January, 20th 2020

Comparing Paths to Decarbonization by Measuring Feedstock Efficiency of Bio-Distillates

Matt Herman
Manager, Sustainability

REG RENEWABLE ENERGY GROUP

ABOUT REG

Accelerating Fuel Forward

Renewable Energy Group in 2018:

2.1M → **$2.4B**

MT of fuel sold[1] → In revenue

1.6M → **4.3M**

MT produced → Metric tons of carbon reduction

[1]Includes all biomass-based diesel and petroleum gallons sold: domestic, international and third-party gallons.

REG At A Glance

20+
YEARS
of biodiesel industry leadership

1.65
MMTY
Nameplate capacity

COMPETITIVE FUEL LINEUP
Biodiesel, renewable diesel, ULSD, blended fuel, more

DEDICATED SERVICE
and technical support

REG Products – High Quality And Value

REG-9000 Biodiesel
- Premium quality biodiesel
- Marketed based on fuel characteristics, not feedstock type

REG-9000 Distilled Biodiesel
- Superior cold weather performance
- Easy to blend with petroleum

REG Renewable Diesel
- 100% hydrocarbon product
- Use at any blend level

REG Ultra Clean™ Diesel
- Proprietary blend of biodiesel and renewable diesel
- Low carbon intensity, strong performance

REG Bio-Residual™ Oil
- Renewable heavy fuel oil
- Provides up to 41 MJ/kg

Production And Distribution

45+	13
TERMINALS	BIOREFINERIES

DELIVERED PRODUCT TO:

49	6	10
STATES	CANADIAN PROVINCES	COUNTRIES

Waste Feedstocks, Resource Efficiency, & Carbon Intensity

Resource Efficiency & Climate Change

- **Resource efficiency** means using the Earth's limited resources in a sustainable manner while minimizing impacts on the environment. It allows us to create more with less and to deliver greater value with less input.[1]
- There is an urgent need to reduce the amount of GHG's emitted into the atmosphere
- It is better to reduce emissions sooner, rather than later. However, reductions also should be made smartly
- A note on fatty acid thermodynamics:
  - Nature used sunlight and CO_2 to create energy dense carbon chains
    - It is most efficient to process these carbon chains minimally before consumption
    - Different fuel production technologies process lipids more or less efficiently
  - From a thermodynamics perspective, more efficient processes will preserve more of the naturally-occurring energy in raw materials than less efficient processes

1. https://ec.europa.eu/environment/resource_efficiency/

Environmental Value Should Drive Economic Value

- Lipids are in high demand globally for biofuel production
  - "Waste feedstocks" in particular have become highly valued
    - Any feedstock that is truly a waste inherently has limited annual volume
    - We should strive to achieve the maximum GHG reduction for each MT of feedstock processed into fuel
- Carbon Intensity ("CI score") is often considered an appropriate metric to reward alternative fuels, but alone provides a limited perspective
  - Certain regulatory mechanisms such as mandates and multipliers may provide counterproductive incentives for specific biofuels
  - A focus on resource efficiency should be considered
    - For example, MT CO_2e reduced per MT of feedstock processed
    - This is important for waste feedstocks in particular, because of their limited quantity

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"CI Score" Alone has Shortcomings

- It is assumed that a lower carbon intensity for the primary product means greater emission reductions
  - Primary product carbon intensity can fail to account for the efficiency of resource consumption
  - A more holistic analysis would also include an EROEI* metric and a resource efficiency analysis
- Primary product CI Score can be misleading:
  - Increased co-product production can lead to a lower energy allocation %, resulting in a lower CI
  - Using a single fossil fuel reference CI is not enough, one must consider what fossil product is actually being replaced
  - No/low CI waste feedstocks mask the negative impact of low yield on the final CI of fuel

** Energy Return on Energy Invested*

Analysis Overview

- Life Cycle Assessment was conducted for three fuel pathways
  - Waste UCO biodiesel plant
  - Waste UCO HVO facility producing primarily HVO (i.e., Renewable diesel)
  - Waste UCO HVO facility producing primarily HEFA-SPK (i.e., Renewable jet fuel)
- Carbon intensity and total emission reductions were estimated
  - California's GREET model and emission factors were utilized
  - Carbon intensity for each material calculated as gCO_2e/MJ
  - Each renewable product displaced its respective petroleum counterpart
  - Total Emissions, or '*resource efficiency*' was calculated as total MT CO_2e reduced per MT of feedstock processed

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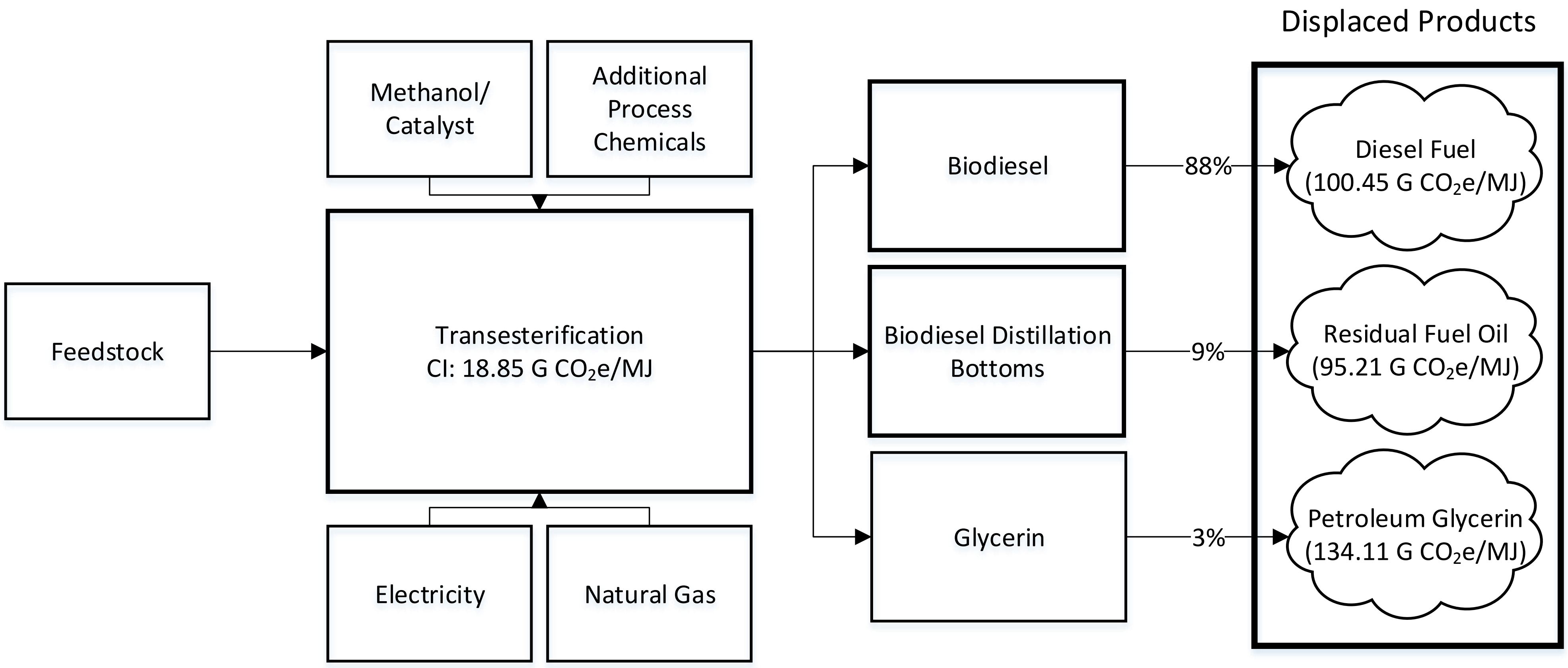
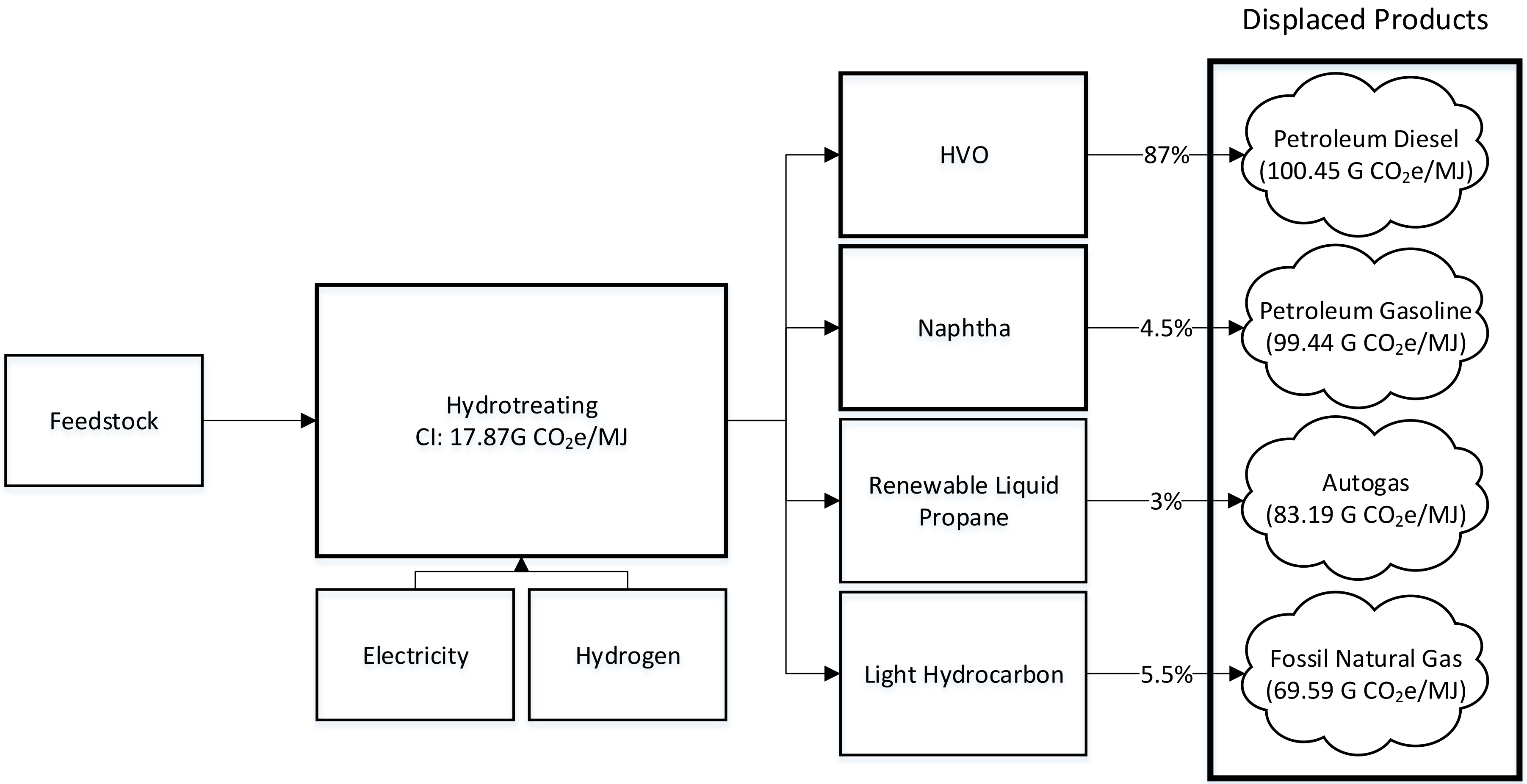
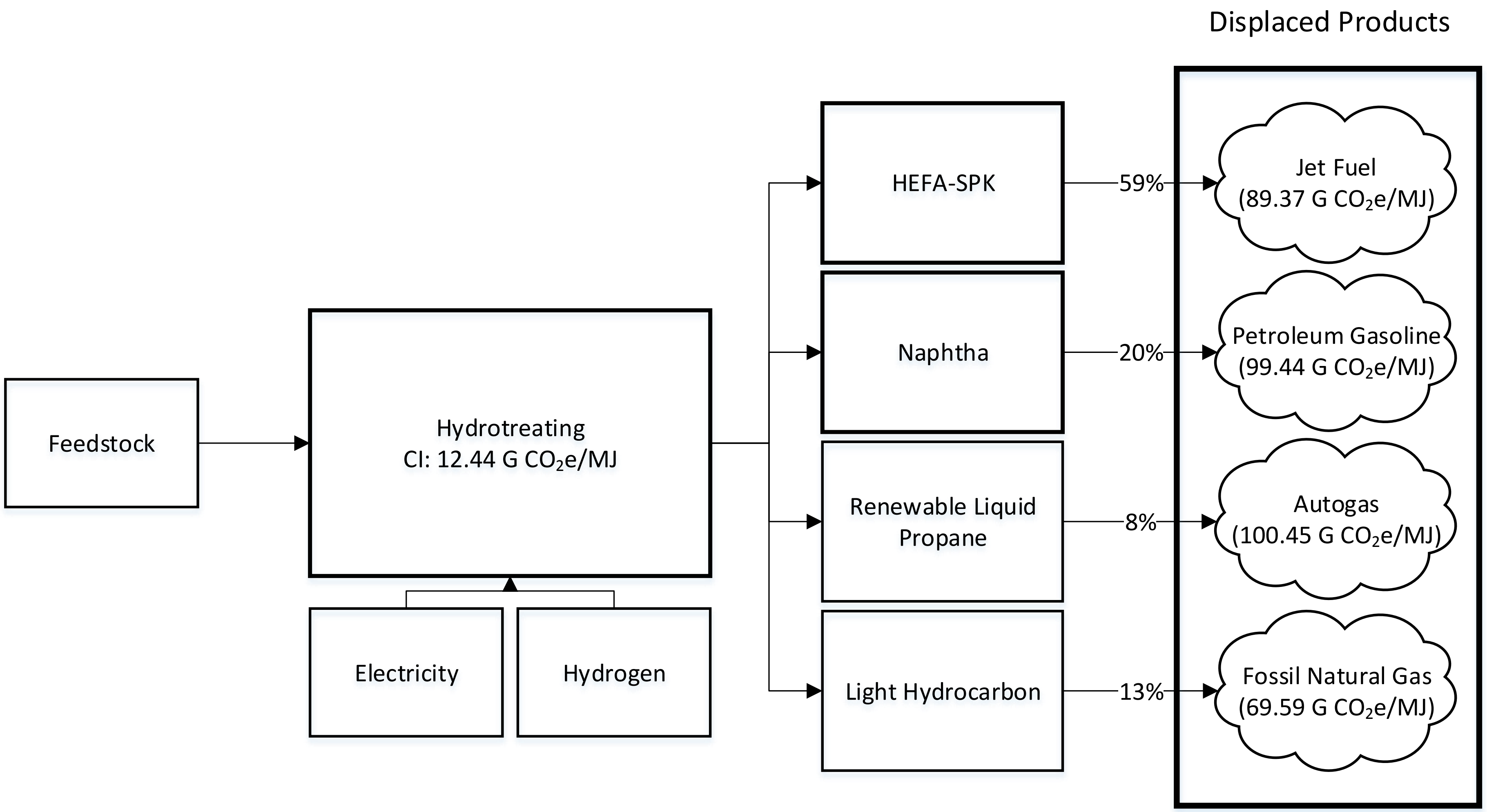
Biodiesel System Boundary



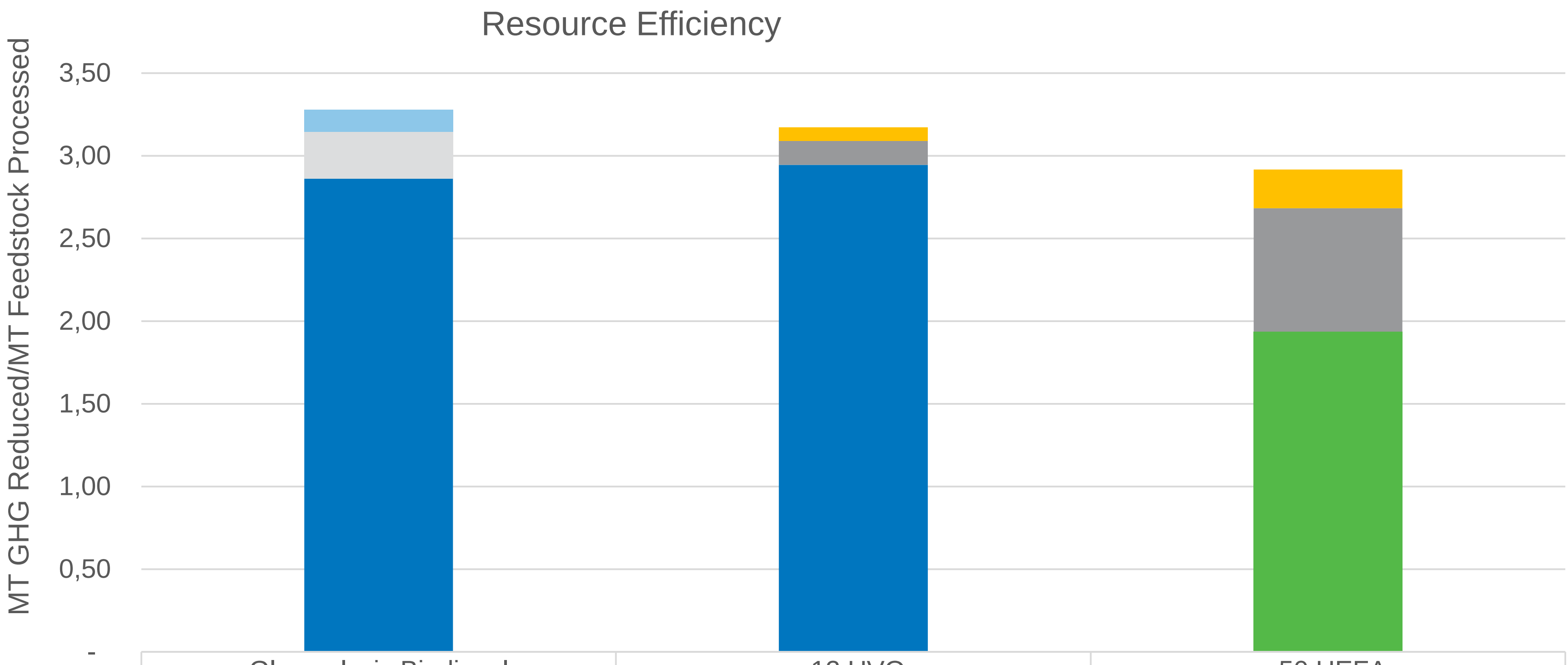
HVO System Boundary



HEFA-SPK System Boundary

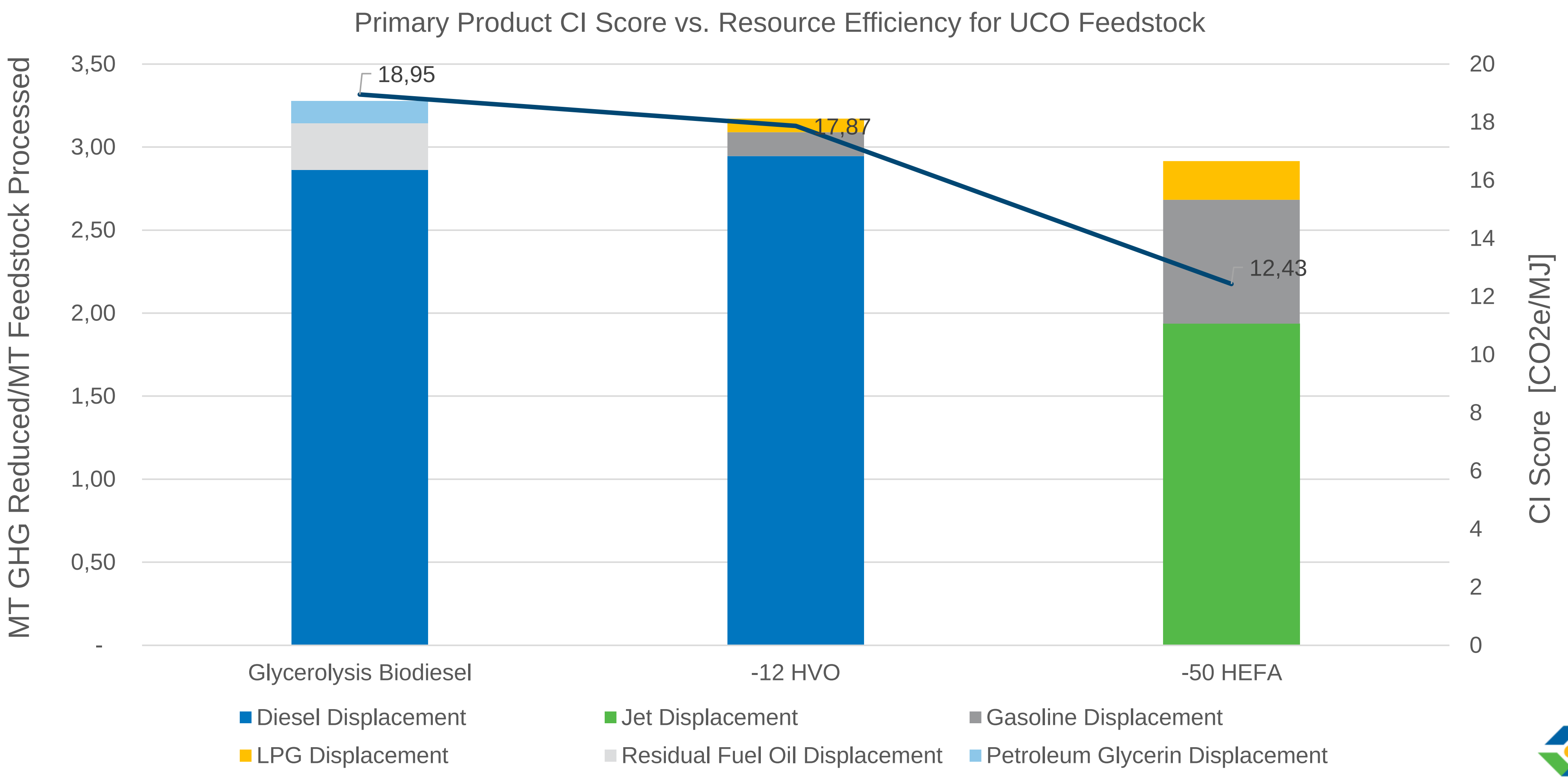


Resource Efficiency



	Glycerolysis Biodiesel	-12 HVO	-50 HEFA
Petroleum Glycerin Displacement	0,13	-	-
Residual Fuel Oil Displacement	0,28	-	-
LPG Displacement	-	0,08	0,23
Gasoline Displacement	-	0,14	0,75
Jet Displacement	-	-	1,94
Diesel Displacement	2,86	2,95	-
Total (MT GHG Reduced/ MT Feedstock)	3.27	3.17	2.92

Carbon Intensity and Resource Efficiency



Results

- Between 2017-2019 the EU consumed 8,380,000 MT of UCO[1]
- Below we have estimated the emissions reductions if all UCO used in fuel production went to either biodiesel or HEFA-SPK
- If all UCO would have gone to HEFA-SPK the community would have reduced far *less* CO_2e

Emission Reduction Potential of UCO (MT CO_2e)	
HEFA Emission Reduction	24,439,598.78
Biodiesel Emissions Reduction	27,466,218.87
Difference	(3,026,620.08)

1. USDA EU-28 Biofuels Annual Report, 2019 consumption is forecasted
https://www.fas.usda.gov/data/eu-28-biofuels-annual-1

Conclusion

- Waste lipids, by definition, have a limited annual supply
  - *Feedstock Efficiency* is a new metric idea which could be used to compare the overall GHG reduction impact of fuel production processes
    - MT of CO_2e Reduced per MT of Feedstock Processed
- Regulatory programs should look beyond the "CI Score" of the primary product when incentivizing fuel markets
- REG's analysis indicates that of the processes compared, a high-yield biodiesel plant provides the greatest total GHG emissions reductions per unit of waste lipid feedstock
- Due to low yield for the primary product, significant cracking of carbon chains, and lower fossil baseline, HEFA-SPK production provides the lowest total GHG emissions reductions per unit of lipid feedstock

Thank you.

Matt Herman
Manager, Sustainability
Matt.Herman@REGI.com

Appendix, Emission Factors (G CO_2e/MJ)

- Displacement Emission Factors
  - Diesel[1] - 100.45
  - Aviation fuel[1] – 89.37
  - Residual fuel oil[1]- 95.21
  - Gasoline[1] – 99.44
  - LPG[1] – 83.19
  - Natural gas[1] - 69.59
  - Petroleum-based glycerol[2] – 134.11
- Renewable Fuel 100% UCO-Based
  - Biodiesel[3] – 18.85
  - HVO[3] – 17.87
  - HEFA-SPK[3]– 12.44

1. CA-GREET 3.0
2. EcoInvent
3. REG Calculations