Environmental Sustainability Studies of Biohub Archetypes

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Presentation summary

- Aim and objectives
- Biohub Archetypes
- Life Cycle Assessment methodology
  - What is LCA?
  - Supply chain and System boundaries
  - Life cycle inventory analysis
- Results and Discussion
- Conclusions
- Key findings
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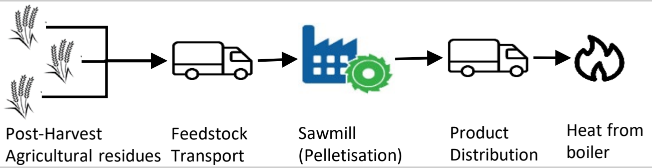
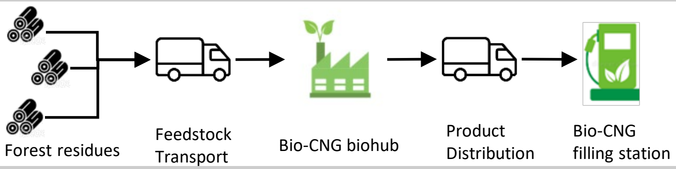
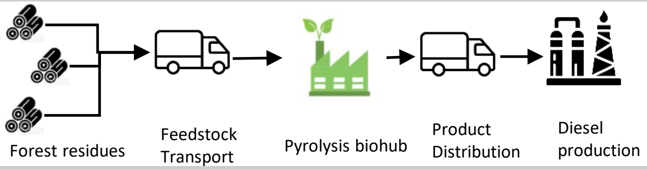
Aim and Objective

- **Aim**: To Investigate the environmental impacts of three biohub archetypes

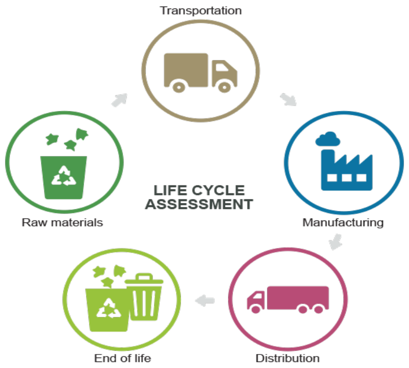
- **Objectives**:
  - Collaborate with IEA task 43 members to procure mass and energy inputs for the environmental sustainability study
  - Learn OpenLCA software
  - Design supply chains of final products from biohub archetypes
  - Perform Life Cycle Assessment to determine the global warming potential of biohub archetypes

Biohub Archetypes

Biohub	Biohub-1	Biohub-2	Biohub-3
Location	Croatia	Ireland	Ireland
Feedstock	**Post-Harvest agricultural residues**. Such as Cereal straw, Soy straw and other Plant post-harvest residues	**Forest residues** Unmerchandisable wood (Tip-7cm) in diameter	**Forest residues** Unmerchandisable wood (Tip-7cm in diameter
Pathway	Pelletisation and packaging	Gasification + gas cleaning +methanation + compression	Pyrolysis + biochar separation+ co-processing with vacuum gas oil hybrid diesel production at oil refinery
Final product/ end use	Burned in Boilers for domestic heat application	Biomass-derived compressed natural gas (Bio-CNG) Transport fuel for forestry fleets	Pyrolysis Oil based Hybrid diesel as transport fuel for fleets Biochar as soil fertilizer
Reference system	Coal production and combustion in boilers	Diesel production and combustion in forestry fleets	Gasoline and diesel production produced from fossil based resources (i.e. Crude oil) and fuel combustion
Flow diagram			
Literature	[1], [2]	[3], [4]	[5], [6]

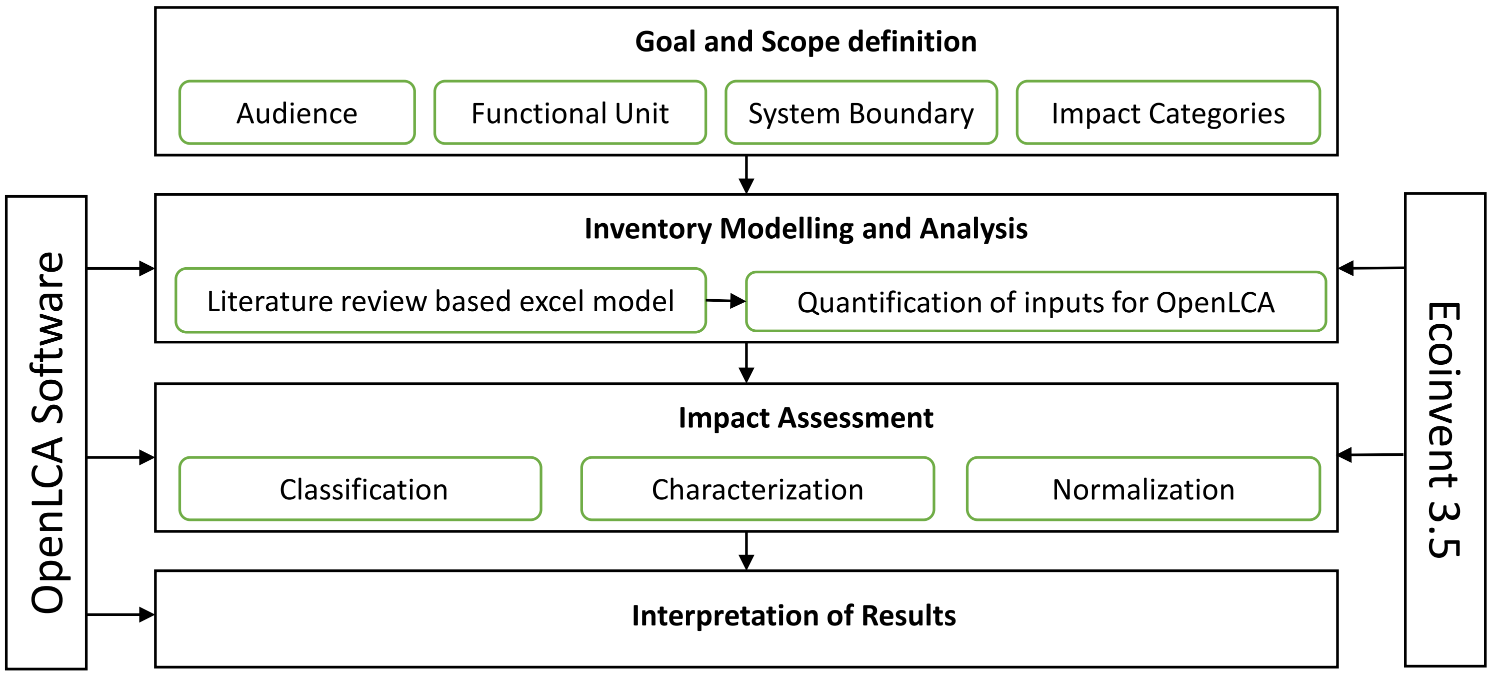
Methodology: Life cycle assessment

What is Life cycle assessment?

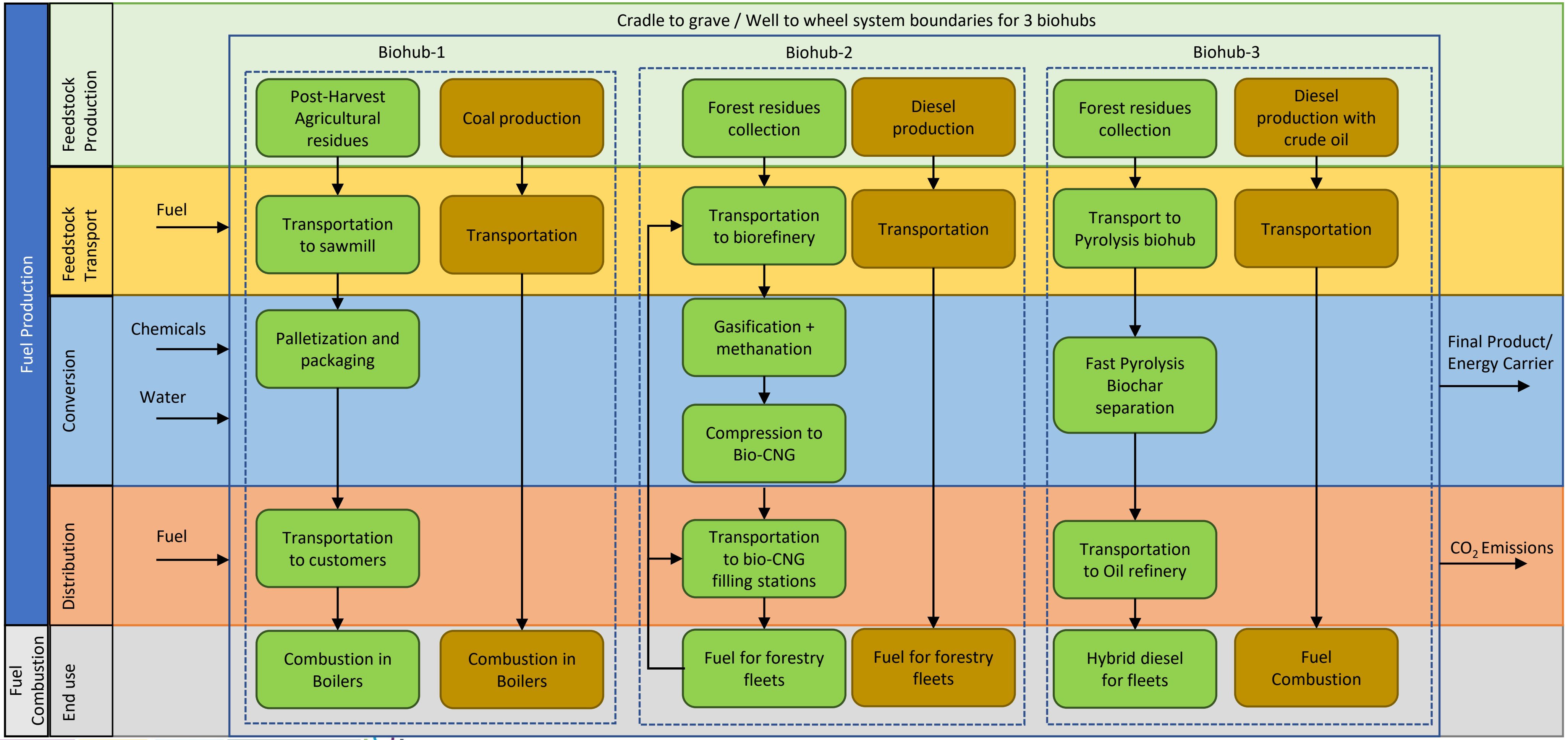


- Life Cycle Assessment is a technique to analyse the environmental impacts resulting from the processes involved in life cycle of a particular product
- Following are the characteristics of LCA in this study
  - System boundary: Cradle to grave
  - Function Unit: 1 GJ energy produced
  - Impact assessment method: CML baseline
  - Impact category: Global warming potential (kg CO_2-eq GJ^{-1})

Methodology



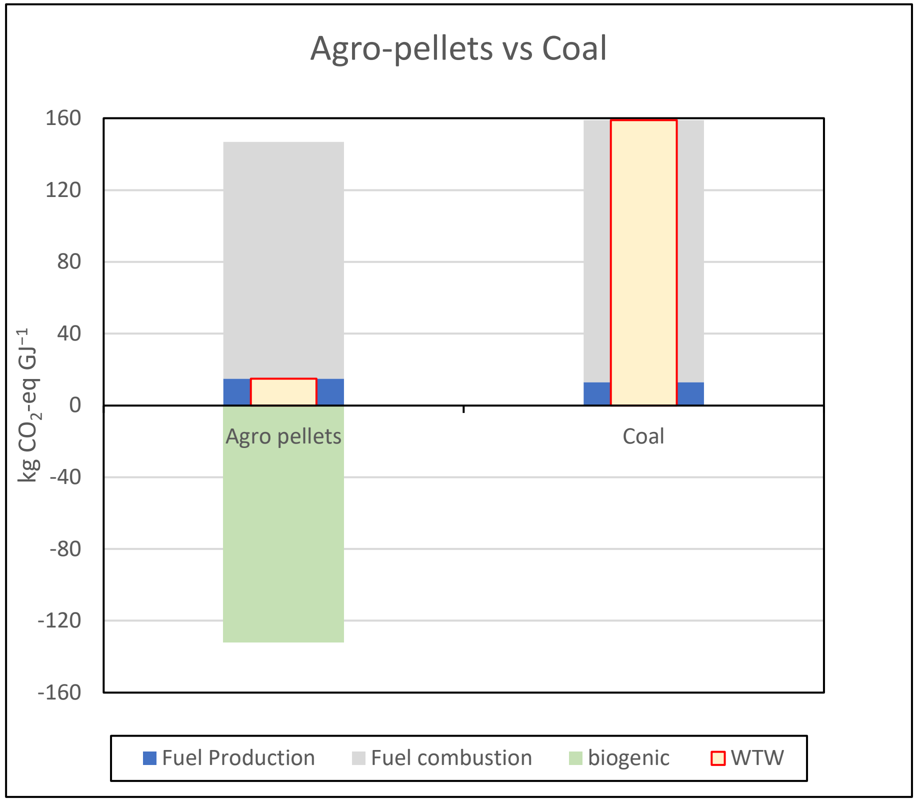
Methodology: Supply chain and system boundary



Methodology: Life Cycle inventory analysis and Literature Review

		Biohub-1			Biohub-2			Biohub-3		
		Process	LCA Input	Quantity	Process	LCA input	Quantity	Process	LCA input	Quantity
Fuel Production	Feedstock Production	Post-Harvest Agricultural residues • Cereal straw, Soy straw and other Plant post-harvest residues	• Biomass input: t/a • Fertilizer: kg/ha	• 2500 • 0	Forest residues	• Biomass input: Dry kg/GJ bioCNG • Energy for collection: MJ/dry tonne of forest residues	• 90 • 267	Forest residues	• Biomass input: Dry kg/GJ bio-oil • Energy for collection: MJ/dry tonne	• 114.5 • 267
Fuel Production	Feedstock Transport	• Transportation to sawmill	• Forest to biohub transportation average distance: km	• 5	Transportation to biohub	• Forest to biohub transportation average distance: km	• 240	Transportation to biohub	• Forest to biohub average transportation distance: km	• 240
Fuel Production	Conversion	• Drying • grinding • Pelleting • Cooling	• Energy: MJ/dry tonne feedstock	• 324.8 • 189.5 • 339.2 • 8.7	Drying and chipping	• Energy: MJ/dry tonne feedstock	• 324.8	Drying and chipping	• Energy: MJ/kg Liq.fuel	• 1.8
Fuel Production	Conversion				Gasification and upgrading	Chemicals(kg/GJ bioCNG) • Calcium carbonate: • Potassium carbonate: • Olivine: • Activated carbon: • RME: • Water:	• 1.58 • 0.016 • 0.91 • 0.03 • 1.47 • 91	Pyrolysis	• Energy: MJ/kg Liq.fuel	• 1.8
Fuel Production	Conversion	• Packaging		• 15 kg bags	Compression to bio-CNG	• Electricity: MWh/ MWh bioCNG	• 0.011	Hydro-treatment	• NG for H_2 reforming: MJ/kg Liq.fuel	• 9.3
Fuel Production	Distribution	• Transportation to customers • Truck- 2200 t • Local consumption- 300 t	• Biohub to customers average distance: km	• 100	Transportation to bio-CNG filling station	• Biohub to bio-CNG filling stations average distance: km	• 200	Transportation to bio-CNG filling station	• Biohub to Oil Refinery average distance: km	• 120
Fuel Combustion	End Use	• **Combustion in boilers**	• 1 GJ heat from boiler	• agro-pellets: 1GJ heat	Combustion in Forestry fleets	• Distance driven in 1GJ fuel	• Bio-CNG : 1Gj	Combustion in heavy duty fleets	• Distance driven in 1GJ fuel • Soil credits from biochar	• Pyrolysis Oil: 1 GJ • BioChar

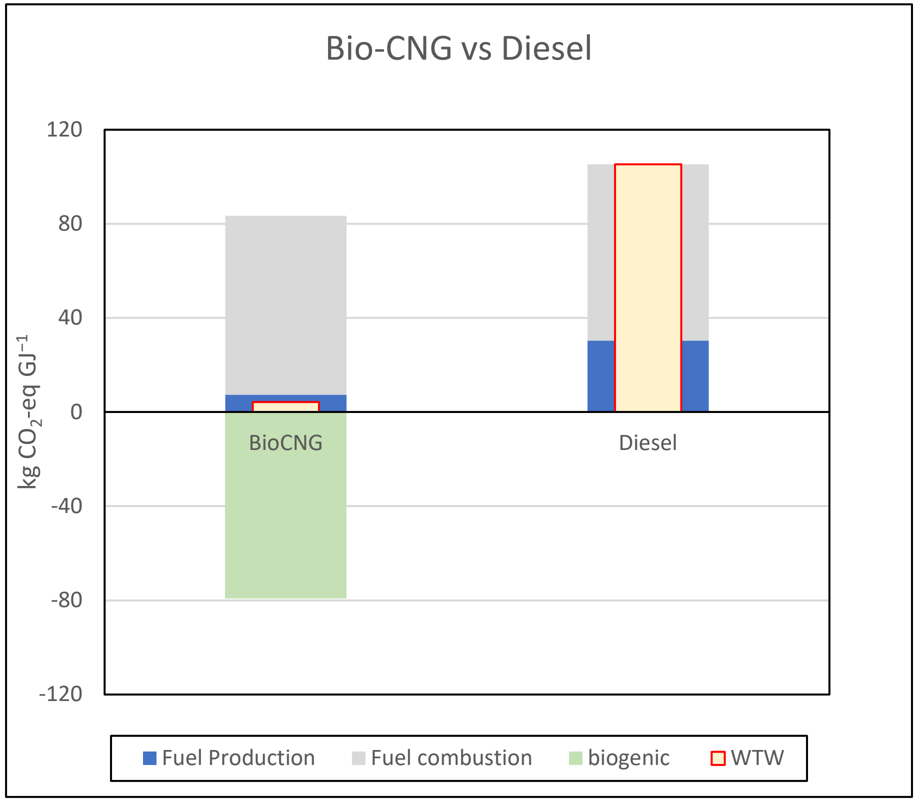
Results and Discussion: Biohub-1



Agro-Pellets vs Coal production:

- The WTW CO_2 emissions for agro-pellets were mainly from Transportation, Conversion, Distribution and End use phases only
- The WTW CO_2 emissions of coal were estimated at 160 kg CO_2-eq GJ^{-1}, of which 9% and 91% were emitted by fuel production and end use phase respectively
- **WTW GHG emissions** of the **agro-pellets** were only **14.9 kg CO_2-eq GJ^{-1} heat**, indicating a **GHG reduction benefit** of **145.1 kg CO_2-eq for each 1-GJ heat** provision when compared with coal WTW
- Feedstock production and end use has no emissions as agro- pellets are derived from renewable resources
- Transportation and distribution phase combined accounted for 15% of GHG emissions in fuel production phase
- Conversion phase contributed up to 80% GHG emissions in fuel production phase due to substantial grid electricity used for pelleting and cooling
- Coal WTW analysis is a combination of all processes in fuel production and end use for 1GJ of energy used

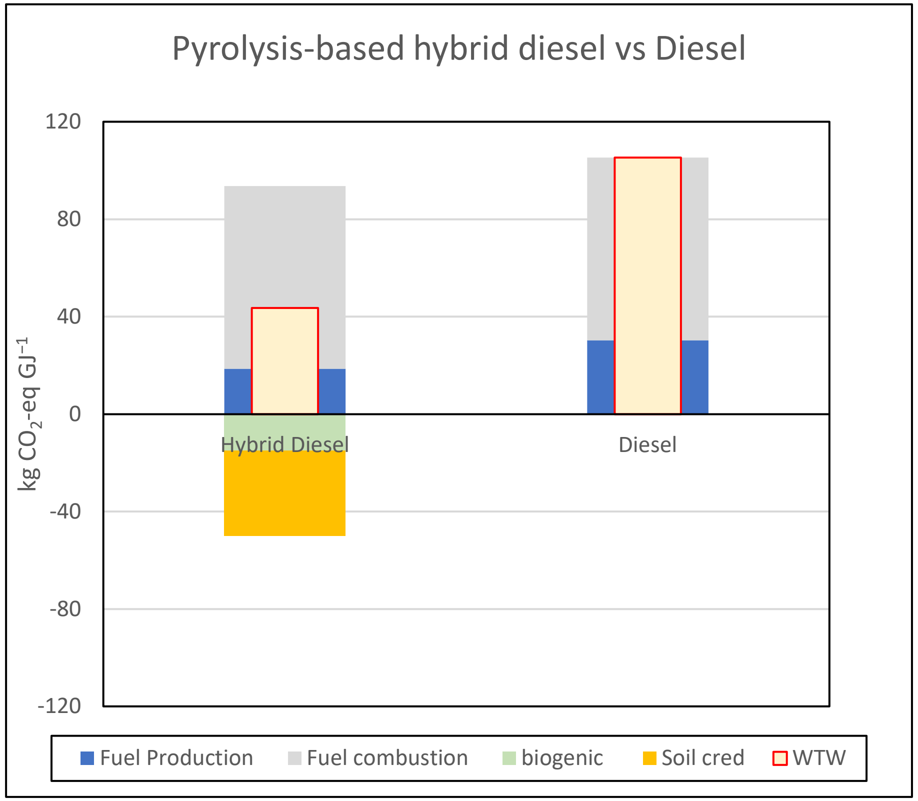
Results and discussion: Biohub-2



Bio-CNG vs Diesel production:

- The **WTW CO_2 emissions for bio-CNG** production was **4.32 kg CO_2-eq GJ^{-1}** indicating a **GHG reduction potential** of **101 kg CO_2-eq GJ^{-1}**
- Bio-CNG is assumed to replace diesel in forestry fleets, therefore, CO_2 emissions for Feedstock production, Transportation, Distribution and end use phases are considered to be biogenic CO_2
- Main contributor to emissions in fuel production is the conversion phase accounting for 7.4 kg CO_2-eq GJ^{-1}. This is due to the production of chemicals and electricity required during the conversion phase. Their respective contribution to emissions in fuel production are as follows:
    - Electricity for compression: 38%
    - Potassium carbonate: 3%
    - Rape-seed methyl ester: 37%
    - Activated Carbon: 21%
- The WTW CO_2 emissions of diesel was calculated to be 105 kg CO_2-eq GJ^{-1} . Where fuel production and end use accounted for 28% and 72% of total GHG emissions.

Results and Discussion: Biohub-3



Pyrolysis-based hybrid diesel vs diesel production:

- For Pyrolysis-based hybrid diesel WTW CO_2 emissions were mainly from feedstock collection Transportation, Conversion, Distribution and End use stages
- The WTW CO_2 emissions of diesel was calculated to be 105 kg CO_2-eq GJ^{-1} . Where fuel production and end use accounted for 28% and 72% of total GHG emissions.
- Total **WTW GHG emissions** for Pyrolysis-based hybrid diesel was **43.6 kg CO_2-eq GJ^{-1}** , indicating a **GHG reduction benefit** of **61.4 kg CO_2-eq for each 1-GJ fuel** provision when compared with diesel WTW
- Transportation and distribution phase combined accounted for 15% whereas Conversion phase contributed up to 80% GHG emissions in fuel production phase, mainly due to substantial grid electricity use and natural gas for H_2 production
- **Biochar** being rich in carbon content contributed to a **significant reduction in WTW GHG emissions** of hybrid diesel when used as soil fertilizer

Conclusions

- Main source of GHG emissions for biohub-1,2 was from conversion phase, whereas for biohub-3 it was from conversion and end use phase
- The GHG emissions reduction potential of biohub-1,2,3 are 145.1, 101, 61.4 kg CO_2-eq GJ^{-1} when compared to their fossil counterparts respectively.
- **Biohub-1** has the **highest GHG emissions reduction potential** per GJ heat produced. However, this is only due to the high emission intensity of coal.
- The WTW GHG emissions of **Biohub-1** was14.9 kg CO_2-eq GJ^{-1} which is the highest among the biohubs studied. This is mainly due to significant requirement of electricity for drying, pelleting and cooling process in conversion phase.
- The WTW GHG emissions of **Biohub-2** produced 4.32 kg CO_2-eq GJ^{-1} **lowest** among the biohubs studied.
- As the transportation and distribution phase of fuel production are assumed to be emitting biogenic CO_2,the main contributor for emissions was conversion phase due to chemicals and electricity used for compression.
- Owing to the majority of electricity required for the process being produced with heat recovery systems the fuel production phase of biohub-2 shows less emission burden that other biohub scenarios.
- The WTW GHG emissions of **Biohub-3** produced 61.4 kg CO_2-eq GJ^{-1} which is **highest** among the biohubs studied. GHG emissions mainly resulting from conversion and end use phase. However, direct carbon sequestration in the form of **biochar** resulted in significant amount of soil credit.
- **Biohub-3** has **highest emissions burden** for **fuel production phase** when compared to other biohubs mainly due to high electricity requirement and Natural gas for reforming into H_2

Key findings

Biohub-1

- Main Source of emissions Conversion Phase
- highest GHG emissions reduction potential per GJ heat
- Due to high carbon intensity of coal

Biohub-2

- Main Source of emissions Conversion Phase
- Lowest WTW GHG emissions
- Lowest dependency on fossil based resources for fuel production
  - biogenic CO_2 from feedstock transportation and distribution phase
  - electricity production from heat recovery systems

Biohub-3

- Main Source of emissions Conversion Phase and End Use
- Highest WTW GHG emissions
- Highest dependency on fossil based resources for fuel production
  - high electricity requirement
  - Natural gas for reforming into H_2
- Biochar plays a significant role in reducing the WTW emissions

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