Renewable Propane Basics

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Renewable Gas 360 Webinar

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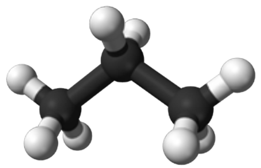
What is Renewable Propane?

Propane => C_3H_8



Fossil Propane: Carbon atoms from Fossil sources

- Natural gas
- Crude oil (associated natural gas)
- By-product from crude petroleum oil refinery operations

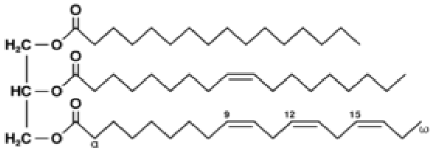
Renewable Propane (RP): Carbon atoms from renewable feedstocks

- Identical to fossil propane (drop-in)
- Produced as by-product from HEFA[1] renewable diesel and SAF[2] plants
  - 200,000 tons per year global production
- Current HEFA feedstocks include fats, oils, greases (FOGs)

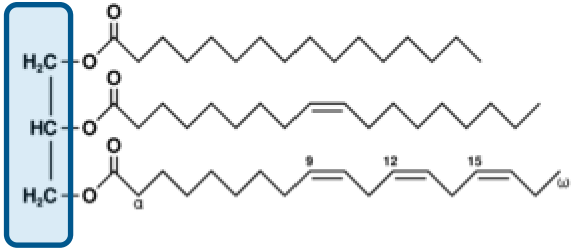
1. HEFA = hydrogenated esters & fatty acids
2. SAF = sustainable aviation fuel

HEFA Technology

- HEFA = hydrogenated esters and fatty acids
- HEFA Feedstocks contain triglycerides (TAGs)
  - Vegetable & plant oils (palm, soybean)
  - Animal fats (tallow)
  - Used cooking oil



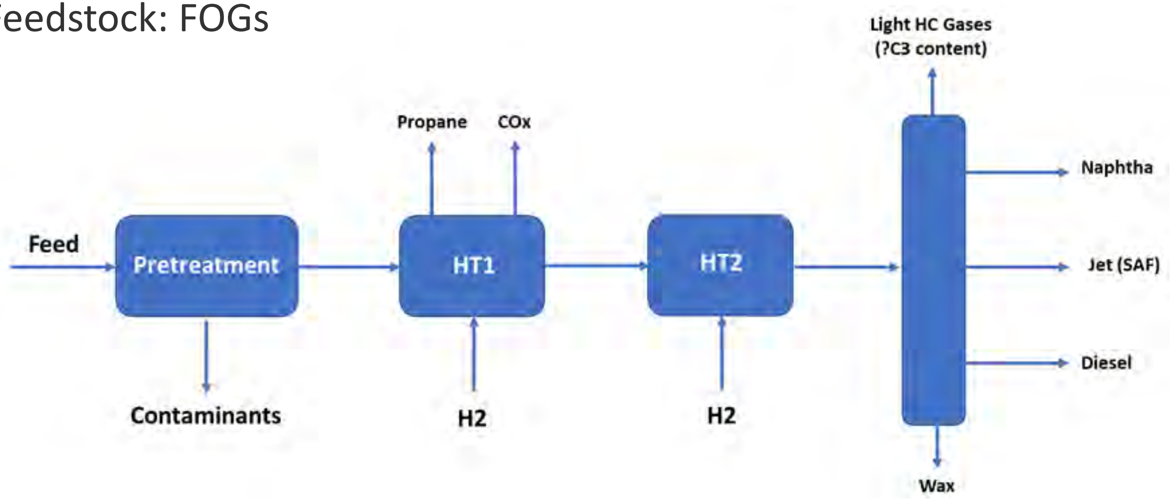
- Propane produced as by-product of TAG hydrocracking
  - Commercial technology (UOP, Neste, Syntroleum)
  - Yield of RP ≈ 5wt% based on FOG



$\xrightarrow[\text{Catalyst}]{+H_2}$ 1 mol propane + 3 moles long-chain fatty acids

Feedstocks and Current Sources of RP

- Current US production of RP ≈ 10.5M gallons/year
- Production plants (USA)
  1. REG, Geismar LA & Valero Diamond Green, Norco LA
     - Technology: HEFA – produces primarily renewable diesel
     - Feedstock: FOGs
  2. World Energy (formerly Alt Air), Paramount CA
     - Technology: HEFA – produces primarily Sustainable Aviation Fuel
     - Feedstock: FOGs



Future Sources, USA

	Current	Expansion (2021)	New construction (2021)	2024
RD/SAF	485M GPY	736M GPY	720M GPY	1,941M GPY
Biodiesel	2,539M GPY		90M GPY	

Assuming all expansion and new construction projects are complete by 2024, nearly 2 billion gallons per year of RD/SAF will be commercially available

=> Huge increase (4X) in availability of RP possible <=

N.B. - Max FOGs currently available ≈ 1.4 billion gallons per year

Potential feedstock gap of 500 million GPY exists in 3 years

TechnoEconomics

Biorefinery operator options

- Use as fuel gas
- Separate from fuel gas stream and sell
  - additional CAPEX and OPEX for RP recovery
  - need to supplement for plant energy requirements (fossil natural gas?)
  - storage & transportation costs not insignificant
  - RIN and LCFS credits could be major economic drivers

RIN Credits

- According to EPA: RP eligible for RIN credits
  - D4/D5 RINs if GHG reduction >50% compared to fossil
  - ≈ $1.80/gallon if using September 2021 D5 RIN

LCFS Credits (CA only)

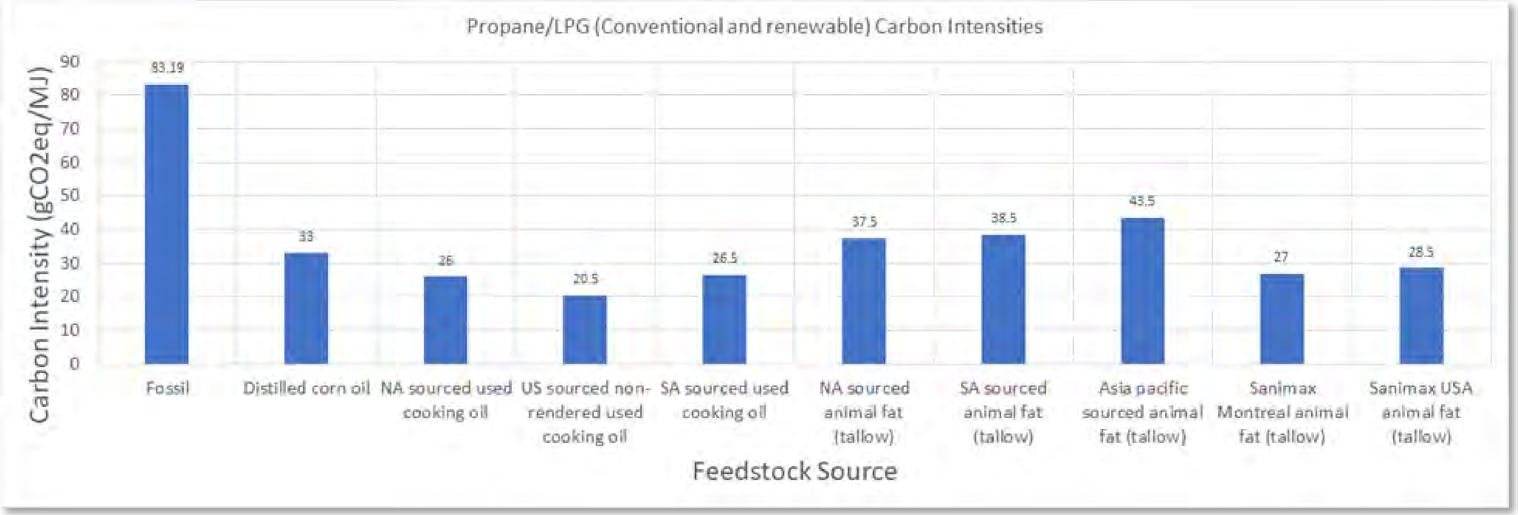
- Depends on carbon intensity of product
  - Strong functions of pathway and feedstock
  - Economic benefits substantial

Why is Feedstock Important?

Carbon Intensity (CI) of RP strong function of feedstock

- LCFS (CA) and other carbon credits
- Significant controversies in feedstock CIs exist
    - Tallow: CI ≈ 19 gCO2e/MJ (at plant gate) or ≈ 187 (at the cow)

<u>CARB data for RP from non-food feedstocks</u>



Next-gen RP Pathways

Lowest carbon intensities for RP from cellulosics (and food waste)

Pathways from cellulosics (forestry & ag residues, other waste C)

- Biochemical; cellulosic sugars => hydrocarbons
- Thermochemical liquefaction
  - Pyrolysis => bio-oil => upgrading to fuels and chemicals
  - Hydrothermal liquefaction => bio-crude => upgrading to fuels and chemicals
- Thermochemical gasification => syngas => catalytic upgrading
  - Methanol-to-olefins (UOP & Lurgi MTO® technology)
- Hybrid (e.g., gasification + syngas fermentation)

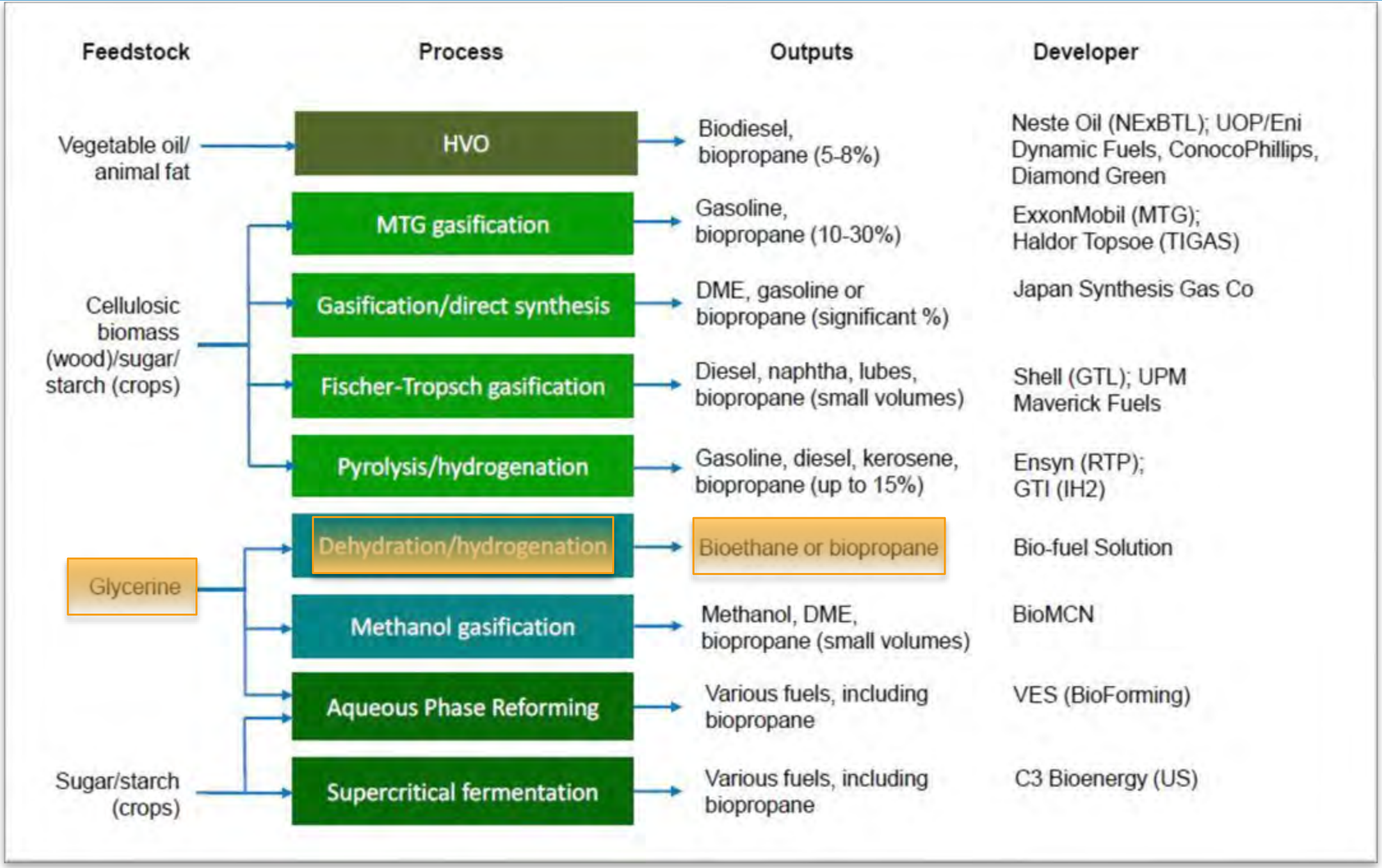
Direct conversion of CO_2 using 'green' electricity (E-2-M, P-T-X)

- Direct air capture
- Waste carbon streams (corn ethanol fermenters, power plants, etc.)

Other

- Anaerobic Digestion – upgrading volatile fatty acids from arrested methanogenesis
  - Pathways with very low CI exist

Other Pathways



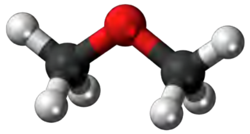
Commercial technology with nearly 100% yield of RP

Source: Gokul Vishwanathan, PERC

Question: What about DME?

DME (Dimethyl ether)

Dimethyl ether => C_2H_6O



Not the same (chemically) as propane – contains oxygen

No natural sources of any significance – mostly synthetic in origin

- Commercially made by dehydration of methanol ($2CH_3OH \rightarrow C_2H_6O + H_2O$)
- Also from synthesis gas ($CO + H_2$)

Shares many properties with propane

- Liquefiable at room temperature and modest pressure (75 psi)
- LHV = 59.1 MJ/nM^3 vs 91 for propane
- Widely used in Europe as a diesel fuel blendstock

Excellent precursor for synthesis of biofuels (HOG[1] and SAF)

1. HOG = high octane gasoline

Thank You

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