Grand Technion
Energy Program

HERAKLION2019
www.heraklion2019.uest.gr

TECHNION
Israel Institute
of Technology

Life Cycle Assessment of Renewable Diesel using Catalytic Pyrolysis and Upgrading

Sabrina Spatari
V. Larnaudie, I. Mannoh, M.C. Wheeler, C.A. Mullen, A.A., Boateng

USDA

SWARTHMORE

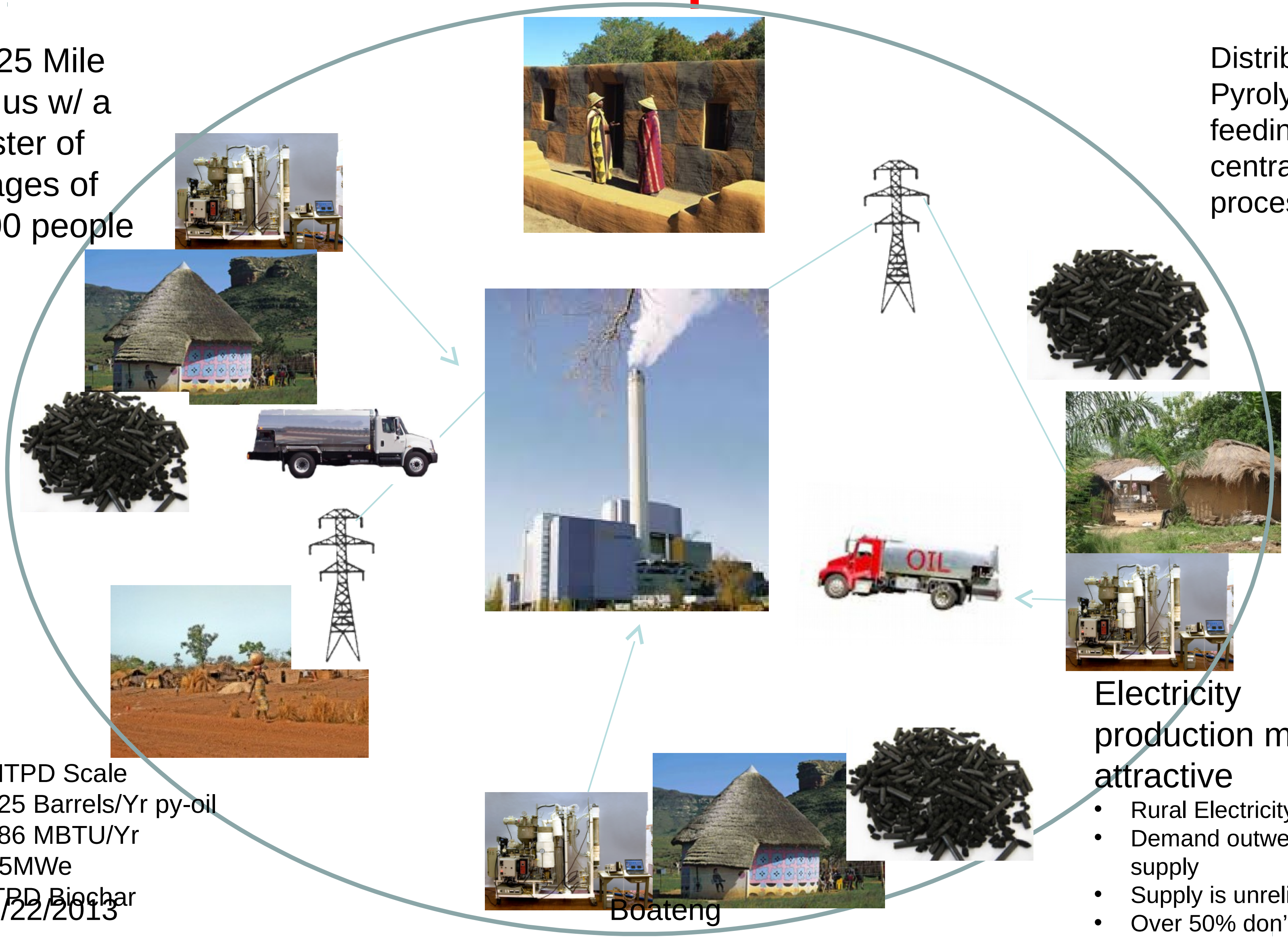
THE UNIVERSITY OF MAINE
1865

Drexel
UNIVERSITY

Policy Context:

- Low carbon and renewable fuel policies have developed around the world
  - LCFS (California, North-east states, Canada), RFS (US), Europe (EC)
  - Reduce GHGs relative to baseline gasoline ~93 gCO$_2$e/MJ
  - **Life cycle assessment (LCA)-based policy**
  - Some call for a policy on low C materials (e.g., polymers)
- Biofuels and policy context for decarbonizing transportation energy supply
  - Energy Independence and Security Act (EISA)
  - Incentives to develop “drop-in fuels”
- Incentives to develop lignocellulosic energy products that avoid major sustainability risks: Better biofuels

Rural Distributed On-Farm Concepts



10-25 Mile radius w/ a cluster of villages of 1000 people

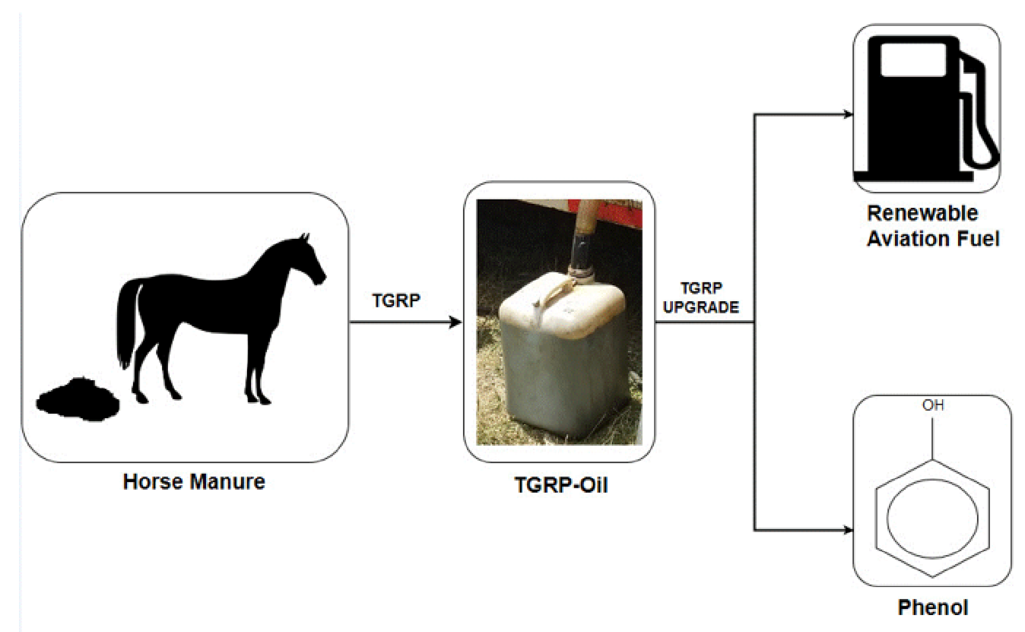
Distributed Pyrolysis feeding into centralized processes

Electricity production most attractive

- Rural Electricity Shortage
- Demand outweighs supply
- Supply is unreliable
- Over 50% don’t have access to the grid

200 MTPD Scale
402,025 Barrels/Yr py-oil
714,486 MBTU/Yr
1.5-2.5MWe
40 MTPD Biochar

Fuels and Chemicals from Animal Waste



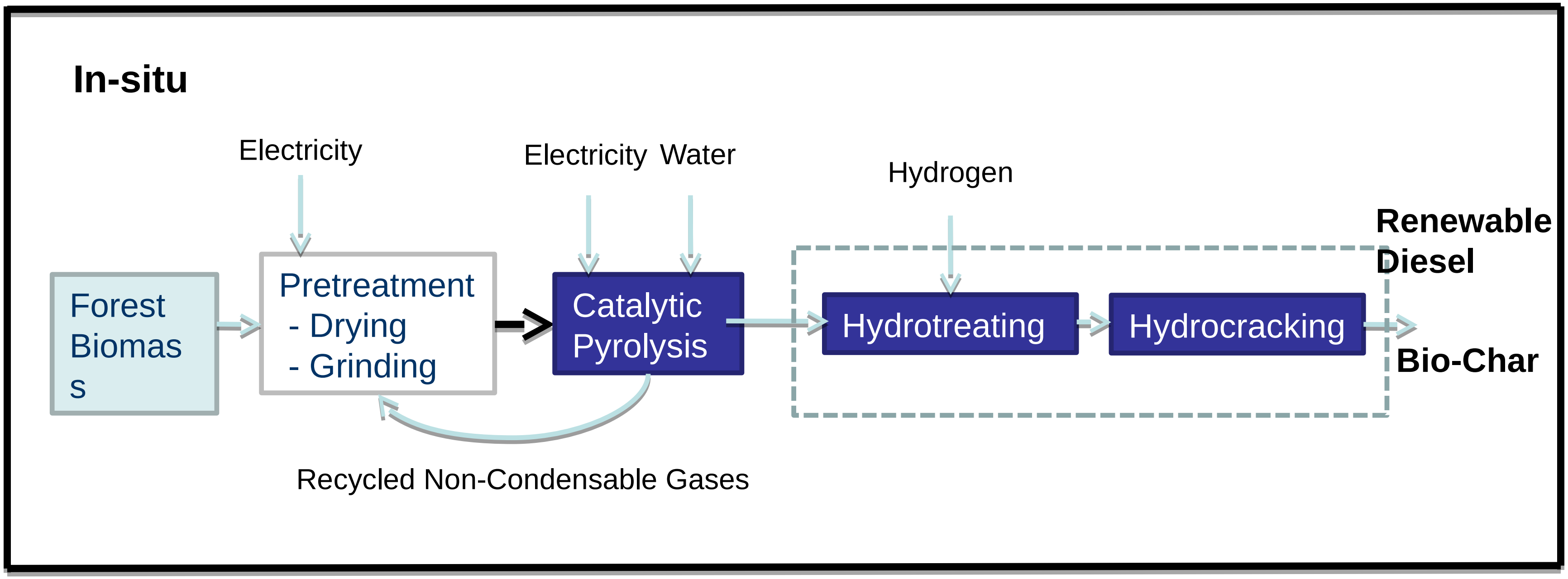
Sorunmu et al. 2017, *ACS Sus Chem & Eng* DOI: 10.1021/acssuschemeng.7b01609

Fast Pyrolysis of Forest Residues-to-Renewable Diesel

Life cycle model development:

- Aspen Plus, Simapro and GIS modeling:
  - Feedstock production, collection, transport
  - Material/energy balance basis (feedstock conversion);
- Integration with experimental research:
  - Pyrolysis bio-oil blendstock development
    - In-situ catalytic pyrolysis products
    - Ex-situ catalytic pyrolysis products
  - Combustion experiments for
    - Non-catalytic pyrolysis products
    - Catalytic pyrolysis products

LCA Framework:



In-situ

Electricity

Electricity Water

Hydrogen

Forest Biomass

Pretreatment
- Drying
- Grinding

Catalytic Pyrolysis

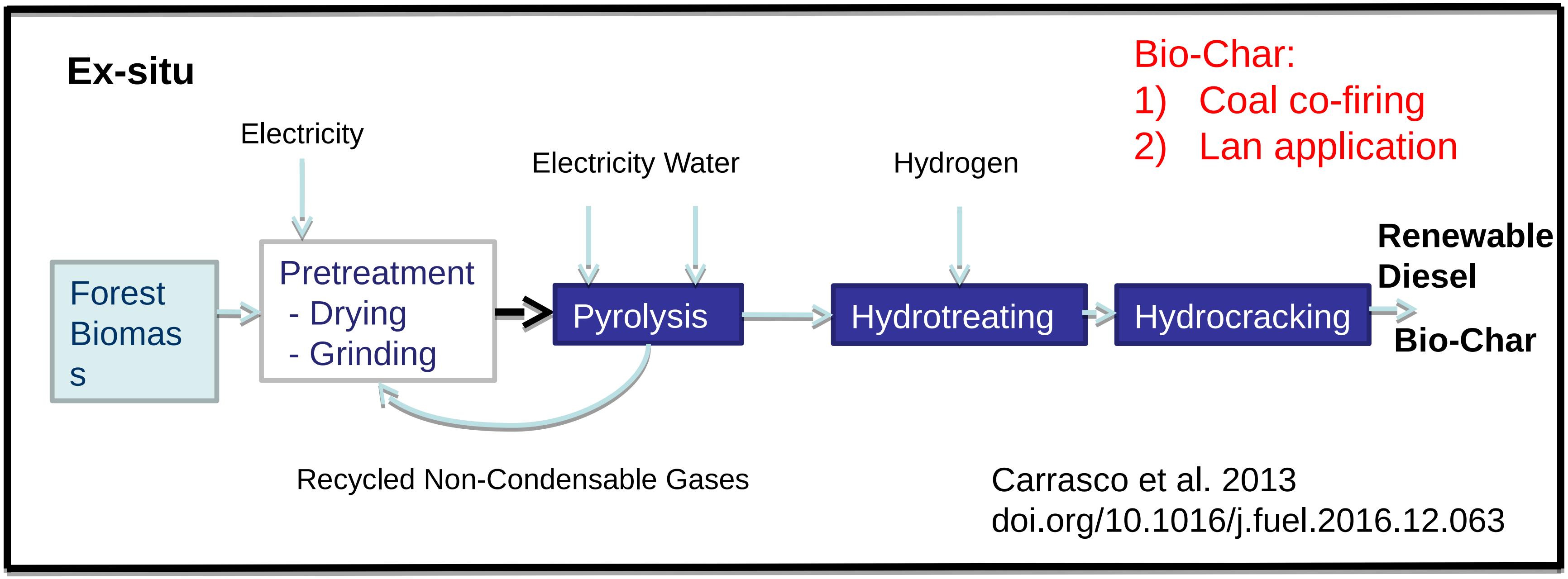
Hydrotreating

Hydrocracking

Renewable Diesel

Bio-Char

Recycled Non-Condensable Gases



Ex-situ

Bio-Char:
1) Coal co-firing
2) Lan application

Electricity

Electricity Water

Hydrogen

Forest Biomass

Pretreatment
- Drying
- Grinding

Pyrolysis

Hydrotreating

Hydrocracking

Renewable Diesel

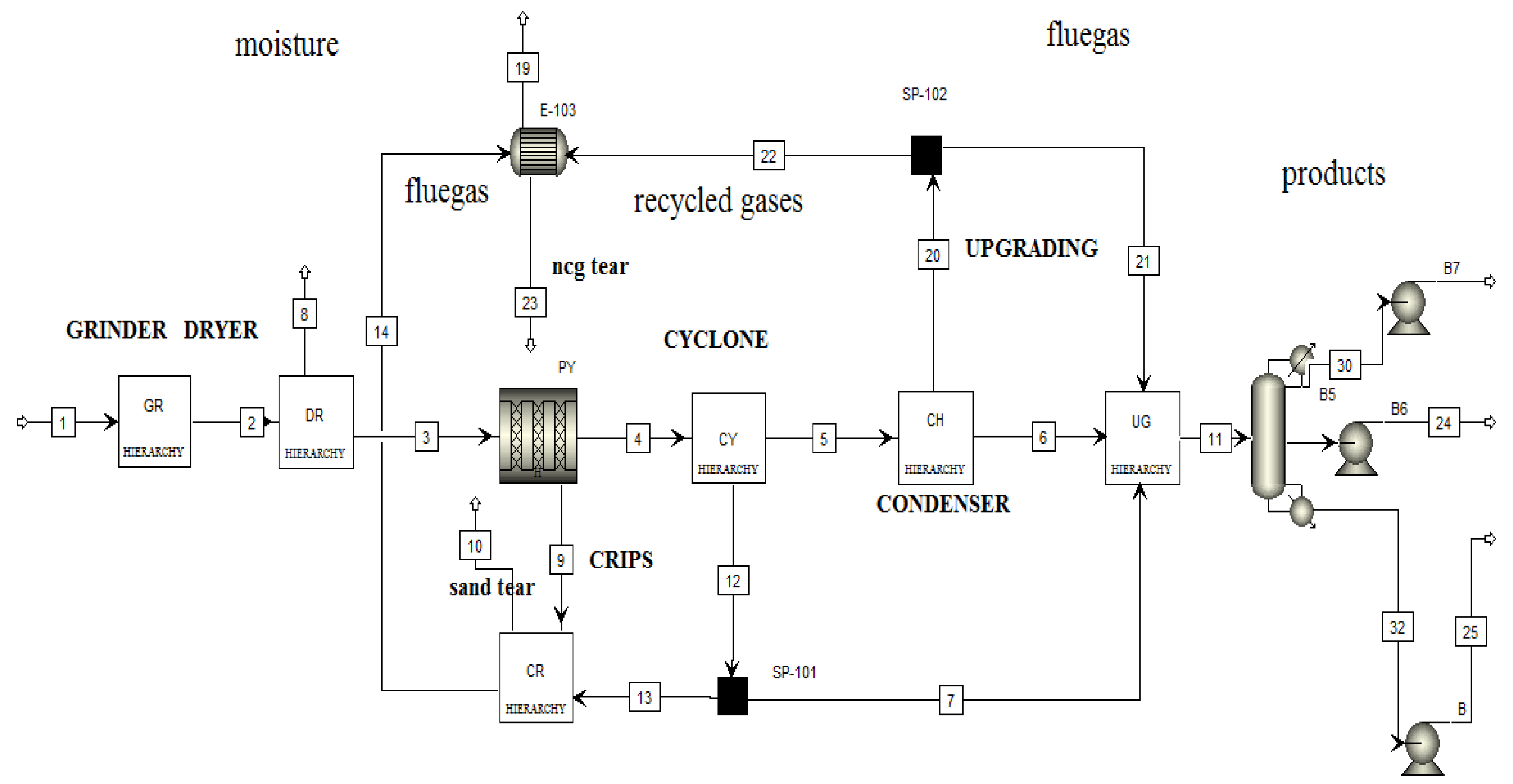
Bio-Char

Recycled Non-Condensable Gases

Carrasco et al. 2013
doi.org/10.1016/j.fuel.2016.12.063

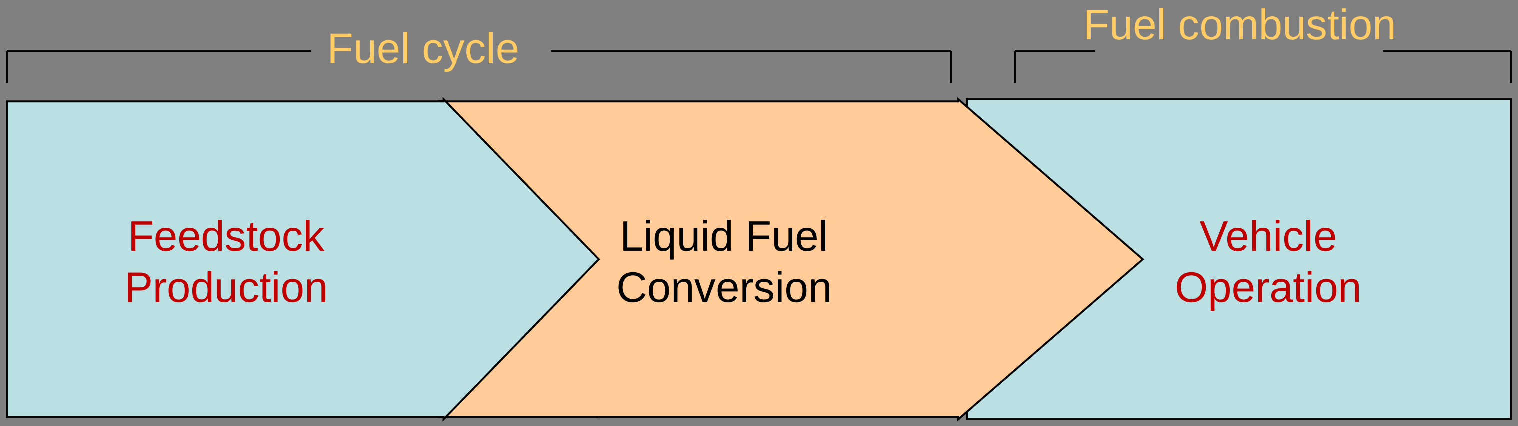
→ Transport

Catalytic Pyrolysis and Upgrading:



Carrasco et al. 2013, http://dx.doi.org/10.1016/j.fuel.2016.12.063

Advanced Bio-oil Markets



- Harvesting equipment and energy
- Transportation steps

Feedstocks:
- Woody biomass (Forest residues)

- Electricity
- Feedstock provides thermal energy

Technologies:
- Fast Pyrolysis or Catalytic pyrolysis
- Hydrotreating
- Hydrocracking

- Renewable diesel
- Value-added chemicals
- Bio-char (co-product)

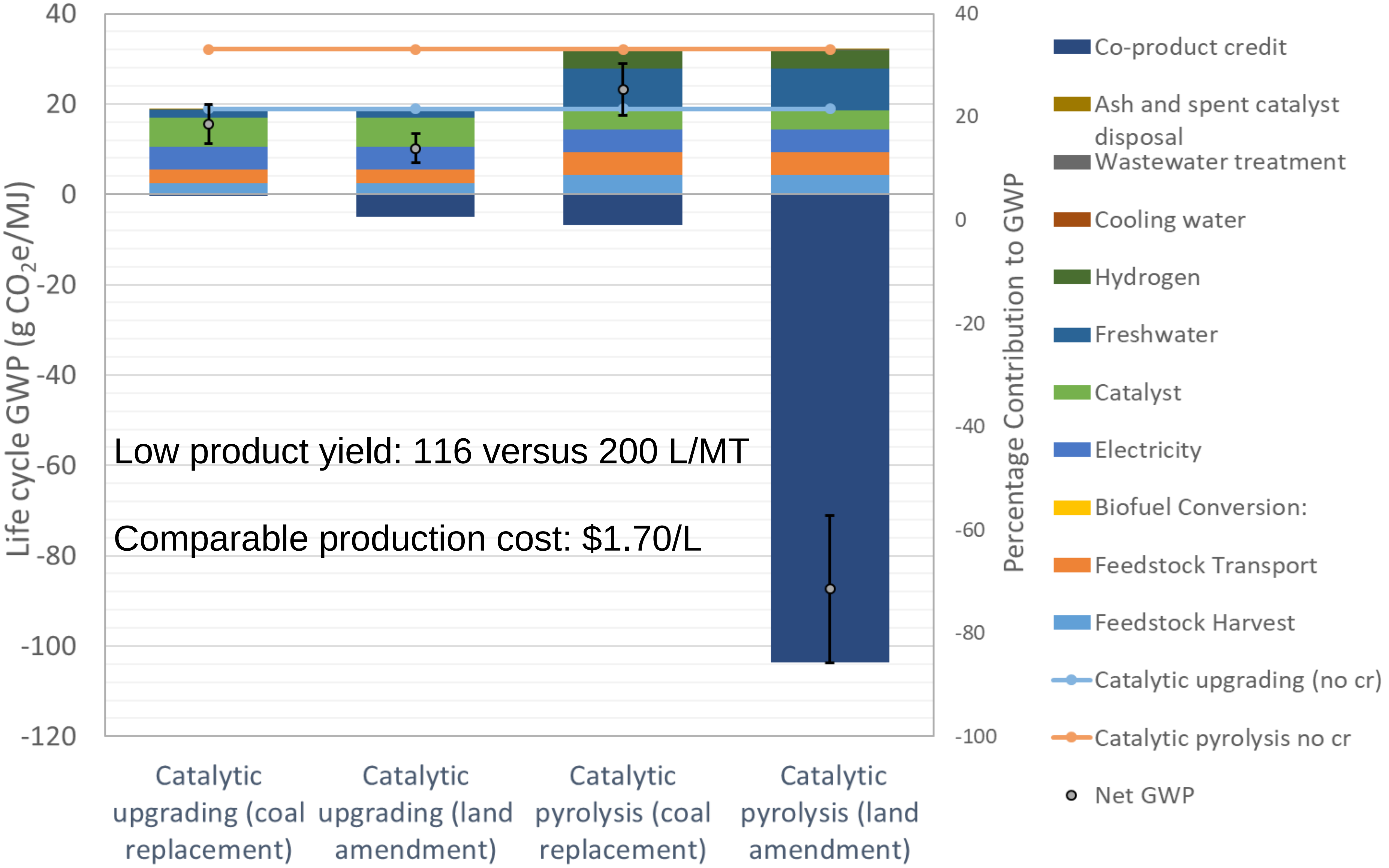
Transportation fuel/lubricant market:
- Substitute for gasoline, diesel, petrochemical (e.g., bio-lubricants)
- Co-products may substitute for coal or be land applied (sequestration)

Forest Residue Field Operations – Maine Woods

- Feller-Buncher
  - Fells trees and piles
- Grapple Skidder
  - Transports piles to Roadside and Chipper
- Chipper
  - Chips biomass
- Transport

*Not accounting for forest C stocks

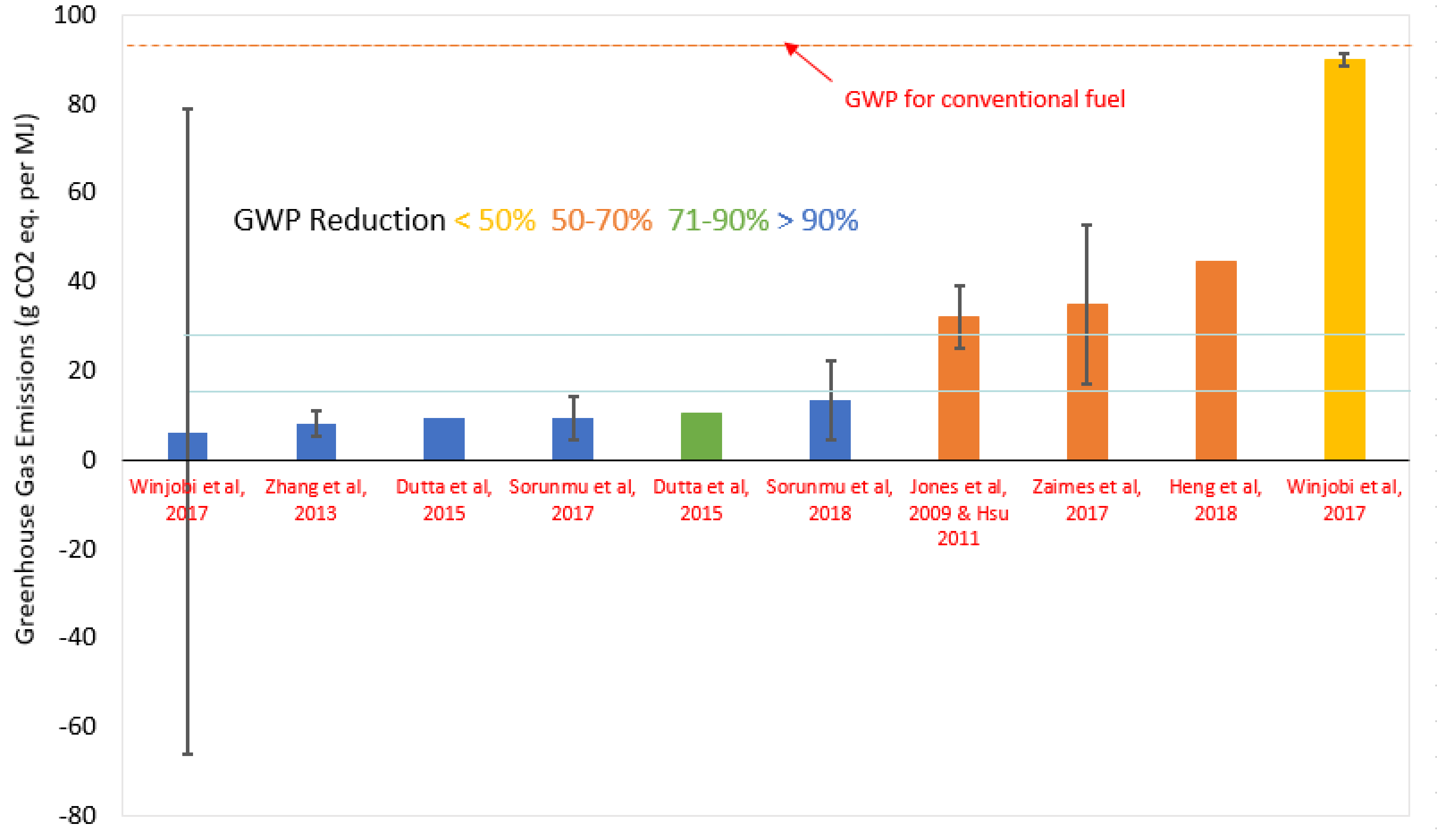
Life Cycle GHG Emissions



Low product yield: 116 versus 200 L/MT

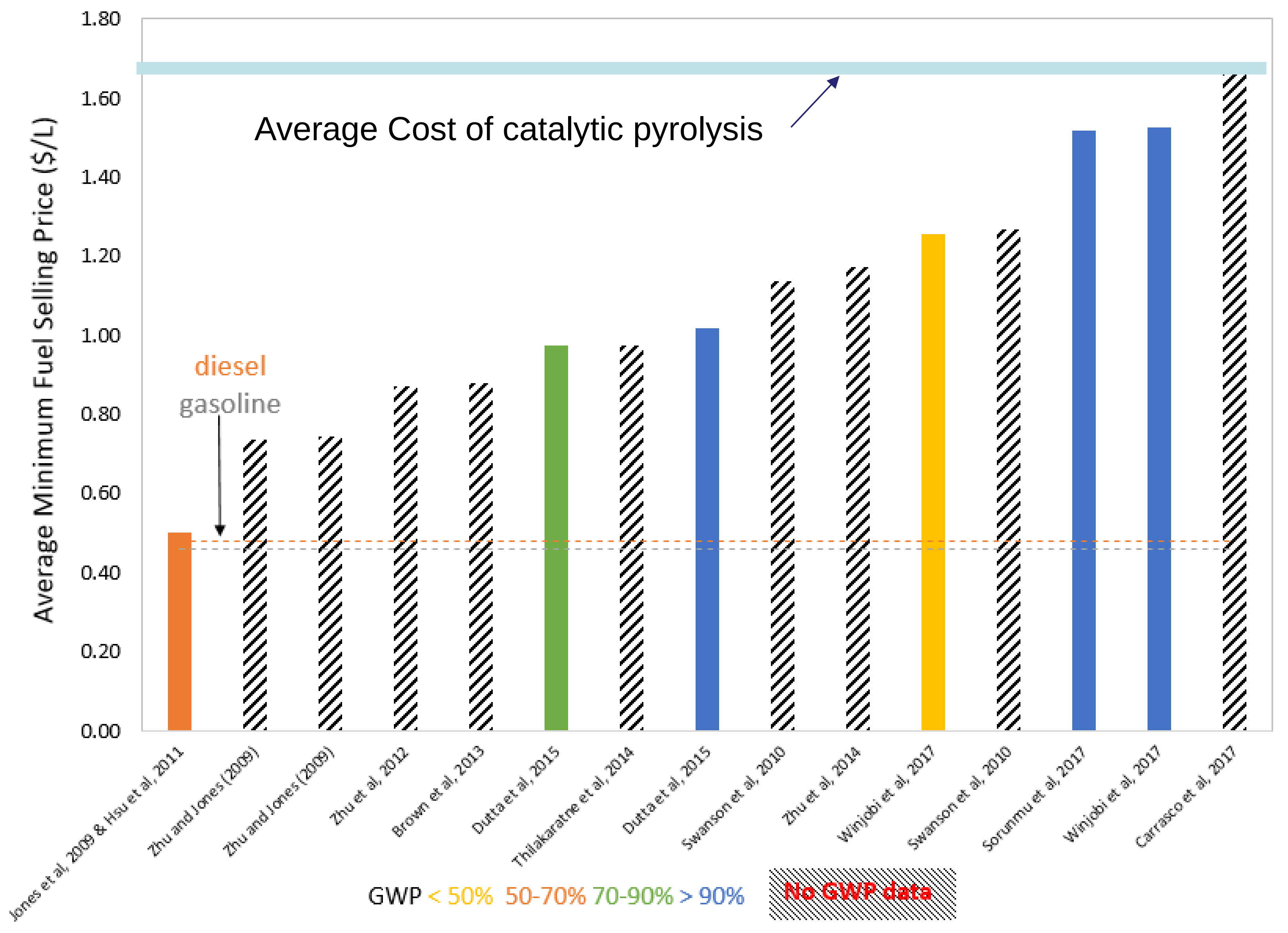
Comparable production cost: $1.70/L

Review of Environmental Performance



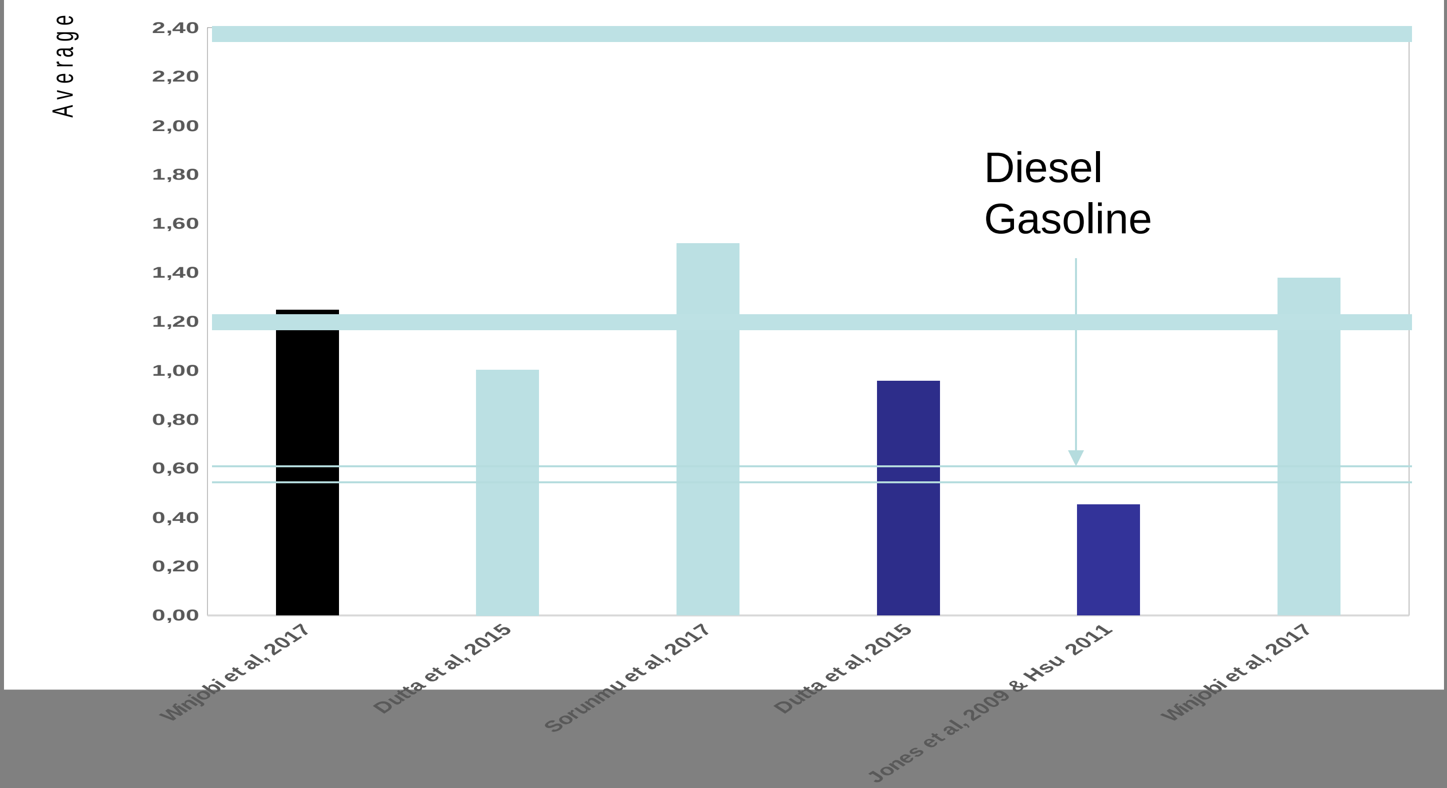
Sorunmu et al., In Prep

Economics (MSP) – Literature Review



Effect of SCC on Economic Performance

Average Cost of catalytic pyrolysis
SCC = \$35/MT CO_2



Diesel
Gasoline

Sorunmu et al., In Prep

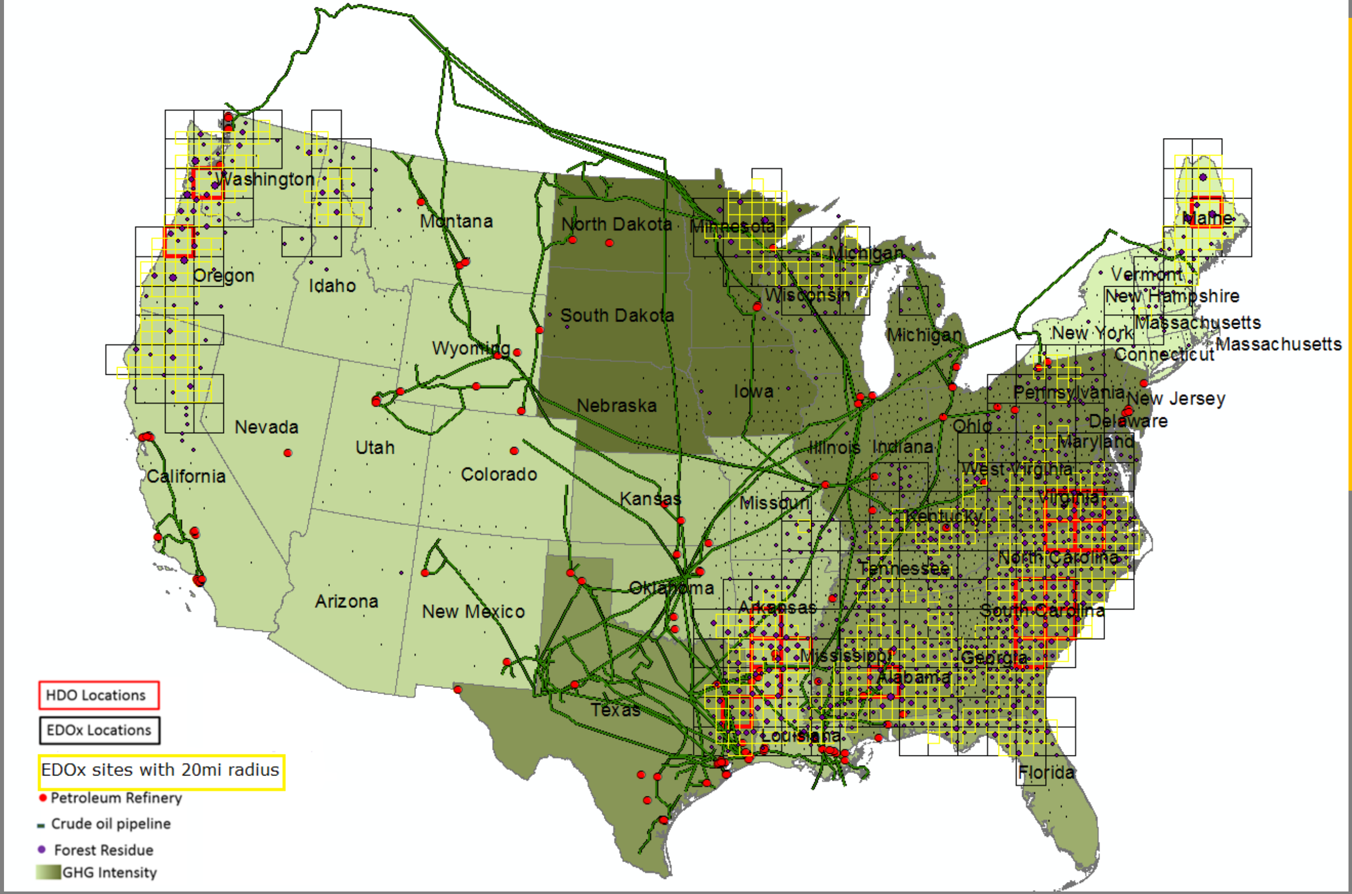
Findings

- Low fuels yields for catalytic pyrolysis versus fast pyrolysis (116 versus 196 L/dry MT)
- High fraction of biochar, very negative GHG emissions
- Daily catalyst regeneration a significant process input and source of GWP
- Economics of both processes only favorable with valuation of carbon

Thank you!

- Research supported by; USDA-NIFA-BRDI: 2012-10008-20271

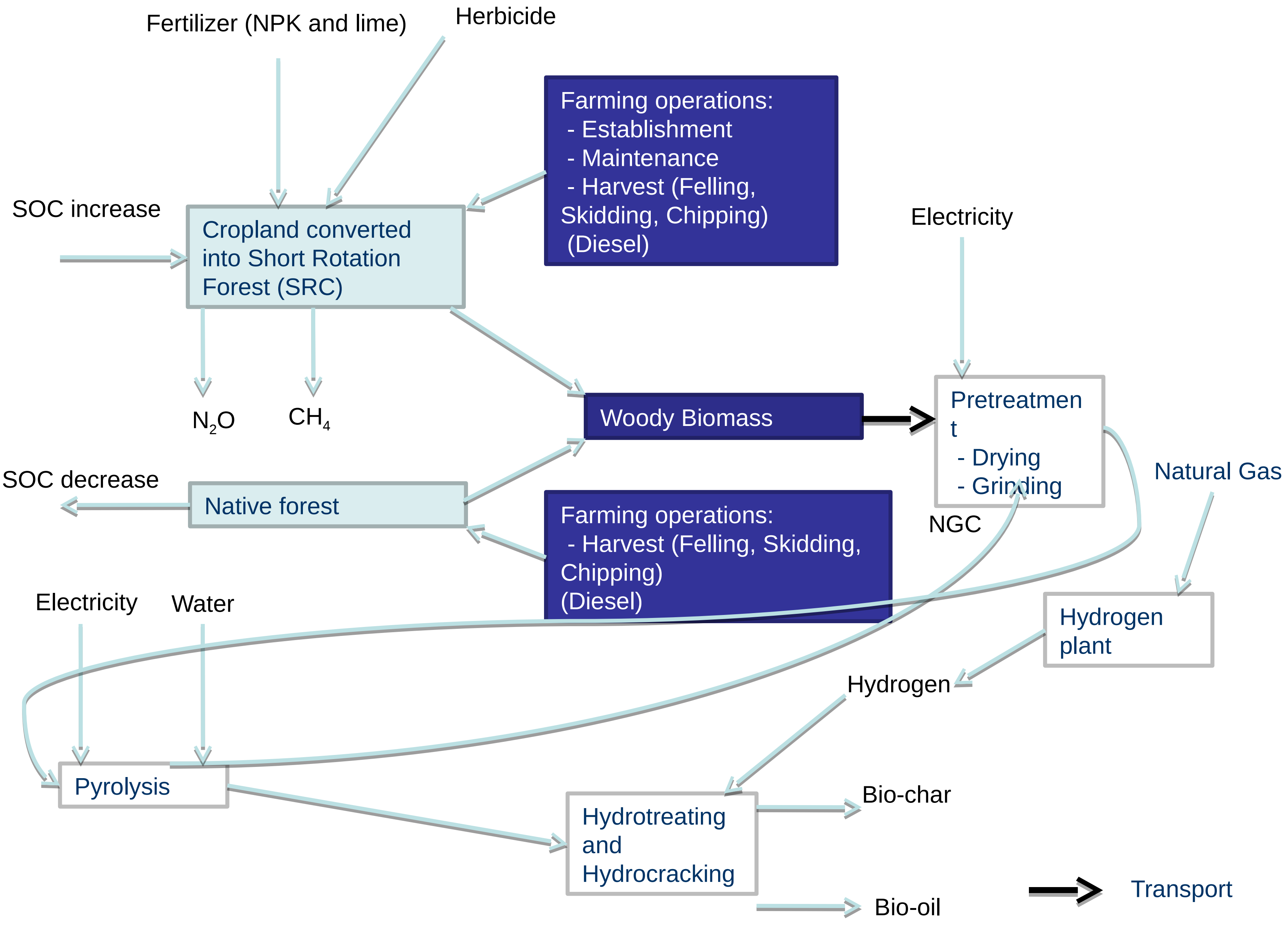
Stable pyrolysis oils can serve as densification hubs for biorefineries



- ➢ EDOX (300MTPD) and HDO (2000MTPD) locations
- ➢ Forest residue available within <20mi radius of EDOx facility proposed locations
- ➢ EDOx locations near petroleum refineries (red dot) show opportunity for improving intermediate product transport/logistics in relation to final upgrading

Sorunmu et al. 2017

Forestry Feedstock:



Fertilizer (NPK and lime)

Herbicide

Farming operations:
- Establishment
- Maintenance
- Harvest (Felling, Skidding, Chipping) (Diesel)

SOC increase

Cropland converted into Short Rotation Forest (SRC)

Electricity

N_2O

CH_4

Woody Biomass

Pretreatment
- Drying
- Grinding

Natural Gas

SOC decrease

Native forest

Farming operations:
- Harvest (Felling, Skidding, Chipping)
(Diesel)

NGC

Electricity

Water

Hydrogen plant

Hydrogen

Pyrolysis

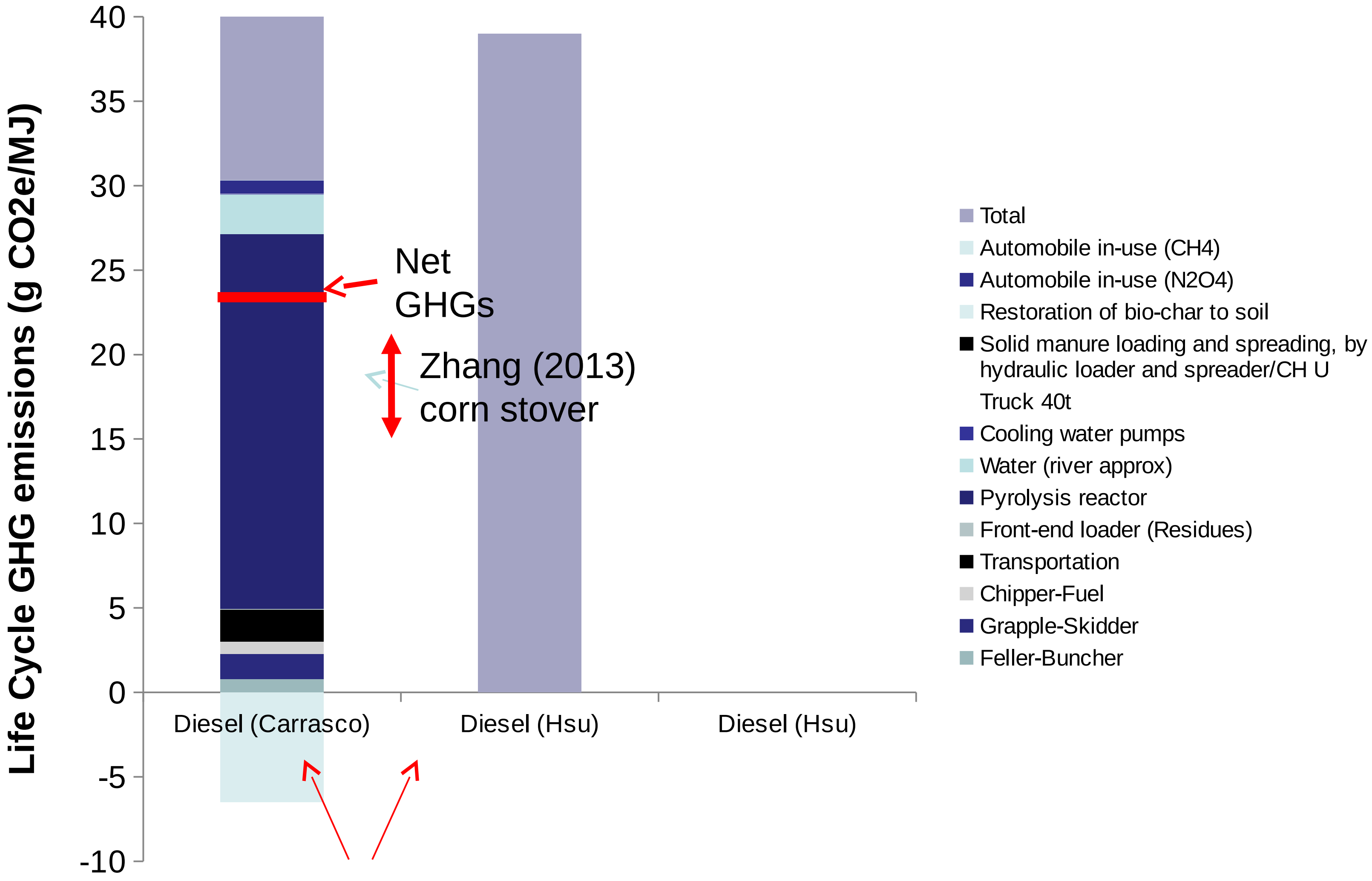
Hydrotreating and Hydrocracking

Bio-char

Bio-oil

→ Transport

Results: GHG



Net GHGs

Zhang (2013) corn stover

Electricity (on-site)

Purchased Electricity

Life Cycle GHG Emissions