

Dairy Manure to Fuel: Advanced Liquid Biofuels under California's LCFS

Dairy and Livestock Subgroup #2
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Vantage Point

- Fuel and Carbon Attorney
 - ✓ Regulatory Analysis and Compliance Counseling
 - ✓ Advocacy and Rule making
 - ✓ Focused on Environmental Attributes= \$\$\$
- Executive Director, Low Carbon Fuels Coalition
 - ✓ Expansion of sound low carbon fuel policies
 - ✓ Policy Tracking



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Converting Manure to Money

- Diverse Technologies
 - Daisy Chain of Components
 - Proven at What Scale?
 - Yield, Energy Intensity, Reliability
- Fuel Value and Logistics
- Low Carbon Fuel Standard
 - Quick Program Summary
 - Key Variables to Consider
- Renewable Fuel Standard
 - Additional Revenue Stream
- Co-products



How Does the LCFS Judge Fuels?

- The LCFS Looks at Fuels from a Carbon Emissions Perspective
- Key Measurement: How much carbon pollution is released per unit of energy?
- Custom analysis using CA- GREET
 - ✓ Feedstock- energy inputs, ILUC, transportation, alternative fate
 - ✓ Facility- detailed energy data
 - ✓ Fuel- ethanol, RNG, electricity
 - ✓ Transportation, co-products



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Feedstock is a Key Variable in LCFS

Manure is NOT Fungible

- Life cycle assessment of manure under CA-GREET (California-modified Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation model)
- Lowest carbon intensity- must receive credit for:
 - ✓ capture of methane that would otherwise behave as a short-lived climate pollutant compared to business as usual
 - ✓ use of that energy as a transportation fuel
 - ✓ release of more benign gases from tailpipe/smokestack
- Recognize value of § 1383 language- *the state board shall (...) ensure that projects developed before the implementation of regulations adopted pursuant to subdivision (b) receive credit for at least 10 years.*



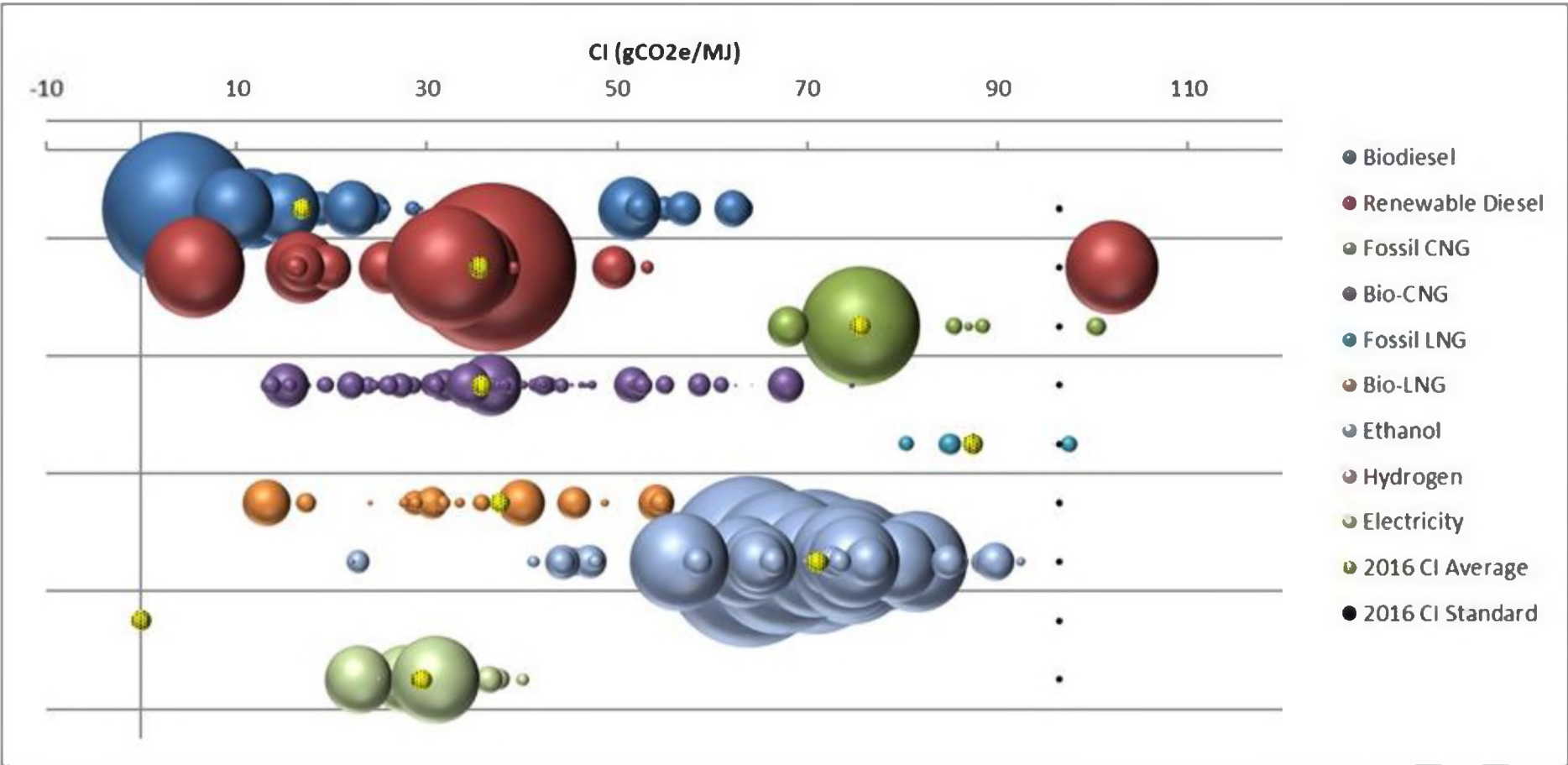
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Feedstock Variables to Consider

- California Bioenergy LLC holds gold standard at – 278 for Dairy Biogas from Kern County from dairy manure covered anaerobic lagoons to CNG in California
 - Certified Pathway
 - Accounting for Avoided Methane per ARB Livestock Offset Protocol under Cap and Trade which includes eligibility rules, methods to quantify GHG reductions, project-monitoring instructions, and third party verification.
- For Liquid Fuels from Manure:
 - GHG Profile of the Manure is Key
 - Commercialized technologies perform better with dried manure or require higher energy inputs
 - Solar and other non-GHG intensive methods to dry



2016 Volume-weighted Average Carbon Intensity by Fuel Type



Last Updated 08/02/2017

This figure provides perspective on the performance of actual quantities of fuel consumed in California. Each sphere represents a certified fuel pathway; the size of the sphere represents the reported volume of the fuel in 2016, while its position on the horizontal axis indicates the carbon intensity of that fuel.

¹ The alternative fuel's CI value is divided by its Energy Economy Ratio (EER) in order to obtain the EER-adjusted CI value, representing the emissions which occur from the alternative fuel per MJ of conventional fuel displaced.

Advanced Pathways to Liquid Fuels from Biomass Sources

- High temperature processes
- Variable levels of oxygen content
- Typically first produce biogas or syngas
- Flexibility regarding gases and liquids derived from the biogas
- To liquid fuels via Fischer-Tropsch (90 year old process) like CTL produced by Sasol
- Reductions to F-T scale and energy inputs



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Comparison of thermal processes illustrates disparate outcomes.

| | Pyrolysis | Gasification | Combustion |
|--------------------|---------------------------|--------------------------|-----------------------|
| Carbon Conversion | 60-70% | 80-90% | 100% |
| Gas Quality | 500 BTU/scf | 100-300 BTU/scf | None |
| Biochar | 10-15% of biosolids feed* | 5-10% of biosolids feed* | No biochar, ash (<5%) |
| Oxygen | No oxygen | Oxygen-starved | Oxygen-rich |
| Conversion Process | Thermochemical | Thermochemical | Combustion |

*Feed is biosolids wet cake.

Kore Infrastructure Slide, Steve Wirtel

Approved Gasification Pathway

- Fulcrum Sierra BioFuels, LLC- Fischer-Tropsch Diesel via Gasification and FT syntheses of Municipal Solid Waste= 14.78
- Prospective Pathway under 2015 LCFS
- Design Based Pathway under proposed LCFS regulations
- Otherwise require one quarter of operations data



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Approved Pyrolysis Pathway

- Ensyn Technologies Inc.- Renewable gasoline from forest residues via pyrolysis and co-processing of bio oil.
- CI Score of 21.17 if transported via rail from Ontario, Canada to California.
- Ensyn also holds renewable diesel pathways based on pyrolysis technology.



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Future Pathway: Biomass to Jet

- Velocys began producing diesel and naphtha in June 2017 at the Enviva JV in Oklahoma City
- Feedstock is landfill gas and natural gas
- Velocys plans to produce alternative jet fuel from woody biomass for California market



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Testing Opportunity for Feedstocks

Design-based, Provisional, and Full Pathways in the LCFS



Kore's technology thermally converts organic waste into RNG, RH_2 and biochar. It is skid-mounted and requires little space.

Questions and Discussion

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