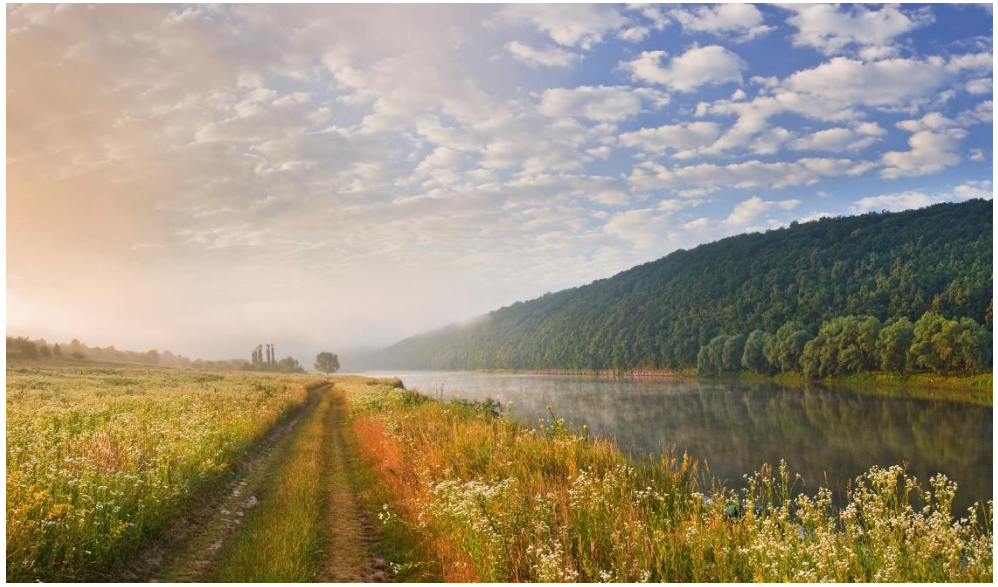
IEA Bioenergy
Technology Collaboration Programme



USA Country Update

IEA - T33 Meeting

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October 18, 2022

Updates on Commercialization Activities

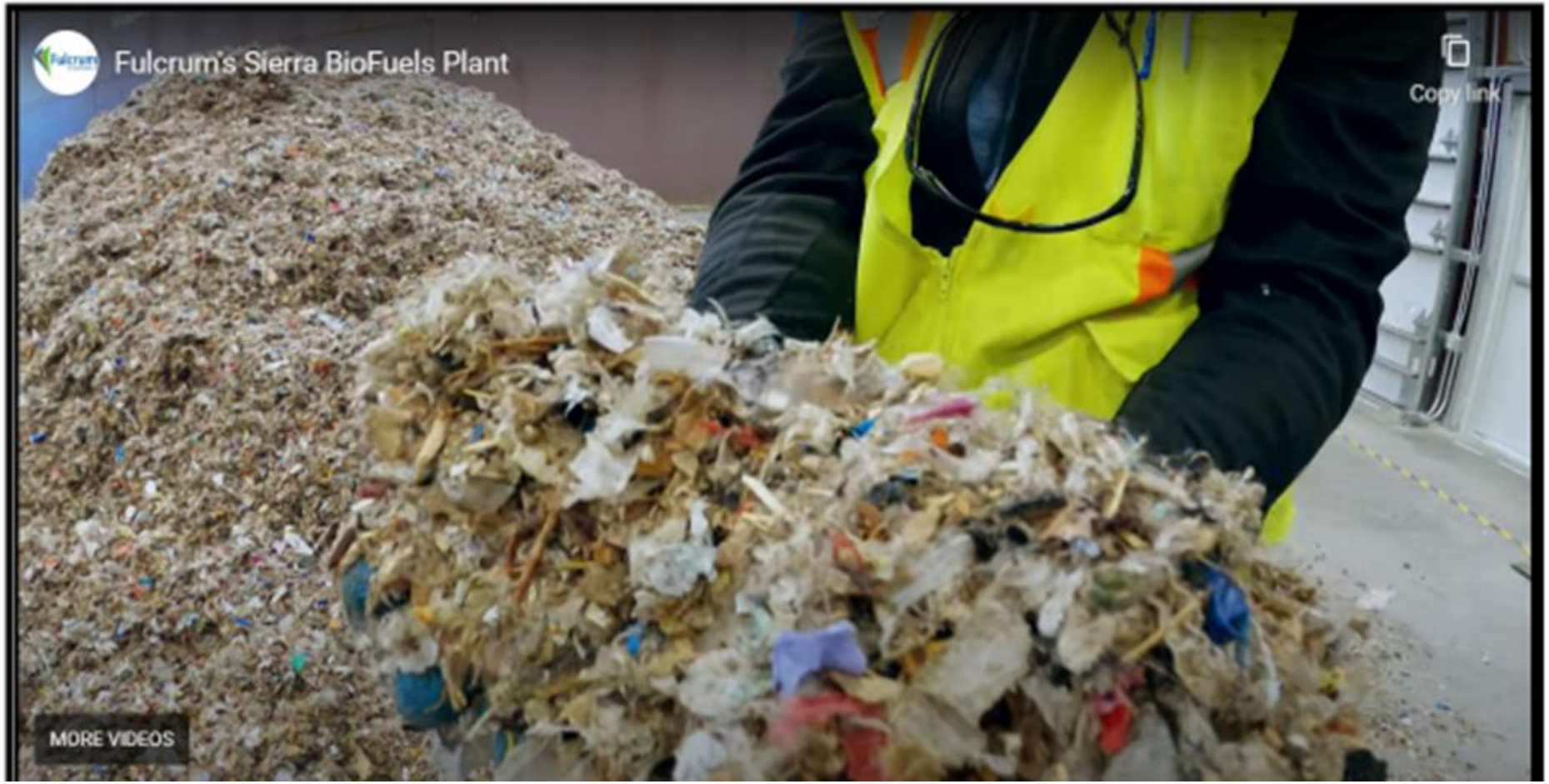
- Fulcrum Sierra Biofuels
- Red Rock Bio
- Other commercialization activities
- Comments on the political environment

Fulcrum Bioenergy/Sierra Biofuels

Fulcrum Bioenergy/Sierra Biofuels, Reno NV: (11MM GPY)

1) MRF operational since 2016; at landfill 10 miles from biorefinery
   a) 350,000 tons per year raw MSW => 175,000 tons per year prepared MSW
   b) 20 TPH throughput
2) Gasification/FT
   a) MSW feedstock/TRI indirectly heated fluid bed steam reforming gasifier
   b) Johnson Matthey DAVY™/BP fixed-bed FT
3) Phase I is for Fischer-Tropsch wax
   a) Wax to be refined by Marathon
   b) Other offtakers include United and Cathay Pacific, BP Air, World Fuels
   c) FT jet fuel capability to be added in Phase II
4) Plant is 'full scale'; scale up (3X) planned with parallel trains
   a) 12 new projects currently planned/underway
5) Status: Plan now undergoing start-up operations

Feedstock – Sorted MSW



Fulcrum BioEnergy/Sierra Biofuels

Plant Construction Activities, Late 2020

Red Rock Bio

Red Rock Bio, Lakeview, OR (15MM GPY)

1) Gasification to Fischer-Tropsch Jet Fuel
2) Technology providers
   a) Gasification: TCG Global
   b) FT technology: Velocys and Emerging Fuels Technology
      - Parallel FT trains
   c) Hydroprocessing: Haldor Topsøe
3) Feedstock: forest residue (166,000 dry tons per year)
4) Products: SAF, diesel, and naphtha
5) Offtakes: Southwest Airlines, FedEx
6) Status: anticipated construction completion; Q4 2022

Red Rock Biofuels Construction Progress

IEA Bioenergy

Other Commercialization Activities

San Joaquin Renewables; San Joaquin, CA

- Gasifier: Frontline BioEnergy RNG
  - Pressurized fluid bed (10 Bar)
  - Air or oxygen with steam (TarFreeGas®; PMFreeGas®)
- Feedstock: Ag wastes
- Product: RNG (15 million gallon-equivalents)
- Status: engineering in progress; approvals for injection in existing pipelines received

Mote

- Gasifier: SunGas Renewables
  - Pressurized fluid bed (10 Bar) with CCS
- Feedstock: Ag residues
- Product: low-carbon Hydrogen
- Status: initial stages of project planning

Other Commercialization Activities

Arbor Renewable Gas, Beaumont TX

- Gasifier: SunGas Renewables
  - MTG: Haldor Topsøe
- Feedstock: woody biomass
- Product: 1,000 BPD renewable gasoline (MTG)
- Status: Commercial production in 2024

Madera Gas, Houston TX

- Gasifier: SunGas Renewables (with CCS)
- Feedstock: woody biomass, 100,000 TPY each train
- Product: RNG; 5 production trains => 5B SCFY RNG
- Status: construction on first train in 2023; operational in 2024

Other Commercialization Activities

Velocys, Natchez MS and Immingham UK

- Velocys microchannel FT reactor
- Feedstock: woody biomass (Natchez); MSW (Immingham)
- Product: 35M GPY sustainable aviation fuel (Natchez); 20M GPY (Immingham)
- Status
  - Immingham: planning underway – start-up in 2027; BA fuel offtaker
  - Natchez Bayou Fuels: engineering unerway – start-up in 2027; SouthWest Airlines fuel offtaker

USA Bioenergy – Texas Renewable Fuels

- Gasification + Fischer-Tropsch
- Feedstock: woody biomass
- Product: SAF, renewable diesel, naphtha
- Status: Planning underway for first biorefinery in Bon Wier, Texas

Other Commercialization Activities

Lanzatech

- Gasifier: Sekisui (Japan), Ankur (India)
- Feedstock: biomass, MSW
- Product: bio-ethanol and other oxygenates
- Status: developmental work in progress

Aries Clean Energy

- Gasifier: Fluid bed and downdraft gasifiers for syngas production
- Feedstocks: ag waste and bio-solids
- Products: biochar and power
- Status: 3 projects operational (NJ, CA, TN)

Sierra Energy; Ft. Hunter Liggett, CA

- Gasifier: FastOx technology; blast furnace design (~2,200 ºC)
- Feedstock: 20 MTD military waste + woody biomass
- Product: 500 KWhe electricity + 1 BBL/D FT diesel fuel
- Status: operational

The Political Climate

- DOE: Liquid transportation biofuels coming back on the table
  - Sustainability: >70% life-cycle GHG reduction
  - Very strong emphasis on waste carbon feedstocks, SAF, and marine diesel products
  - Variety of SAF pathways under development (in addition to Fulcrum and RRB)
    - gasification => LanzaJet, Vertimass
    - Pyrolysis => Alder Energy
    - Arrested anaerobic digestion (volatile fatty acids upgrading) => Alder Energy

- Infrastructure bill ($1.2T) has large investments in hydrogen
  - Nothing specific called out for biomass
  - **DOE H2 Incubator Prize => Biomass Super Gasifier** (Indianapolis, IN)—an indirectly-heated pyrolytic gasification process to convert carbon-based feedstocks into syngas from which hydrogen can be extracted—with the remaining syngas used in a solid oxide fuel cell to generate power to run the system

- DOE has issued a roadmap to stand up 4-5 operating biofuels demonstration plants (each at ~1M GPY) by 2030
  - 3B GPY SAF is target by 2030 (BioEnergy Technology Office)
  - Gasification + FT is included as a key technology pathway

Thanks for your attention!

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