Role of Biomass in Carbon Negative SAF

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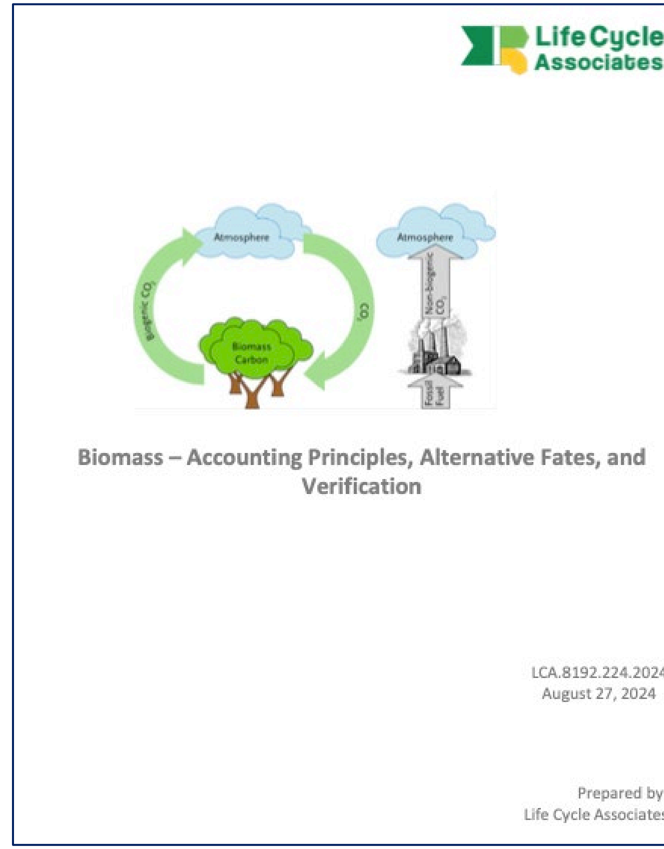
Outline

Synopsis of our recent publication: Biomass – Accounting Principles, Alternative Fates, and Verification

- Who we are
- Biomass categories
- Biomass & SAF
- Policy environment
    - LCFS, RFS, IRA, CORSIA
- LCA models
- GHG emissions results
- Further reading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Biomass – Accounting Principles, Alternative Fates, and Verification

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Prepared by:
Life Cycle Associates

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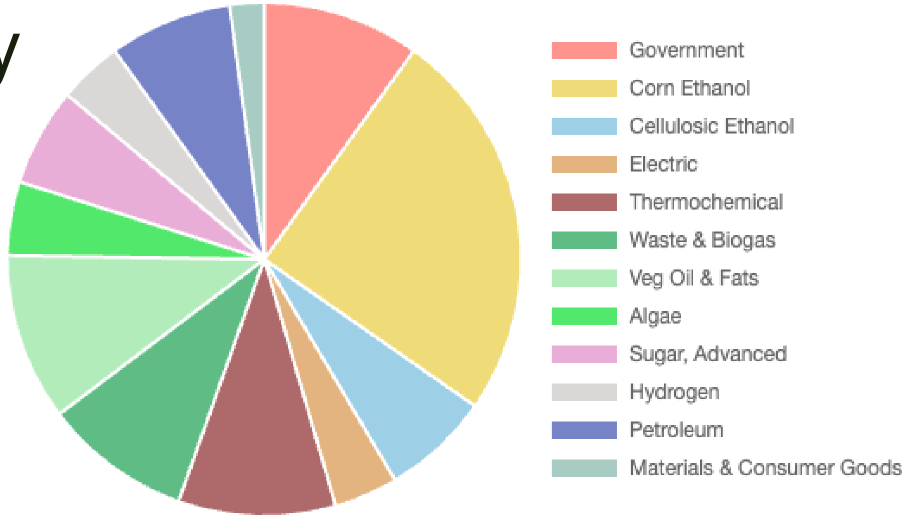
Engineering a Low Carbon Future

- Life cycle analysis – GREET model(s)
- Regulatory compliance
- Process analysis
- Technoeconomic analysis
- GHG reduction strategy
- Sustainability reporting



Biomass categories

The focus today is on forest residues

Energy Crops

Crops that are grown specifically for their energy content.

- Switchgrass
- Miscanthus
- Willow

Crop Wastes

Residues from agricultural crops.

- Corn stover
- Wheat straw
- Rice straw

Forest Residues

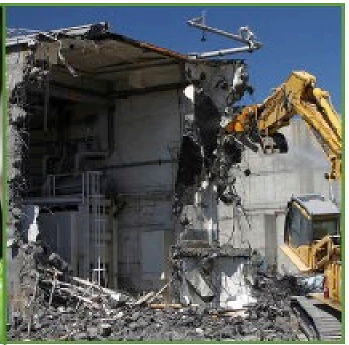
Waste materials from forestry operations.

- Tree trimmings
- Slash
- Stumps

Urban Landscaping Residues

Waste materials from urban landscapes.

- Grass clippings
- Yard waste



C&D Waste

Waste materials from construction and demolition activities.

Forest Waste & Residues

- Less than 20% of California's wood waste is repurposed for commercial use
- Two main sources = slash and thinnings
- Sustainable forest management practices
  - Pre-commercial thinning – slash piles
  - Unmanaged decomposition can result in methane emissions
- Wildfire mitigation
  - Thinning of overgrown forests, diseased or dead trees to mitigate the risk of wildfires
  - Feedstocks for bioenergy, soil amendments, animal bedding
- Management is key and various verification protocols support sustainable practices within the sector

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Why forest residues for SAF?

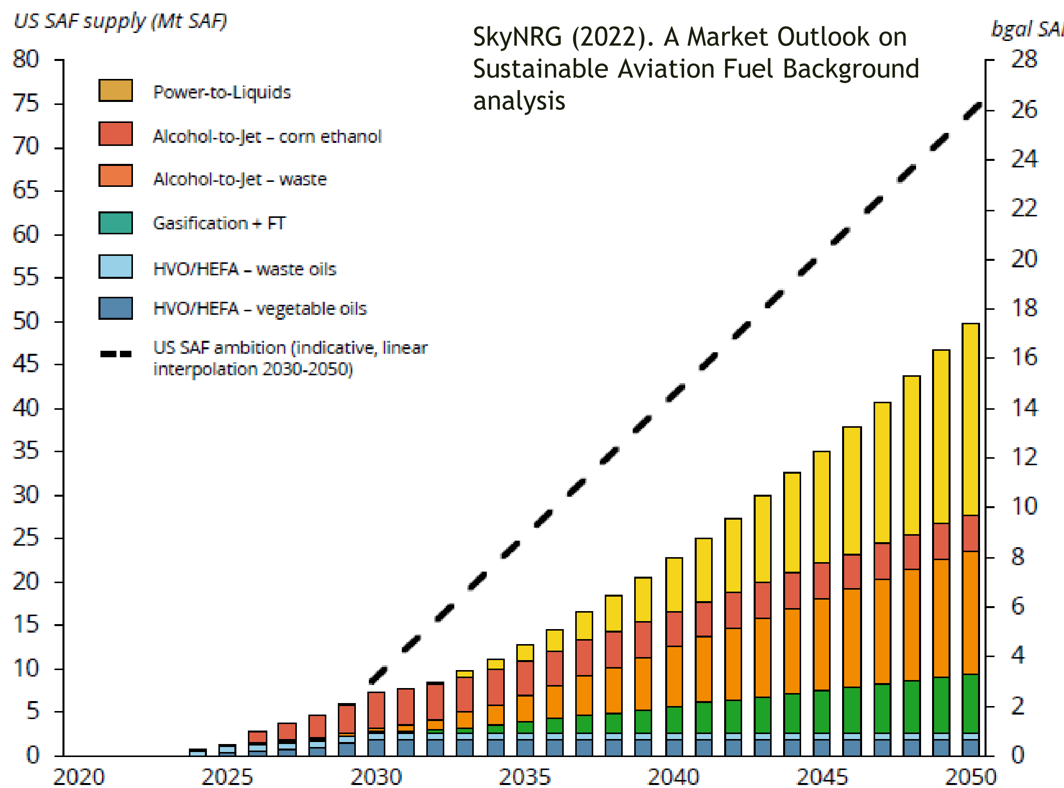
With less than 16 million gallons of production in 2022, all pathways are needed to achieve meaningful market penetration; more stringent reductions

Demand

- Sustainable Aviation Fuel Grand Challenge
- 35 billion gallons/y by 2050
- 3 BGPY by 2030

Supply

- High GHG reductions relative to other feedstocks



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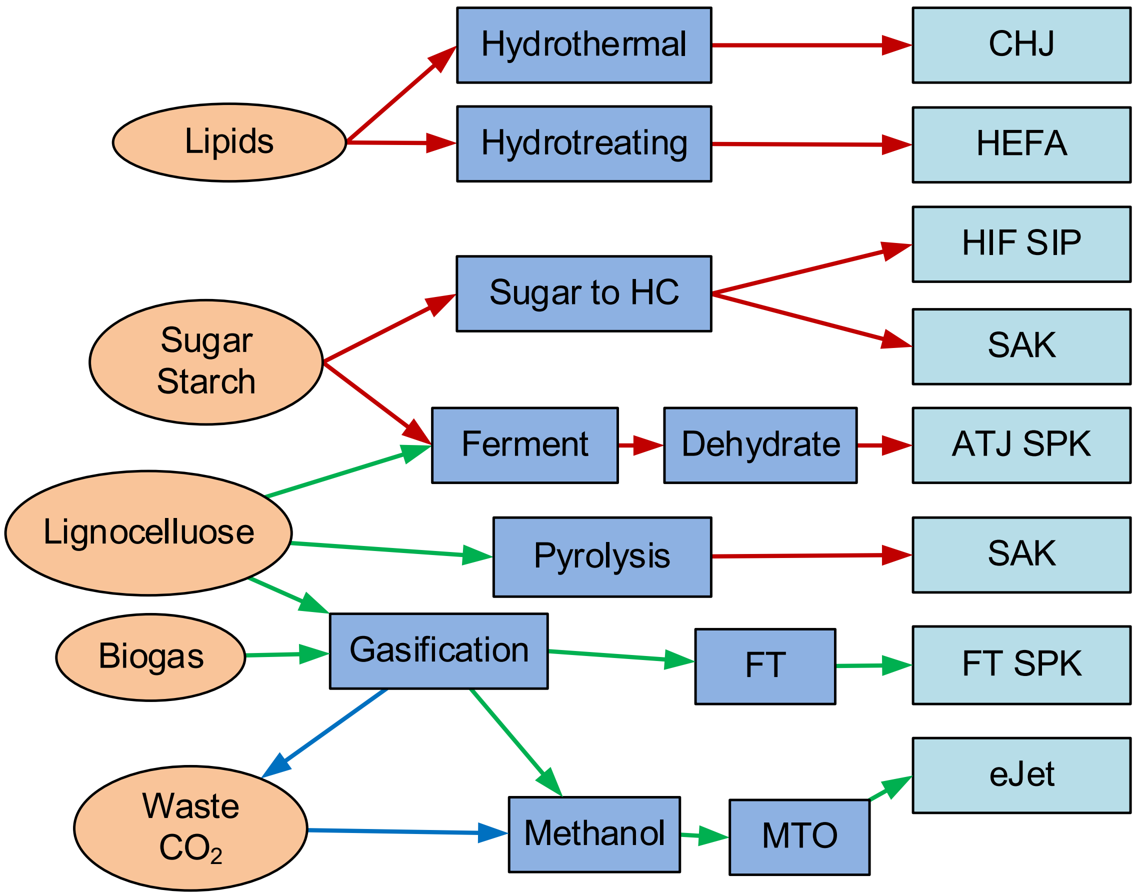
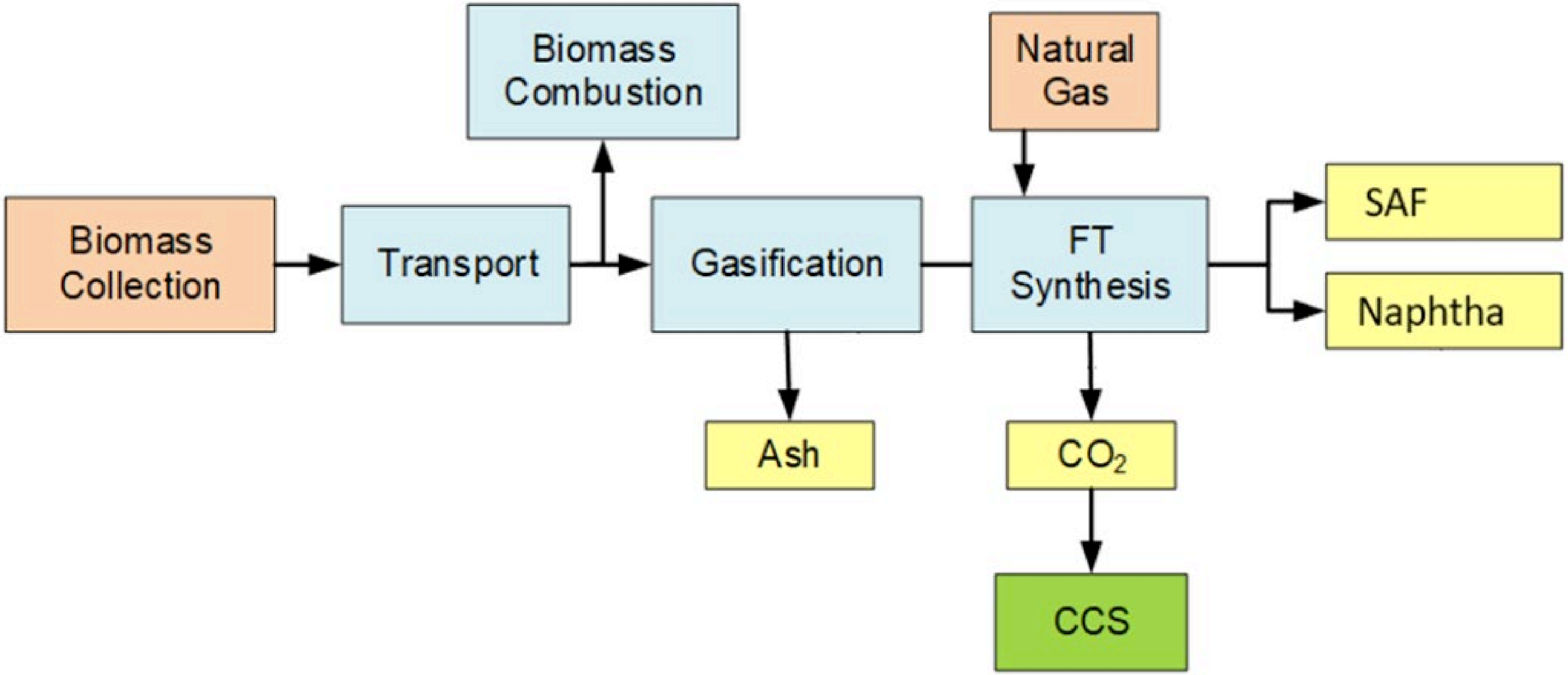
SAF Production Pathways

- Biomass has a role in several SAF Pathways
- Feedstock
- Process energy
- Carbon source for eFuels
- GHG
- Incentives



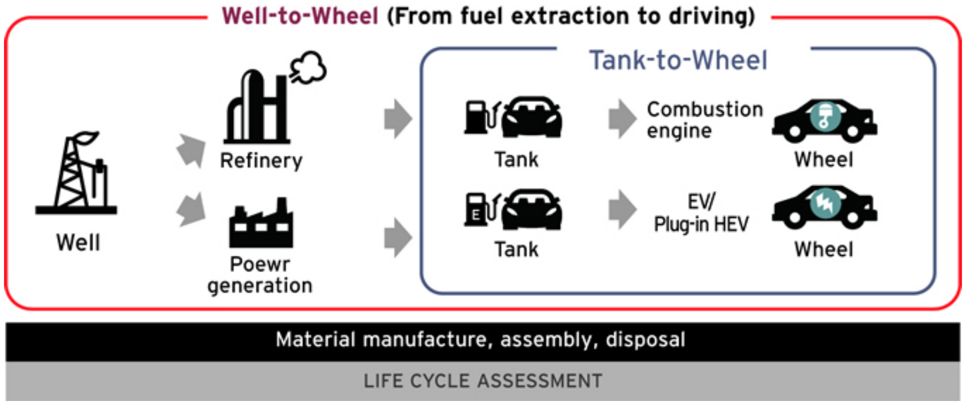
System boundary diagram for biomass to fuel

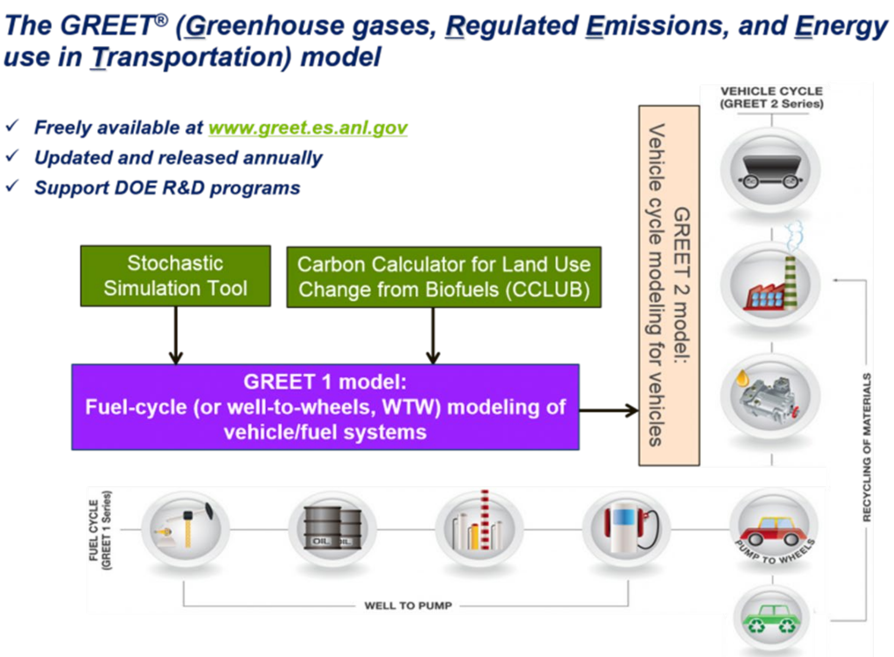


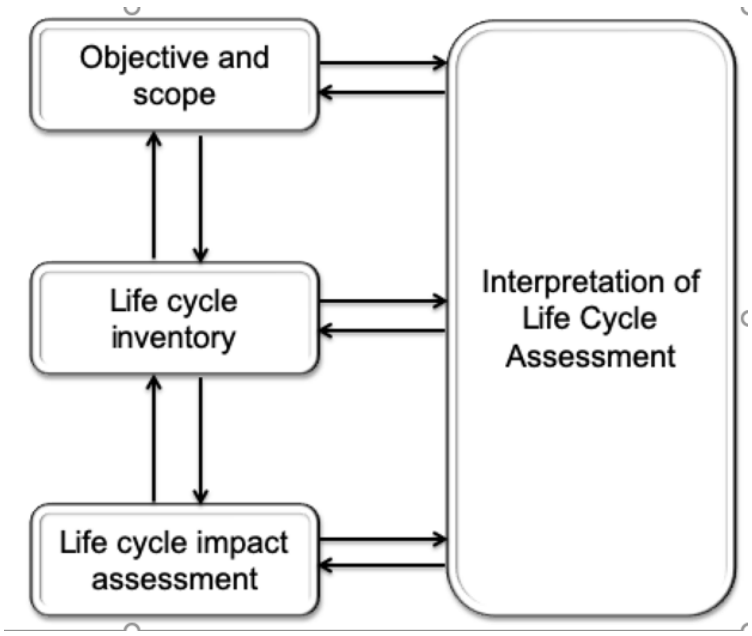
Jiqing , F., et al. Life cycle assessment of electricity generation using fast pyrolysis bio-oil. *Renewable Energy ,* *36*(2), 632-641

History of Fuel LCA

- ISO 14040
- GREET, 40B
- LCFS
- CORSIA







LCA Modeling Differences

- Upstream Life Cycle Data
  - Diesel, fertilizer, electric power
- Indirect Land Use Conversion
  - Soil carbon storage in roots, land conversion from energy crops
- Allocation Methods
  - CORSIA: energy allocation
  - GREET: various methods

SAF GHG Accounting Frameworks

GHG Framework	GREET/ IRA	RFS	CA LCFS	CORSIA	EU RED II
IPCC GWP	AR6	AR2/AR5	AR4	AR5	AR4
LCI Data Source for NG, Power	GREET1_2023	GREET1.8c	GREET1_2016	Any Approved	ISCC 205, RSB Tool
Farm Specific Data	FD-CIC	No	No	Yes	Yes
Co-product Allocation	Various	Consequential	Various	Energy	Energy
Land Use Conversion	CCLUB, GTAP, RFS[a]	FASOM/ FAPRI	GTAP 2011	GTAP, GLOBIOM	Low Risk iLUC
Land Management Changes	In iLUC	In iLUC	In iLUC	In iLUC and Offsets	Yes
Methane Avoidance for Manure	No	No	Yes	No	Yes
Certification Option	TBD	EPA Standard Pathways or Petition	3rd Party Verifier	Custom Calculator, RSB Tool	Custom Calculator, RSB Tool

GREET 40B Calculator Tool

- Model is adaptable to other fuel pathways
  - Requires GREET understanding
- Inputs do not require conversion to “GREET units”
- CI calculations are consistent with 40B calculator

Select a 40B Pathway:		
Forest Residue ATJ		

Ethanol Production (per period of operation)

	Biomass	Unit
Ethanol production	100.0	million gallons
Biomass Consumption	3.0	million tonne (wet)
Total fossil NG consumption	0.0	thousand mmBtu
Grid electricity consumption	4.9	million kWh
Total residual oil consumption	9.4	thousand mmBtu
Total coal consumption	0.0	thousand mmBtu

SAF Production (per period of operation) ATJ

Parameter	Forest Residue	Unit
Feedstock		
SAF production	59.9	million gallons
Renewable diesel production	3.1	million gallons
Renewable gasoline production	0.0	million gallons
Renewable naphtha production	0.0	million gallons
Ethanol	100.0	million gallons
Grid electricity (selected eGRID region)	110.7	million kWh
Renewable Electricity Credit (REC)	0.0	million kWh
Onsite behind-the-meter electricity	0.0	million kWh
Total fossil NG consumption	755.7	thousand mmBtu
Total LFG-derived RNG consumption	0.0	thousand mmBtu
Offsite, Fossil NG-derived H2 consumption	2,658	metric tons
Offsite, 45V Modeled H2 consumption	0.0	metric tons
Offsite, 45V Modeled H2 CI	3.0	kg CO_2e/kg H2

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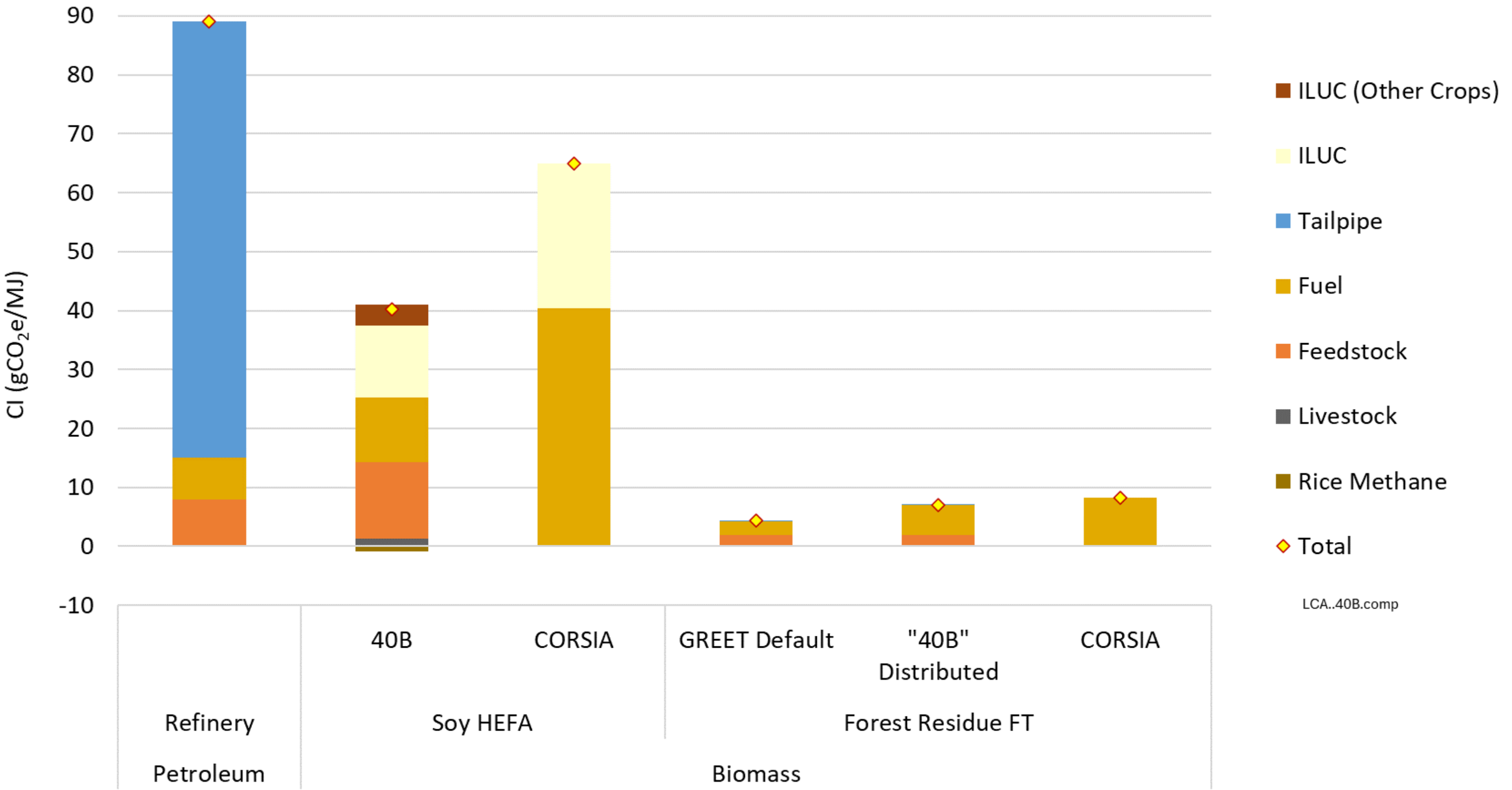
GHG Analysis for SAF

- Several LCA models used to analyze biomass to SAF



Incentive Assumptions

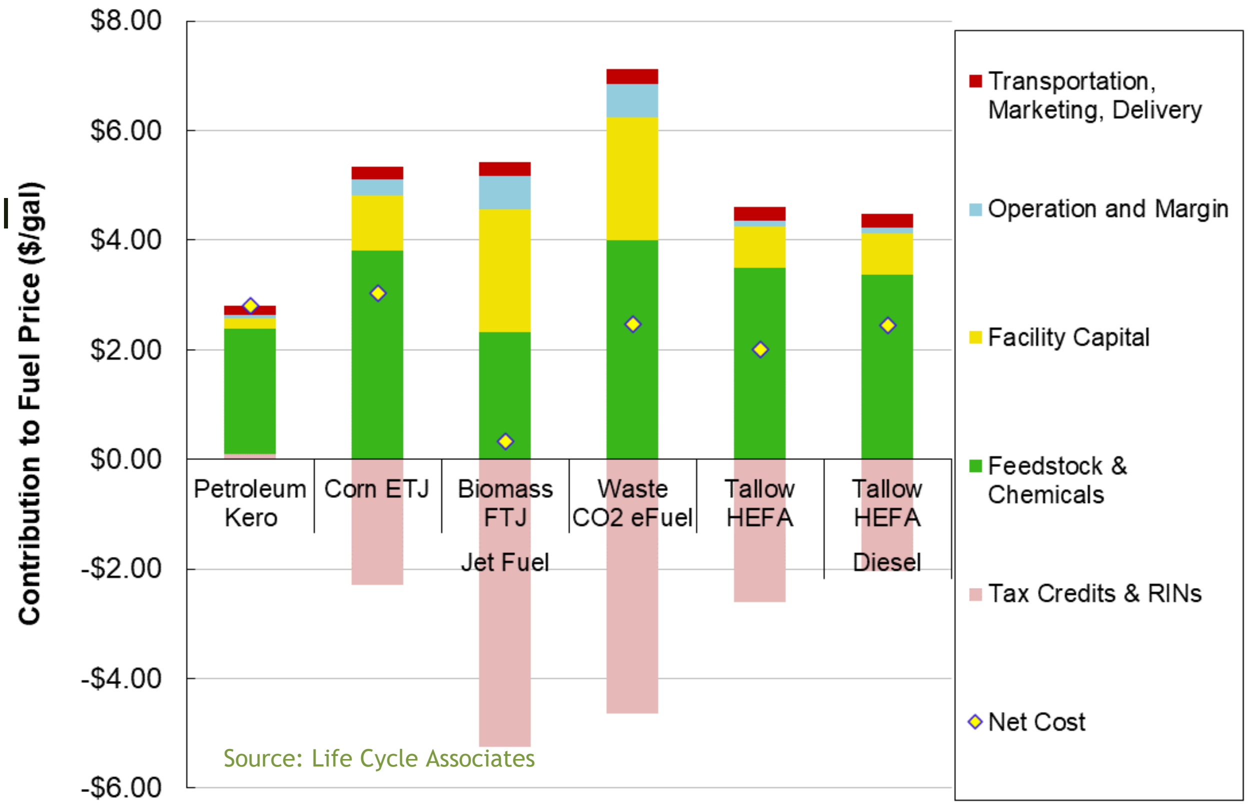
- Basis for CI varies with each policy framework depends on modeling system and feedstock
- Differences in iLUC
- g/MJ vs kg/MMBtu
- Different baseline values
- Different credit prices

Sample Calculation

- GHG reduction depends on change in CI and credit price
- Delta CI × LHV × Credit Price
- LCFS Example
  - 78.79 g/MJ Compliance Curve, 66.1 g/MJ HEFA
  - \$80/tonne CO_2
  - 126 MJ/gal
- (78.79-66.1) × 126 MJ/gal × \$80/tonne/10^6 =\$0.128/gal

Notional SAF Production Costs

- Higher capital costs for emerging technologies
- Feedstock is a key component factor
- Feedstock
  - $90/bbl oil
  - $2.3/gal EtOH
  - $80/t biomass
  - 100 kWh/gal eFuel
  - $0.9/kg tallow



Conclusion

- Biomass plays a potentially significant role in achieving sustainable aviation fuel production targets
- Resources from wastes and residues will allow for volumes that exceed SAF from oils and fats
- Substantial policy incentives are in place from RFS, IRA, LCFS, and voluntary SAFc
- Carbon capture via sequestration or biochar enables a negative CI fuel

Contact & further reading

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- https://www.linkedin.com/company/life-cycle-associates/
- https://www.lifecycleassociates.com/

- https://biomassmagazine.com/articles/pathways-for-carbon-negative-biomass-fuels
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