# Recent progress in the production of low carbon-intensive drop-in fuels – Stand-alone production and coprocessing

Susan van Dyk, Jianping Su, Jack Saddler,

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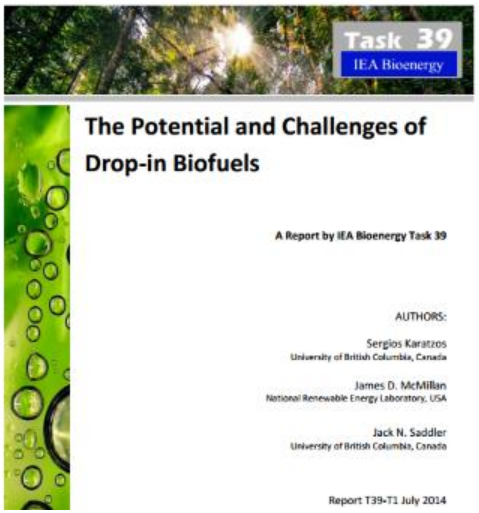
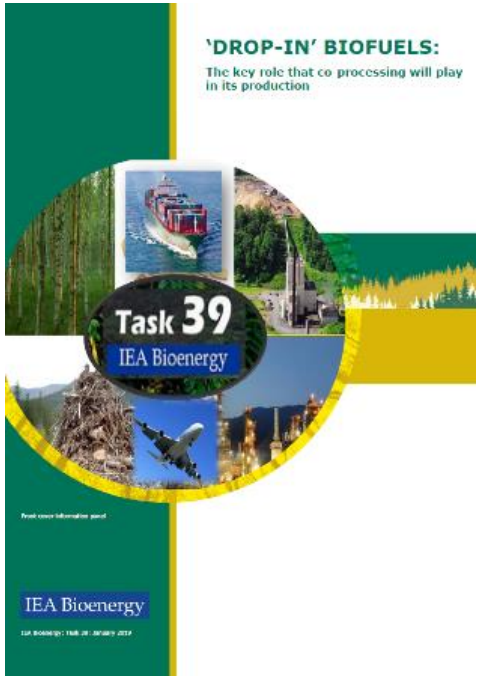
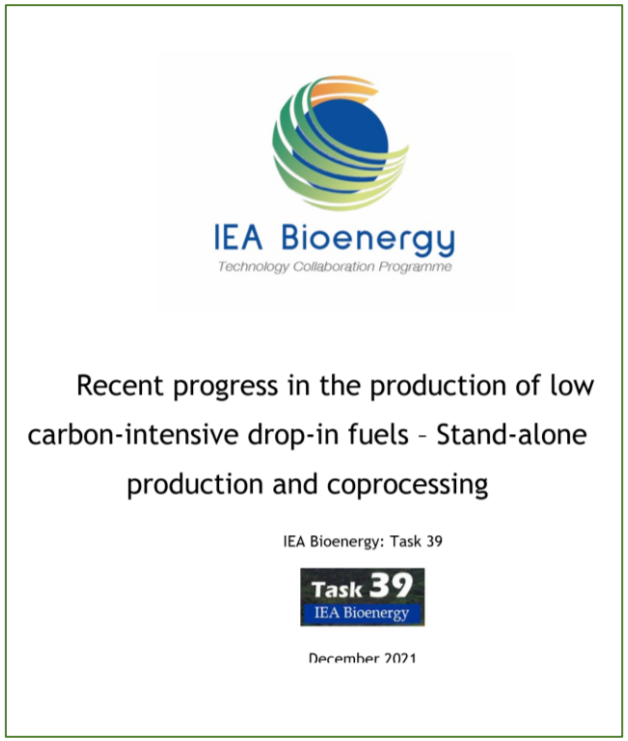
# Drop-in biofuels reports (2014, 2019 & 2021)




## Definition of "drop-in" biofuels

- Drop-in biofuels: are "liquid bio-hydrocarbons that are: functionally equivalent to petroleum fuels and **fully compatible with** existing petroleum infrastructure"

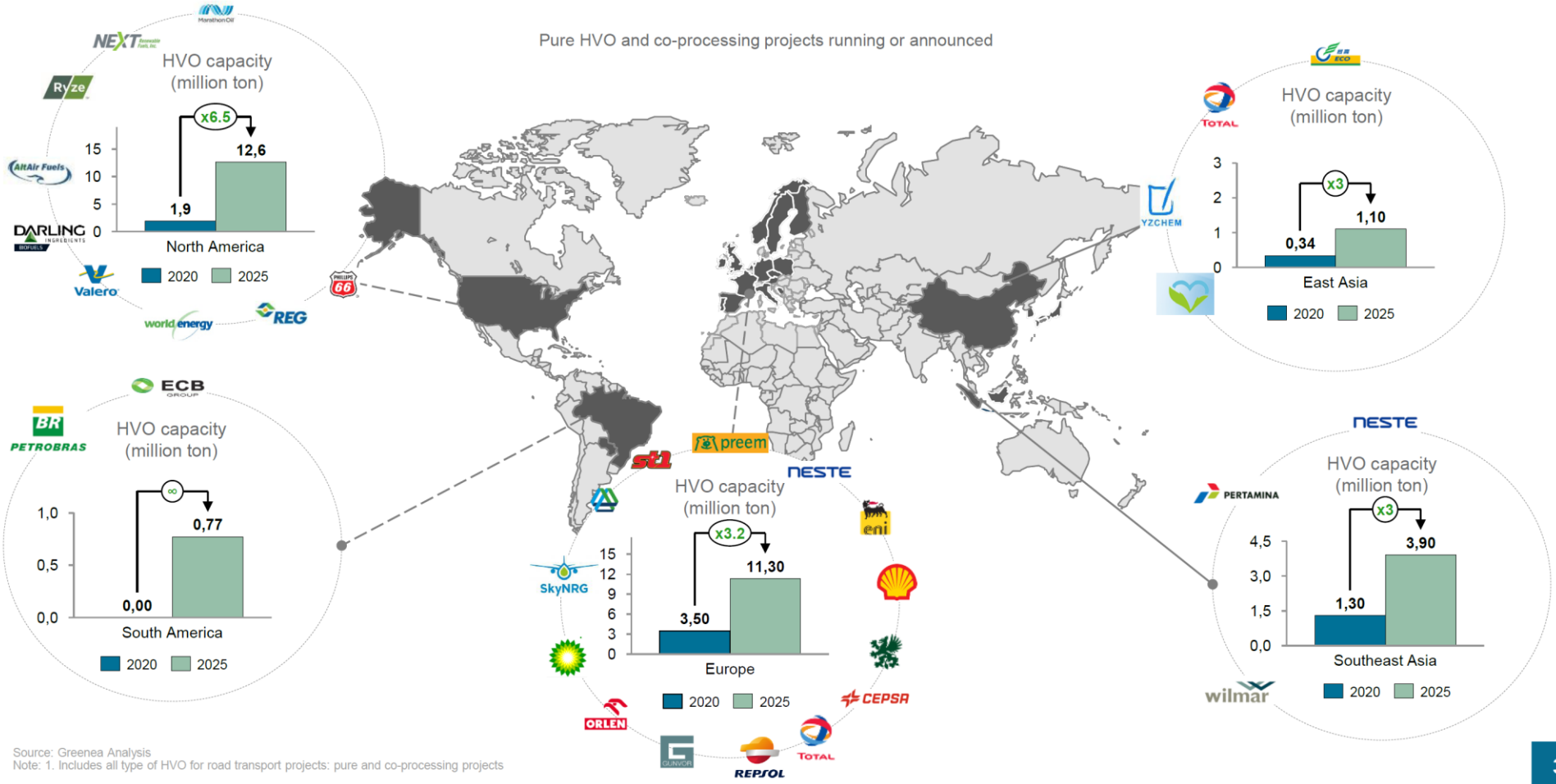
# Progress in drop-in biofuel production

- Stand-alone facilities
  - New construction (HVO/HEFA, Gasification/FT, Alcohol-to-jet, HTL, etc.)
  - Repurposing of old or disused refineries (HVO/HEFA)
  - Stand-alone facilities are prevalent for FOGs, many based on repurposing, e.g. World Energy, Neste, Phillips66, Marathon, etc.
  - Density of FOGs feedstocks allow large-scale facilities to achieve economies of scale

- Co-processing
  - Based on FOGs (fats, oils, and greases) – fully commercial
  - Bio-oil/Biocrude co-processing still being developed (limited volumes, technical challenges)

# Global HVO/HEFA expansion – will be limited by feedstock availability and cost

**Everywhere in the world, new HVO[1] projects are projected to significantly increase by 2025, triple in the EU, six-fold in the US, and three-fold in Asia compared to 2020**



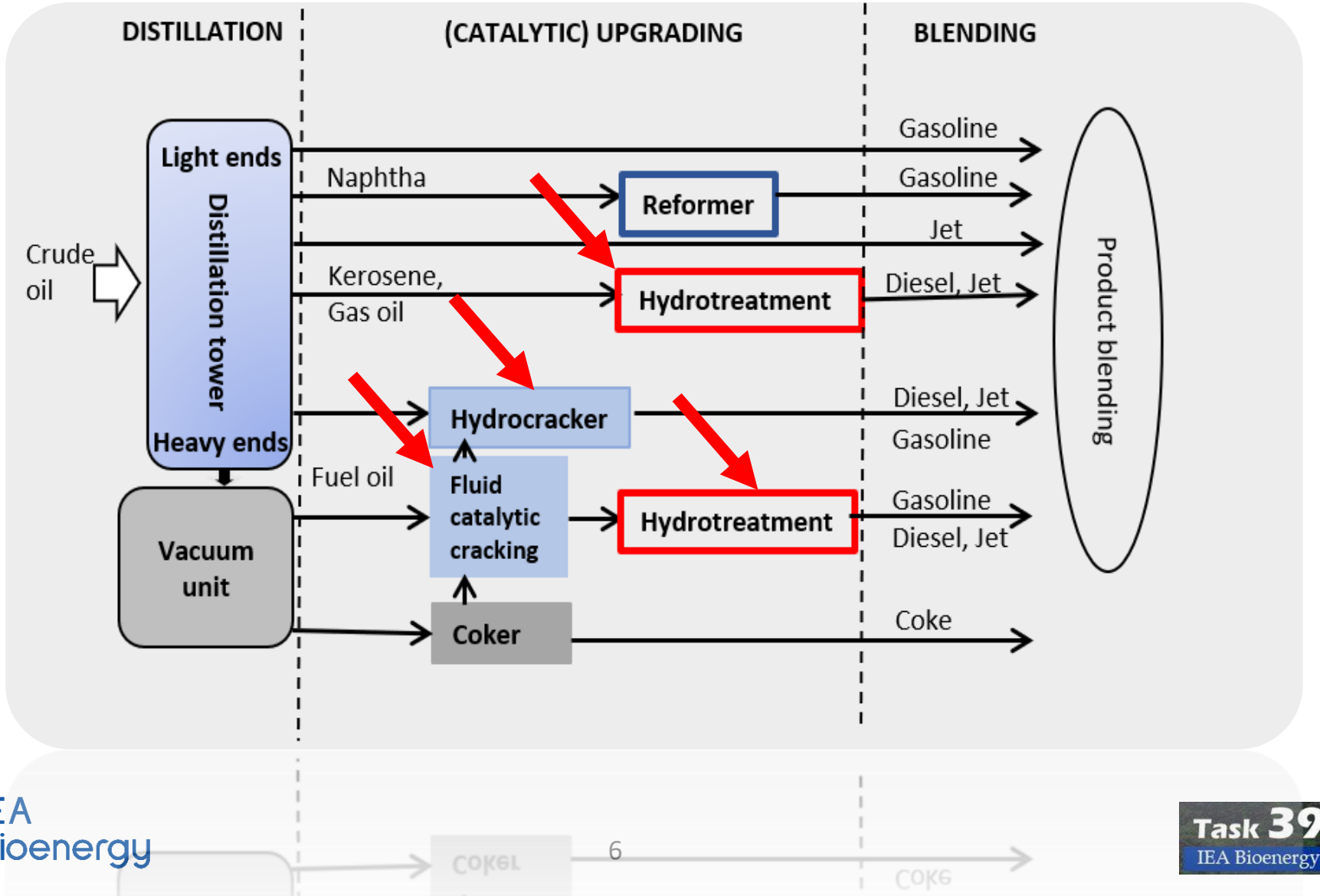

Source: Greenea Analysis
Note: 1. Includes all type of HVO for road transport projects: pure and co-processing projects

# Co-processing – driven by low carbon fuel standards and favourable policies (SAF)

- Refineries want to lower the CI of their fuels to:
  - Meet LCFS targets
  - Access lucrative markets, e.g., SAF

- Co-processing will become critical for refineries who want to remain relevant in a future net-zero world

# Potential refinery insertion points



# Co-processing feedstocks and upgrading

- Feedstocks for co-processing
  - FOGs, bio-oils/biocrudes, FT Liquids
  - Availability of sufficient feedstock and cost will be key challenges (FOGs)
  - Availability and quality of bio-oils/biocrudes will be challenge

- Where and how you insert depends on:
  - Nature of the feedstock – e.g. is cracking required?
  - Refinery configuration & desired products (gasoline or middle distillates) – likely moving away from gasoline as EVs become more prevalent
  - Potential impact on refinery operations (limitation of risk)

# Refineries engaged in co-processing

- Focus on renewable diesel and SAF
  - Preem – 30% tall oil, moving towards 85%
  - BP Cherry point in Washington State (10+% FOGs in hydrotreater)
  - Parkland Refinery in Burnaby, Canada (10+% FOGs in FCC)
  - BP Castellon refinery in Spain (5% FOGs in hydrotreater for SAF)
  - ENI Taranto Refinery in Italy (5% FOGs in hydrotreater for SAF)
  - Chevron, Exxon, Petrobras, Repsol, Shell, Equinor, Honeywell/UOP

# Challenges of co-processing and technology solutions

- Biobased feedstock characteristics influence coprocessing and present a challenge to the refinery
  - oxygen, TAN, water, alkali metals, lack of miscibility with fossil feeds, high hydrogen consumption, high heat generation, impact on sulfur removal
- Technology solutions developed by several companies (Haldor Topsoe, Shell, Axens, Albermarle, Honeywell/UOP)
  - Optimised pretreatment
  - Modified catalysts to limit inhibition/inactivation
  - Modified reactor configuration to prevent blocking
  - Heat management through quenching
  - Separate injection for immiscible biobased feeds
  - Management of corrosion

# Infrastructure investment to facilitate coprocessing

- At low blends, relatively low costs related to storage, pretreatment, new metallurgy, processing unit modification, new catalyst

- At high blends cost become significant, including increased hydrogen production

# Determining the carbon intensity of co-processed fuels

- Various methods – mass balance, carbon balance, C14 – still under evaluation
- Co-processing of FOGs in the hydrotreater relative simply – similar CI to standalone HVO
- Co-processing in the FCC becomes complicated
  - Companies argue for mass balance allocation using a baseline of the fossil feed alone
  - However, this does not give an accurate measurement

- Work carried out by Jianping Su at the Parkland Refinery shows the shortcomings of a mass balance approach

# Challenges in determining the renewable content of the final fuels after co-processing biogenic feedstocks in the fluid catalytic cracker (FCC) of a commercial oil refinery

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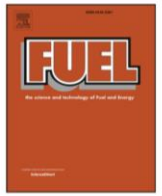


Full Length Article

## Challenges in determining the renewable content of the final fuels after co-processing biogenic feedstocks in the fluid catalytic cracker (FCC) of a commercial oil refinery

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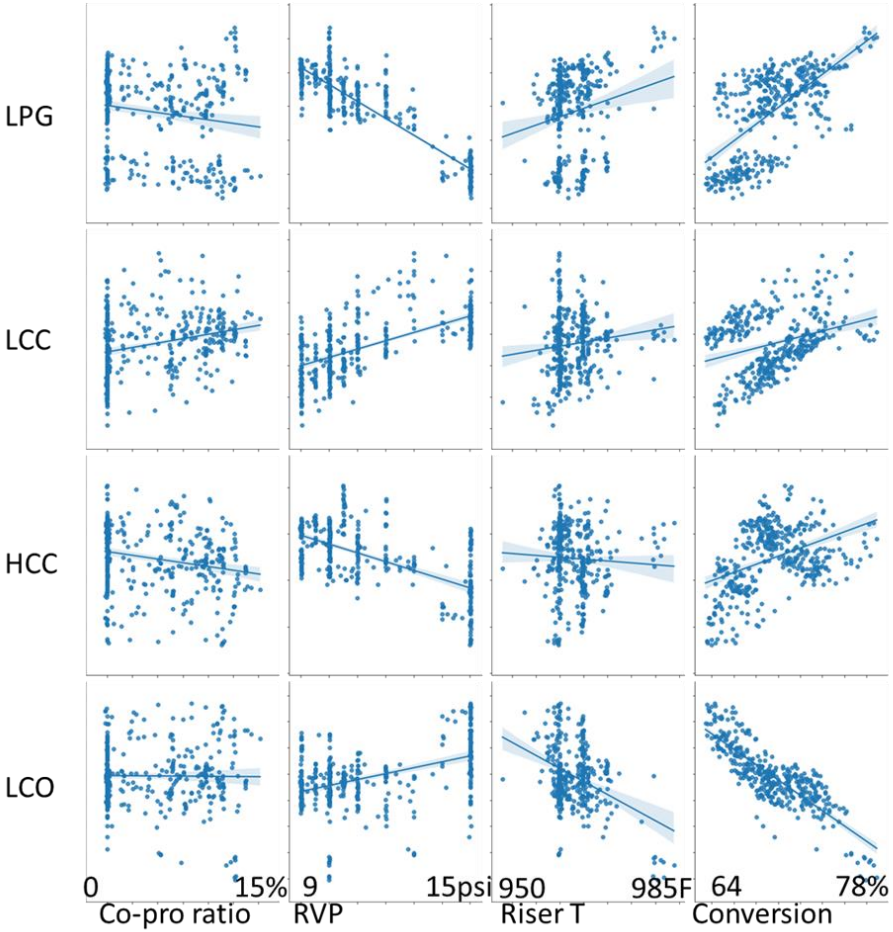
Forest Products Biotechnology

Parkland FUEL CORPORATION

# Refinery baseline and co-process at low percentage




- Baseline noise is too high for FCC co-processing at low % to generate a strong signal
- Mass balance based on observed yield is problematic (assuming biogenic feed is the only changing variable)
- Long-term data and multiple linear regression used to improve the correlation and quantify the impact of biogenic feedstocks – Plus C14

# Determining the amount of “green” coke when co-processing lipids commercially by fluid catalytic cracking

- Paper has been submitted and passed 1st review

**Determining the amount of “green” coke generated when co-processing lipids commercially by fluid catalytic cracking (FCC)**

Jianping Su[a], Liang Cao[b], Gary Lee[c], Bhushan Gopaluni[b], Don O’Connor[d], Susan van Dyk[a], Robert Pinchuk[c], Jack Saddler[a]

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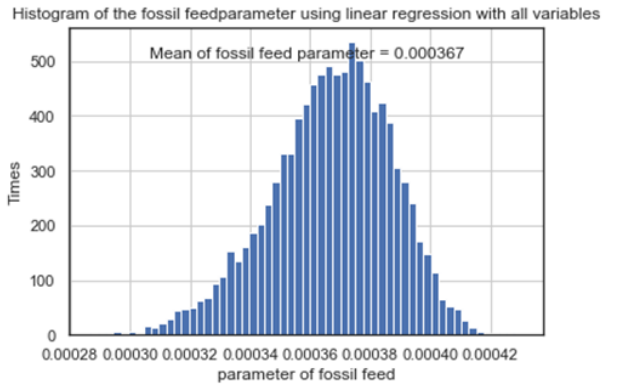
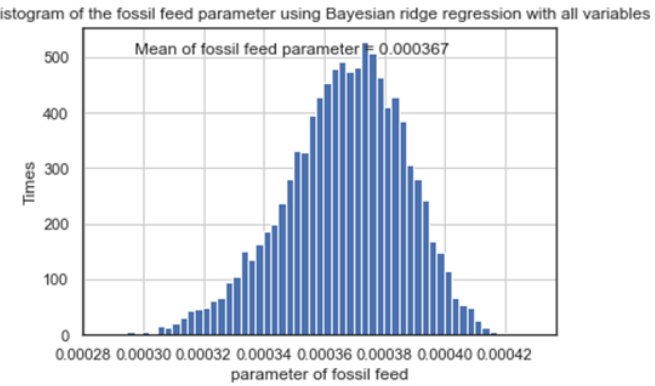
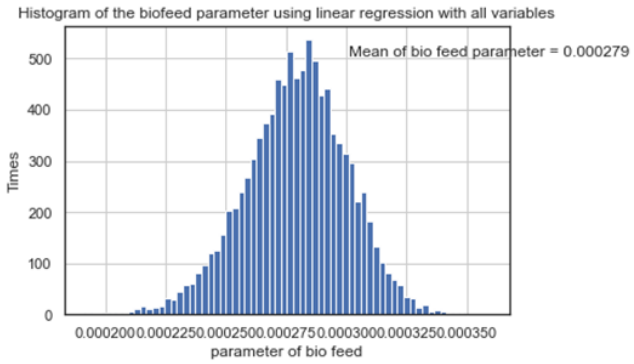
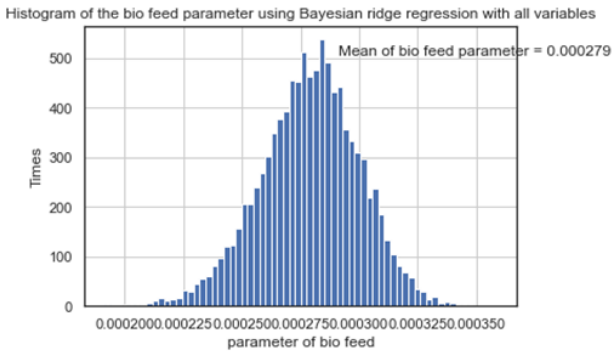
# Green coke determination and bootstrap method to reduce the uncertainties




- FCC co-processing generates green coke
- Can be quantified using a multiple linear regression and use of hourly data
- A bootstrap method can be used to reduce the uncertainties when estimating the coefficients

# Conclusions

- Stand-alone drop-in biofuel production is rapidly expanding, many HVO, but also other technologies
- Co-processing is increasing due to policies such as LCFS and SAF mandates & incentives, but also part of refinery transformation to a net zero future
- Co-processing of FOGs at commercial level and widespread
- Co-processing of bio-oils/biocrudes still under development due to technical challenges and biocrude availability
- Multiple companies entering the co-processing space and many technologies & catalysts are being developed to overcome technical challenges
- Accurate CI calculation is still challenging

# Thank you

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Jack Saddler

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