Potential of Bioenergy in CCUS

Presented by – Dr. Akshay Jain

ACBCCUS-2025

Research Scientist, Energy Centre,

Maulana Azad National Institute of Technology Bhopal, M.P., India

Project :"**Green Hydrogen Production Employing Waste Biomass**"
funded by the **Department of Science and Technology, Government of India**

Shortlisted for **Postdoc Fellowship**,
Interdisciplinary Research **Center for Hydrogen and Energy Storage**,
King Fahd University of Petroleum & Minerals (KFUPM), Dhahran, Saudi Arabia

Ph.D. from **Energy Institute, Bengaluru**, Karnataka, India
A Centre of *Rajiv Gandhi Institute of Petroleum Technology, Jais,* Amethi, U.P.
[An Institution of National Importance set up by the
Ministry of Petroleum and Natural Gas (MoPNG), Government of India]

Introduction

Type of resources - Renewable Energy Resources

- Renewable energy : Solar, Wind, Hydro, Geothermal, **Biomass**.
- Biomass is **organic material** from plants and animals.
- **Biofuels are produced from biomass** which is organic matter like wood, plant, animal residues etc., that contain **stored solar energy**.
- **Biodiesel** production in India supports multiple **Sustainable Development Goals** established by the United Nations, thereby promoting sustainable development in the country.
- According to **National Policy on Biofuels 2018**, an indicative target of 5% biodiesel blending in diesel by 2030.

Introduction

Classification of Biofuels (Useful for Transportation and Power sector)

- Bio-Hydrogen
- Bio-Methane
- Bio-Hythane
- Producer Gas
- Bioethanol
- Biodiesel
- Bio-oil
- SAF- Bio-jet

- Solid biomass: Pellets, Charcoal
- Use of scrubbed CBG in place of CNG.
- Blending of hydrogen in natural gas: Hythane
- Blending of Bio-Hydrogen in Bio-Methane: Bio-Hythane
- Blending of Ethanol in Petrol E20 by 2025.
- Blending of Biodiesel in Diesel.
- Blending of Ethanol as oxygenated fuel additive in Diesel: Diesohol
- Blending of Ethanol in Biodiesel: Bio-Diesohol

Introduction

Biomasses are typically classified as:

- Forestry goods, including wood, trees, bark, shrubs and sawdust.
- Bio-renewable wastes, such as organic waste, mill and urban wood waste and agricultural waste.
- Food crops, comprising sorghum, oil seeds, grains, sugarcane, molasses and sugar beets.
- Energy crops, encompassing switchgrass, short rotation woody crops, grasses, starch crops and herbaceous wood.
- Organic wastes, including municipal solid waste, sludge and industrial organic waste.
- Aquatic plants like water hyacinth, rushes, reeds, water weeds and algae.

Introduction

Variety of feedstocks (Useful for Biofuel Production)

- Water Hyacinth,
- Jackfruit Waste,
- Coconut Fibres And Shells,
- Agricultural Waste,
- Food Waste,
- Waste Cooking Oil,
- Plastic Waste, And
- Waste Tyres

Introduction

Bioenergy for CCUS

- Bioenergy carbon capture and storage (BECCS) is essential for achieving **carbon neutrality** targets.
- A biorefinery is a processing facility that aims to **change biomass** into value-added goods while **minimizing environmental impacts**.
- BECCS involves the capture, utilization, or permanent storage of CO_2 generated **during the combustion or conversion processes of biomass**.
- This approach not only **sequesters carbon emissions** but **also produces bioenergy**, thereby contributing to a **net reduction in atmospheric CO_2 levels** and providing renewable energy sources for future consumption.

Introduction

Water Hyacinth

- **Water Hyacinth** consists of 18 to 35% cellulose, 18 to 49% hemicellulose, and 3.5 to 9% lignin, making it suitable for extracting fermentable sugars through various pre-treatment methods. Water Hyacinth has significant detrimental effects as an **invasive weed**.
- It is recognized for its **rapid growth**, with infestation areas expanding at remarkable rates, such as **13 hectares per day**. In comparison to traditional biomass briquettes produced from wood chips, coffee husk, sawdust, and paper, **WH briquettes** exhibited low moisture content and showed noteworthy influence and fragmented resistance.
- **WH biodiesel** generated from the transesterification of the oil obtained from WH satisfies the ASTM standards.

Summary of the Ph.D. Research

Step-1 Collection of Water Hyacinth	Step-2 Pretreat-ment	Step-3 Drying in sun	Step-4 Water Hyacinth oil extraction	Collection of Water Hyacinth oil	Step-5 Trans-esterifica-tion	Step-6 Water Hyacinth Biodiesel
						

Water Hyacinth Biodiesel Production

Step-1 Collection of Water Hyacinth (Water Hyacinth)	Step-2 Pretreatment	Step-3 Drying in sun
10 kg of fresh Water Hyacinth was collected from Rachenahalli Lake, Bengaluru, Karnataka	Separation of stalks and leaves from roots	Separated stalks and leaves were chopped with the use of kitchen knife and dried in sun to reduce moisture
		

Water Hyacinth Biodiesel Production

Step-4
Water Hyacinth oil extraction by using Soxlet apparatus

- **50 g** of dried biomass of Water Hyacinth was wrapped in muslin cloth and kept inside extractor unit of Soxlet.
- **15% Diethyl Ether and 10% Methylene Chloride in n-Hexane** solution were used in Rehman et al. (2021), were added in the Soxlet apparatus to extract Water Hyacinth oil for present experimentation.
- Process was maintained for **48 hours at 45ºC**. Solvents were recycled after completion of the extraction process with the use of **rotary evaporator** and Water Hyacinth oil remained in the round bottom flask attached to the rotary evaporator.
- **11.32 g** of Water Hyacinth oil was collected after evaporation of solvents which is in a good agreement with Shanab et al. (2016).

Water Hyacinth Biodiesel Production

Step-5 Separation of biodiesel layer from glycerol	Step-6 Water Hyacinth biodiesel
	

- Obtained Water Hyacinth oil was transesterified using methanol to oil ratio 9:1 with 1% (w/w) KOH as catalyst as mentioned in Rehman et al. (2021).
- Process was maintained at 55 ºC for 90 min of time on a stirrer running at 500 rpm.
- Separatory funnel was used to allow separation of biodiesel and glycerol for 2 hours.
- **7.02 g** of Water Hyacinth biodiesel [WHB] was obtained after glycerol separation.
- Water Hyacinth biodiesel was collected and stored for characterization. Process is repeated further for producing 2 L of WHB.

Water Hyacinth Biodiesel Production

S.No.	Process	Weight
1	Collection of fresh Eichhornia Crassipes	10 kg
2	Chopped stalks and leaves (After roots separation)	6 kg
3	After Sun drying	0.68 kg
4	Biomass quantity taken for experimentation	100 g
5	Water Hyacinth oil from 50 g biomass	22.68 g
6	Water Hyacinth biodiesel from 11.36 g oil after transesterification	14.04 g

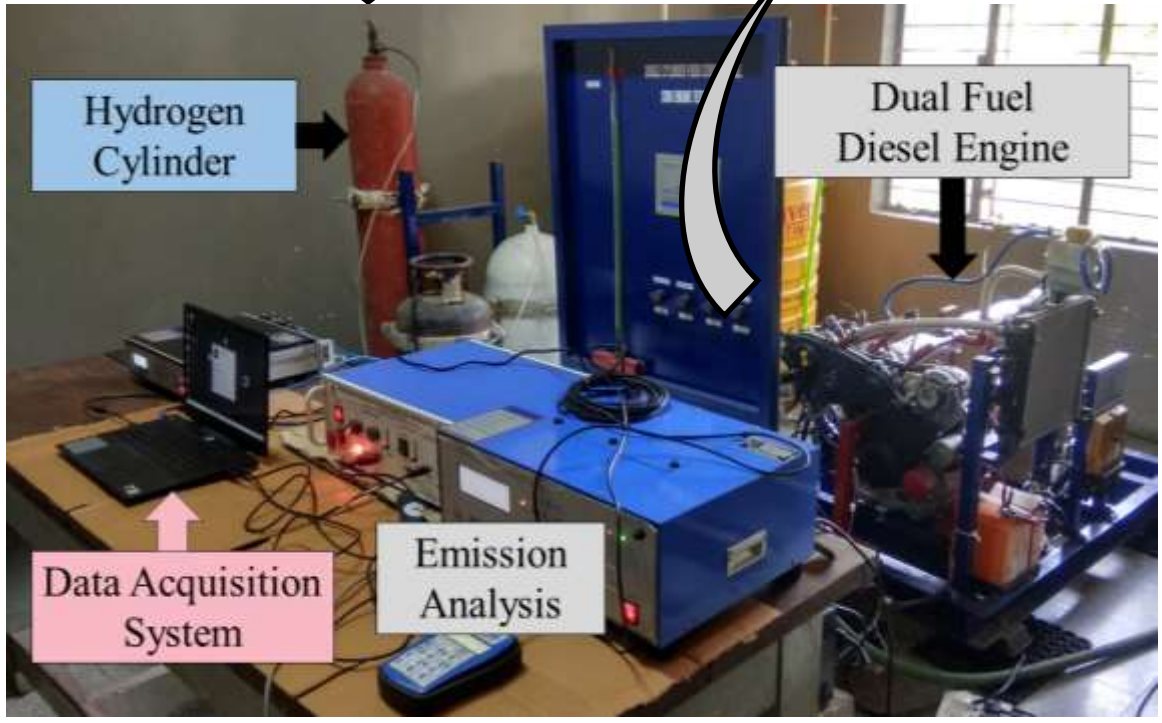
Properties of Diesel, ASTM D-6751-06, WHB

Property [Unit]	Diesel	ASTM Method	Limits	WHBD
Flash Point [℃]	75	D93	130 [Minimum]	148
Kinematic Viscosity [mm^2/sec]	2.76	D445	1.9-6.6	3.96
Cetane	45	D613	47 [Minimum]	55
Density [kg/m^3]	840	D1298	-	874
Calorific Value [MJ/kg]	42	D48069	-	39.87

Dual Fuel Engine Setup

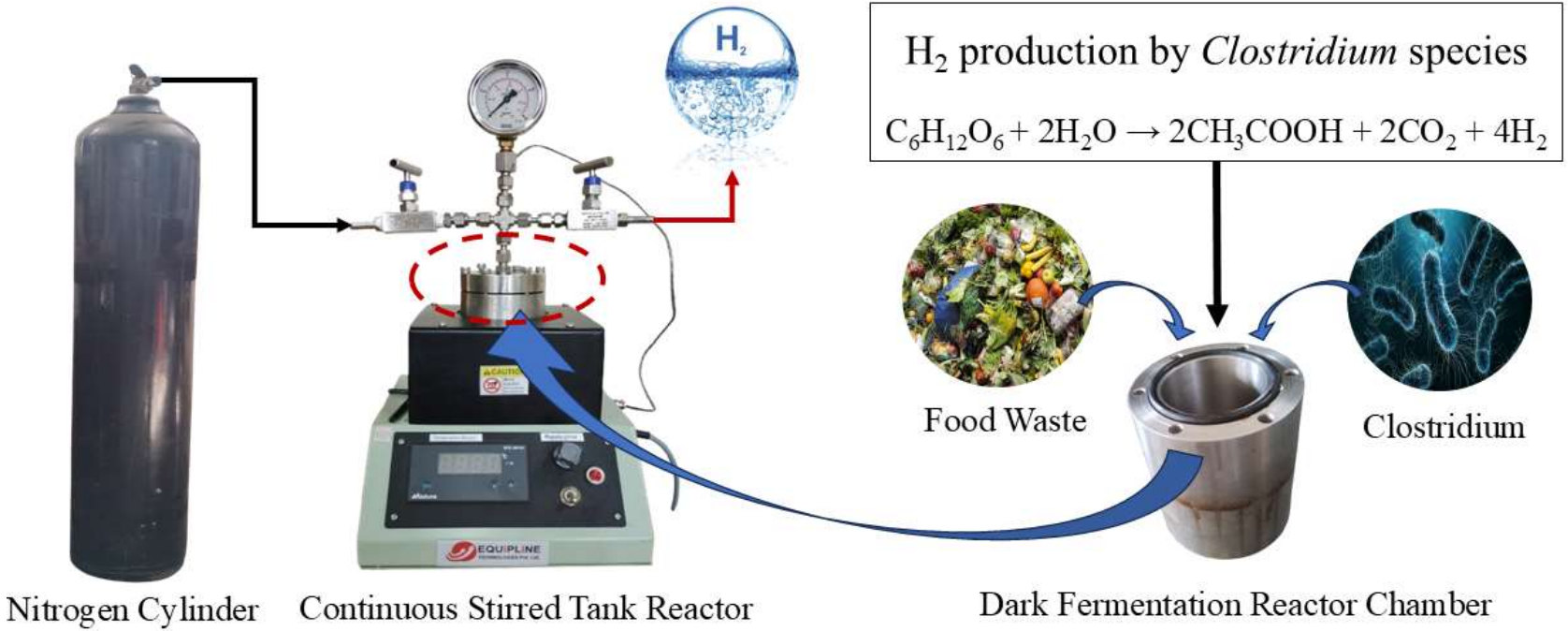
Flame Arrester

Hydrogen Cylinder Valve

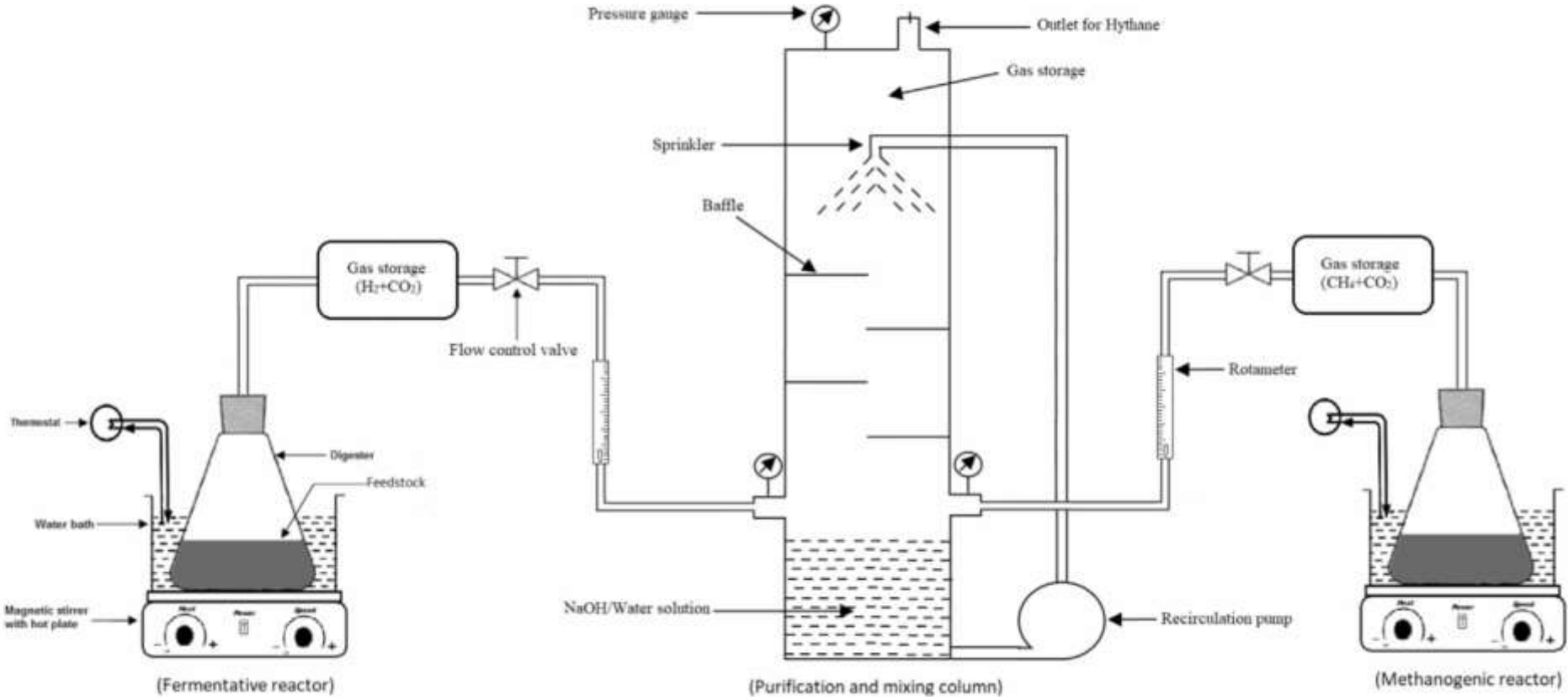


Hydrogen Switch

Bio-Hydrogen through Dark Fermentation



Bio-Hythane Production



World wide Initiatives

CNG-powered

Bajaj - Freedom 125

Ethanol Blend E-20 to E85

Maruti Suzuki - Wagon R Flex-fuel (FF)

CNG powered

Eicher - Pro 2114XP CNG

World wide Initiatives

Ethanol-powered

TVS Apache RTR 200 Fi E100

Compressed Biogas powered

Maruti Suzuki Wagon-R

CBG-Biodiesel powered

Dual-fuel Tractor, CRDT, IIT Delhi

India's Initiatives

Green Hydrogen Electrolyser Plant – *Reliance Industries* and *Adani Group* announced plan to setup Green hydrogen production plant

Public Sector Initiative – The *National Thermal Power Corporation* of India has initiated a pilot project in intercity bus services utilizing hydrogen fuel cell power in Leh.

H_2

Nation Green Hydrogen Mission [2021], *India* - promotes the indigenous production of green hydrogen and its use for energy generation

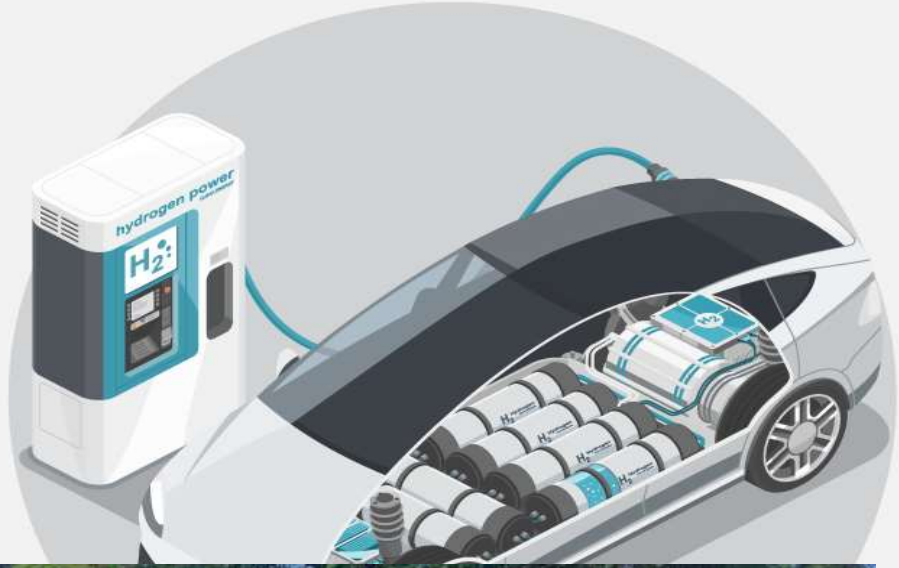
Hydrogen Fuel Blending Trials – *Indian Oil Corporation Limited is* conducting trials to blend H_2 in CNG for use as ICE fuel.

World wide Initiatives

- Hydrogen Mobility Europe [H2ME]
- California Hydrogen Business Council [CHBC]
- Hydrogen Valleys Initiative
- Australian Green Hydrogen Headstart Program
- Hydrogen Combustion Engine Trucks [HyCET] Project, Germany

Mukesh Ambani's Reliance Industries launches India's first **Hydrogen ICE** truck 07-02-2023

Hydrogen- Fuel Cell Vehicles



Toyota
Mirai

- Pricing starts at $50,000
- Range: 402 miles/647 km

BMW
iX-5

- Pricing TBA
- Range: 300 miles/504 km

Honda
Clarity

- Pricing starts at $35,000
- Range: 240 miles/386 km
- Has been pulled from Honda's lineup

Audi
H-Tron Quattro

- Pricing: starts at $115,000* (for its traditional counterpart)
- Range: 373 miles/600 km

WHO	WHAT	WHERE	WHEN
IndianOil + L&T + ReNew (India) Joint Venture		Gujarat and Odisha	2026-27
NTPC Green Energy	0.438mtpa Green Hydrogen	Pudimaka (Andhra)	2026-2032
	1mtpa Green Hydrogen, Green Ammonia, and Green Methanol	Maharashtra	2026-2032
Reliance Industries	3.6mtpa Green Hydrogen	Jamnagar (Gujarat)	2025
	3mtpa Green Ammonia, 0.6mtpa Green Hydrogen	Kandla (Gujarat)	2026-27
Adani Group	3mtpa Green Hydrogen	Mundra (Gujarat)	2025
Acme Cleantech	1.3mtpa Green Ammonia with Green Hydrogen; 4.5GW Solar Power	Gopalpur (Odisha) Kalahandi (Odisha)	2027
	5GW Solar PV, 1.5GW Electrolyser; 1.1mtpa Ammonia Synthesis Loop	Thoothukudi (TN)	2025-26
	1.2mtpa Green Hydrogen and Green Ammonia; 4.95GW Solar Power	Mangaluru (Karnataka)	2027

WHO	WHAT	WHERE	WHEN
Welspun New Energy	Green Ammonia and Hydrogen	Bulandshahr (UP)	
	Green Ammonia and Hydrogen in JV with Gujarat Pipavav Port	Gujarat	2026-27
	0.7mtpa Green Ammonia	Kendrapada (Odisha)	2026-27
Essar Future Energy	1 mtpa Green Hydrogen	Jamnagar (Gujarat)	2028
Avadaa Green H2	0.5mtpa Green Hydrogen and Green Ammonia	Gopalpur (Odisha)	2026
L&T	2.5mtpa Green Ammonia, 0.5mtpa Green Hydrogen	Kandla (Gujarat)	2025
8 other Plants	17.4mtpa Green Ammonia 0.2mtpa Green Hydrogen 0.8mtpa Green Methanol	Ganjam, Gopalpur, Jagatsingpur, Malkangiri and Rayagada (Odisha); Kakinada (Andhra); Prayagraj (UP)	

Thank You

Contact Details:

Dr. Akshay Jain, [Ph.D.]

Mobile: +91-9770662465

e-mail: ajainmech@gmail.com, 20eb0001@rgipt.ac.in

Google Scholar- https://scholar.google.com/citations?user=G-OQq5AAAAAJ&hl=en

ORCID- https://orcid.org/0000-0001-6928-2518

Scopus Author - https://www.scopus.com/authid/detail.uri?authorId=57944457700

LinkedIn- https://www.linkedin.com/in/akshay-jain-8256a689