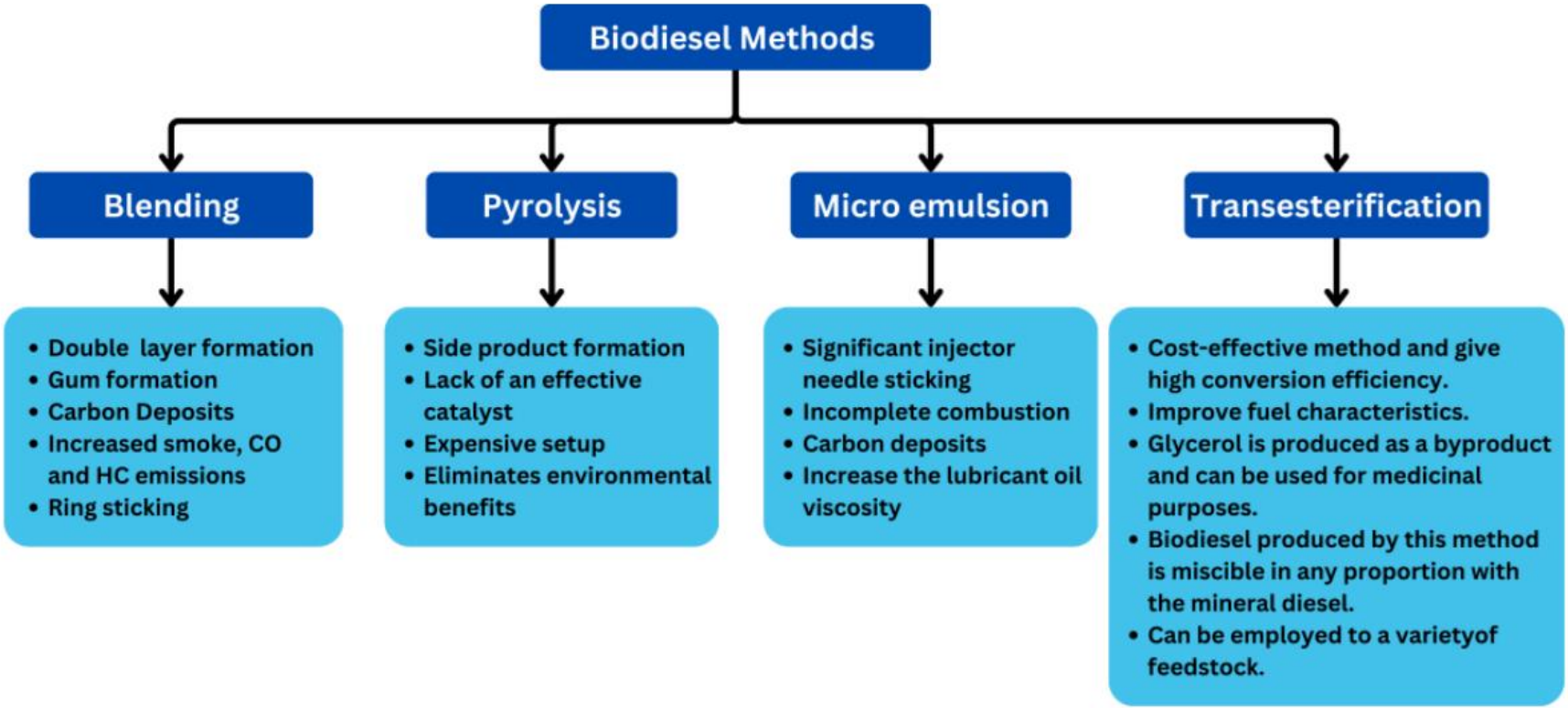
Opportunities and Challenges

- Distributed and scattered biofuel plants – to cater the need of domestic and industrial heating, baking, heat pump and related energy supplies.
- Distributed & variability in feed stocks
  - Local restaurants
  - Animal slaughterhouses
  - High end restaurants
  - Chicken outlets with local slaughtering (1.6 million metric tons per annum)
- Impact on Free fatty acids
- Impact on availability
- Local transportation
- Carbon emissions

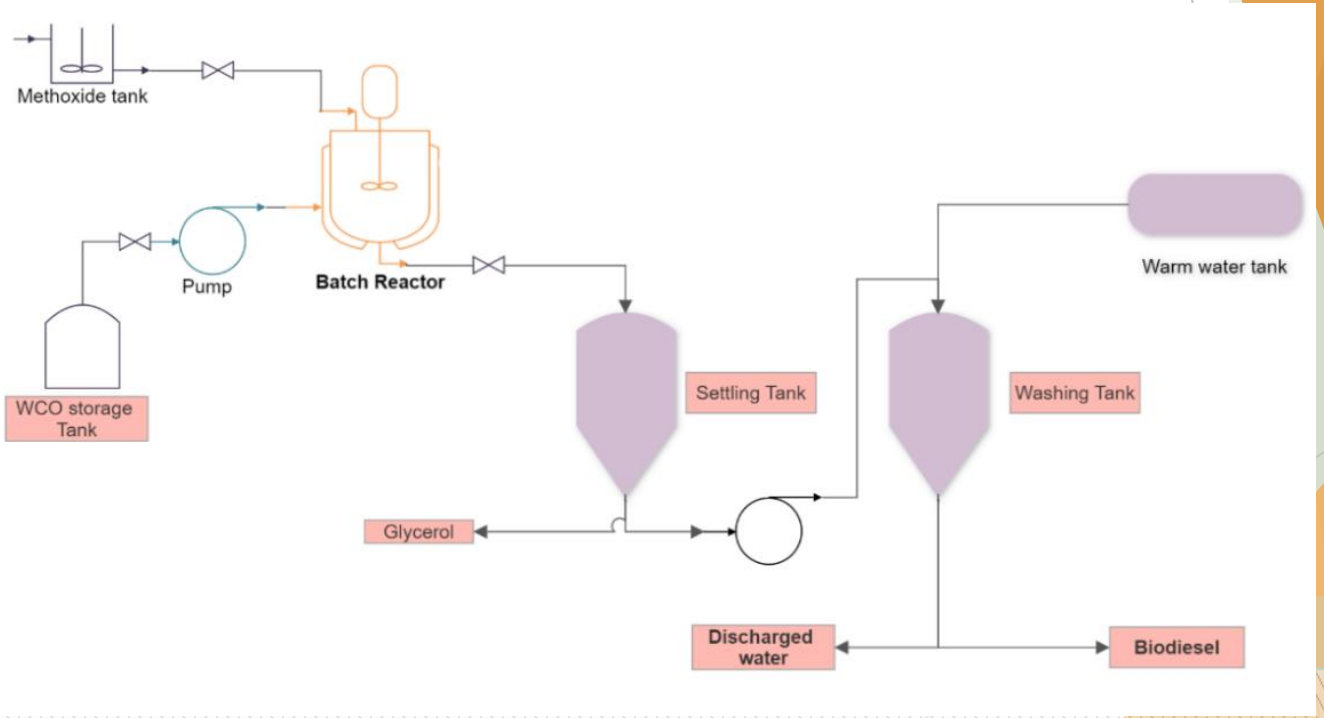
Case Study - Quantity & Supply

Oil Specifications	Used Oil (5-star)	Used oil Local restaurant (2-star)	Palm Oil (virgin oil)	Chicken Feather Oil (remains of chicken)
Code	A	B	C	D
Acid Value	3.5mgKOH/g	5mgKOH/g	4mgKOH/g	4.2mgKOH/g
% FFA Value	1.75	2.5	2	2.1
%Transmittance of Ester Group in FTIR	58.75% (Carbonyl group of esters)	78.2% (Carbonyl group of esters)	57.4% (Carbonyl group of esters)	56.25% (Carbonyl group of esters)
Color	Light Brown Color	Dark Brown Color	Yellowish red	Light Golden Yellow

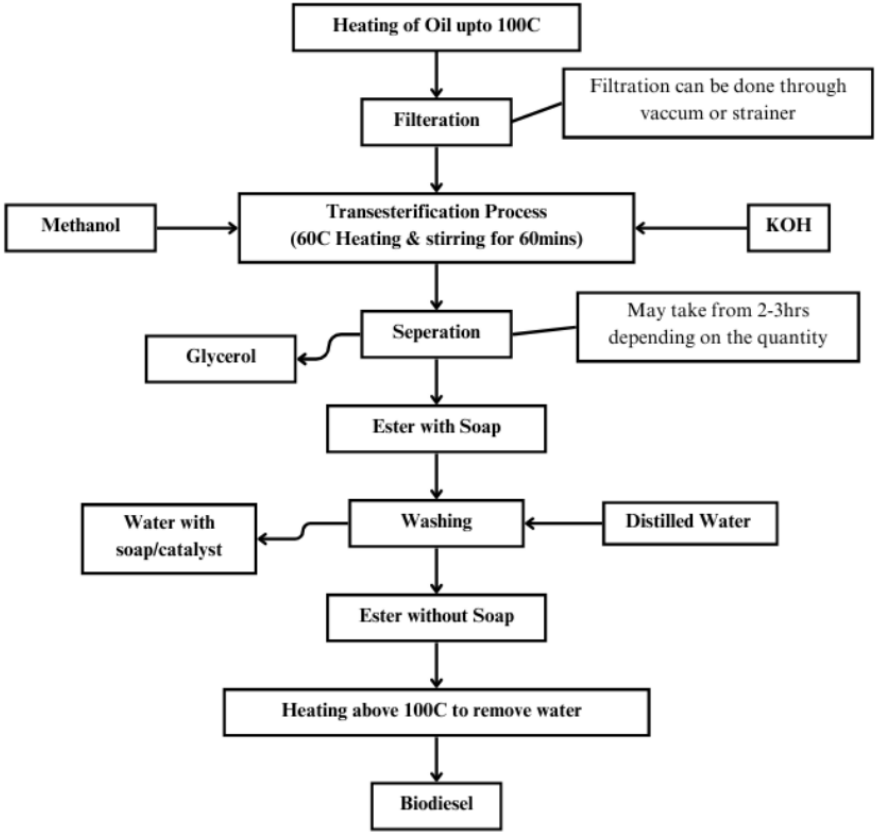
Biodiesel Production Pathways



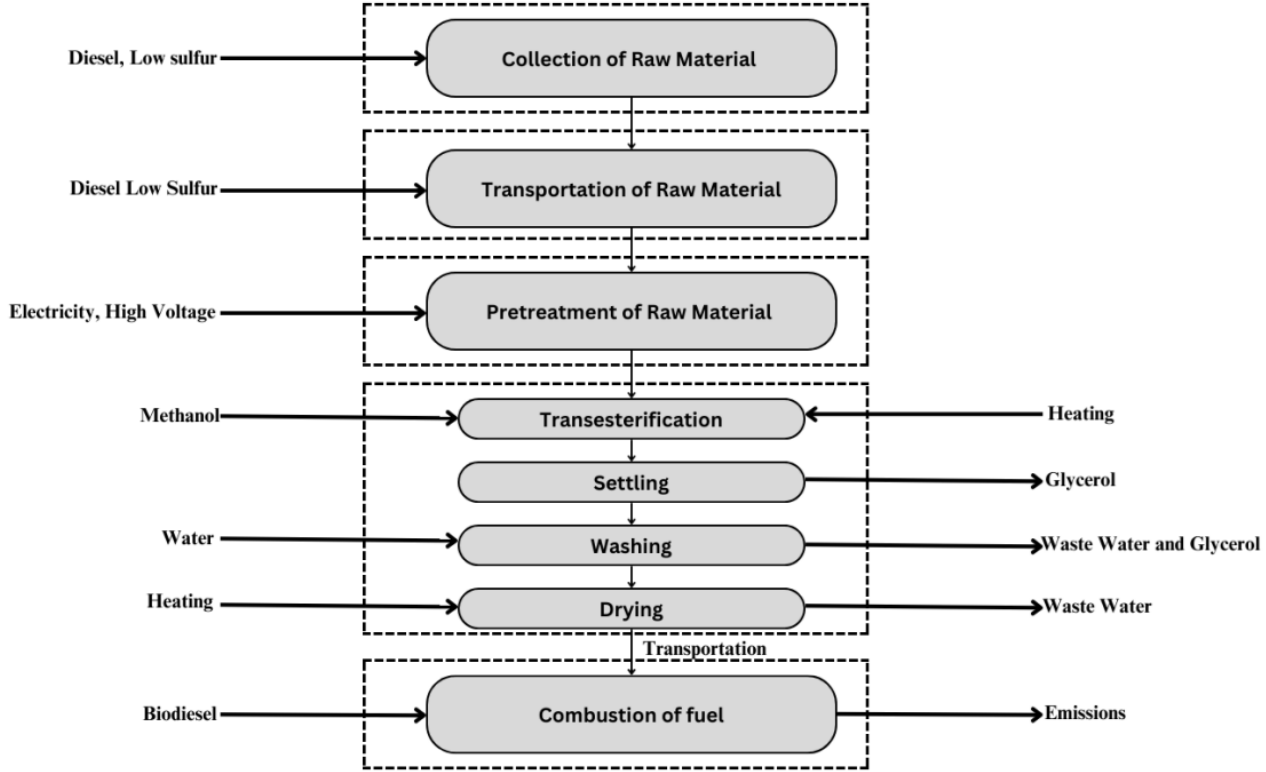
Distributed Biorefinery Production Layout



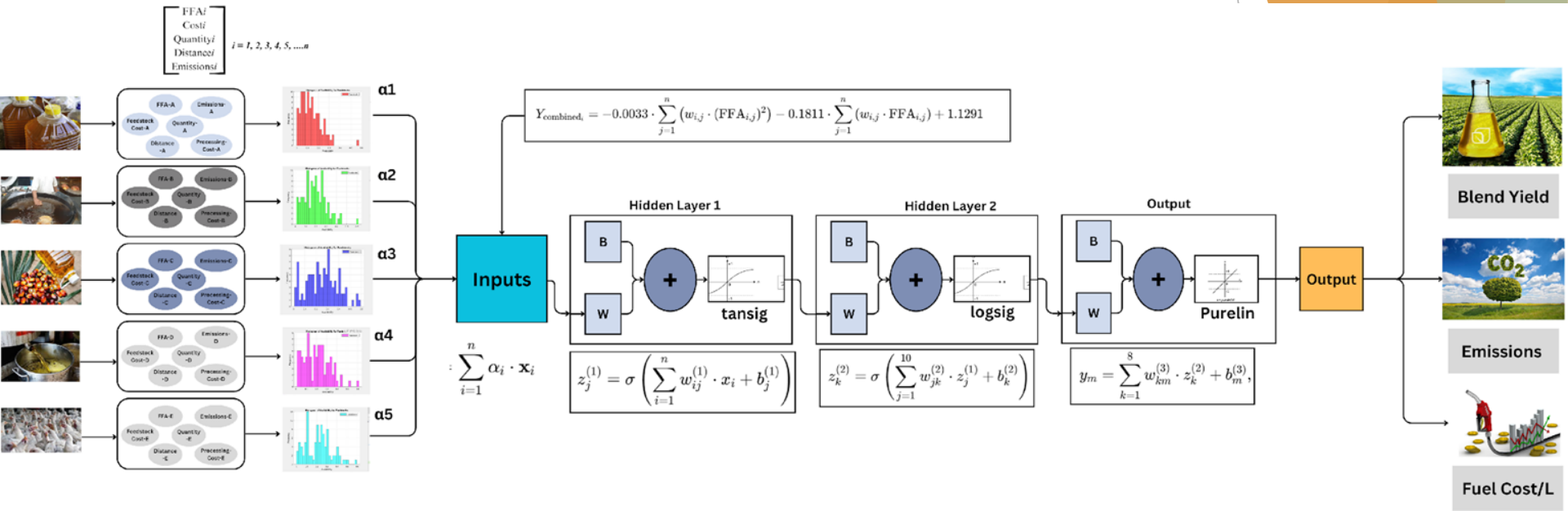
Simplified processing



Mapping the Impact using LCA

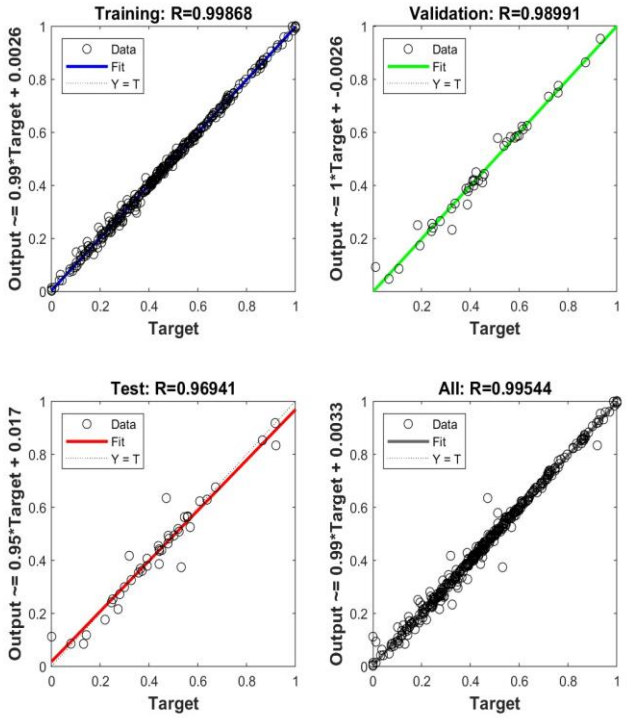


Using ML for BIOFUEL

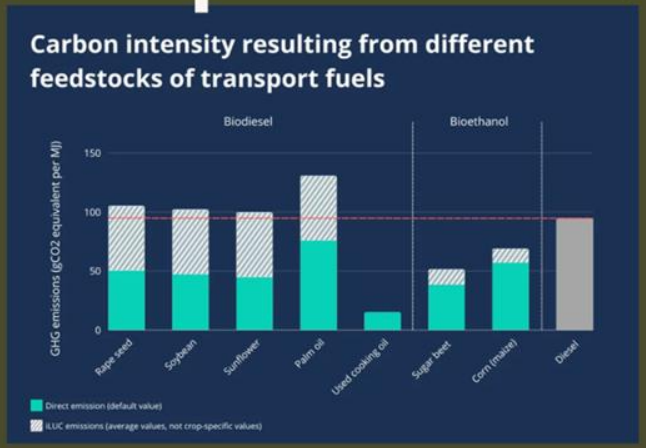


Training

Actual				Predicted outputs				
Actual Yield	Actual Cost (USD)	Actual Emissions (kg CO2/l)	Predicted Yield	Predicted Cost (USD)	Predicted Emissions (kg CO2/l)	Yield Error	Cost Error	Emissions Error
0.650	0.794	1.696	0.659	0.910	1.808	8.95E-05	0.013	0.013
0.660	0.776	1.696	0.700	0.900	1.609	1.58E-03	0.015	0.008
0.850	0.661	1.400	0.755	0.790	1.584	9.06E-03	0.017	0.034
0.750	0.826	1.650	0.690	0.900	1.643	3.59E-03	0.005	0.000
0.700	0.665	1.706	0.684	0.740	1.612	2.64E-04	0.006	0.009



Comparison & Summary

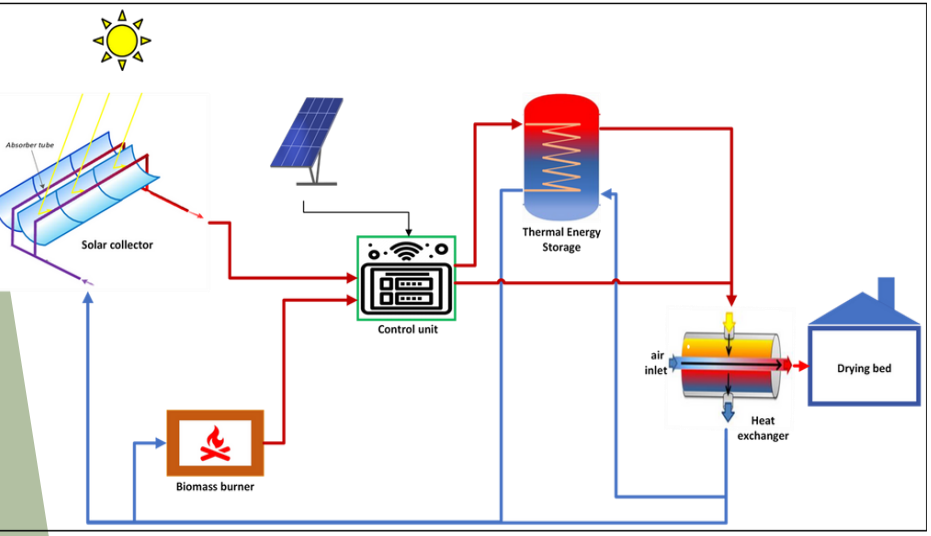


Biofuel	Main Feedstock	Process	GHG Reduction	Key Benefit	Key Challenge
Bioethanol	Sugarcane, corn, residues	Fermentation	30–60%	Octane booster in gasoline	Land use
Biomethane	Organic waste, manure	Anaerobic digestion	80–120%	Waste mgmt + energy	Digester cost
Biodiesel	Veg oils, waste oil	Transesterification	50–80%	Non-toxic, biodegradable	Feedstock supply
SAF	Biomass, waste oils	HEFA, FT, ATJ	Up to 80%	Aviation decarbonization	Cost
HEFA	Waste oils, tallow	Hydrotreating	65–85%	Drop-in fuel	Hydrogen need

Way forward

- Distributed waste to energy using waste – Potential
- Reliability of supply chain – Challenge
- Using data-engineering through Machine Learning/AI for forecasting – Opportunity
- Unverified carbon data, embodied carbon and cost escalations – Threats

Integrated Thermal grid - way forward with application in sustainable practices



The Primary SAF Production Pathways

Abbreviation	Feedstock	Products
HEFA-SPK Hydroprocessed Esters and Fatty Acids Synthetic Paraffinic Kerosene	Oil crops	Jet fuel Diesel Naptha LPG Propane
ATJ-SPK Alcohol to Jet Synthetic Paraffinic Kerosene	Starches	Jet fuel Diesel Naptha
FT-SPK Fischer-Tropsch Synthetic Paraffinic Kerosene	Wood	Jet fuel Diesel Naptha

Thanks
Q/A