Unlocking Billions of Gallons of Installed Capacity for the Production of Cellulosic Fuels

Co-processing Bio-feedstocks in Petroleum Refineries

Biomass Research Development Initiative
Technical Advisory Committee
November 2018

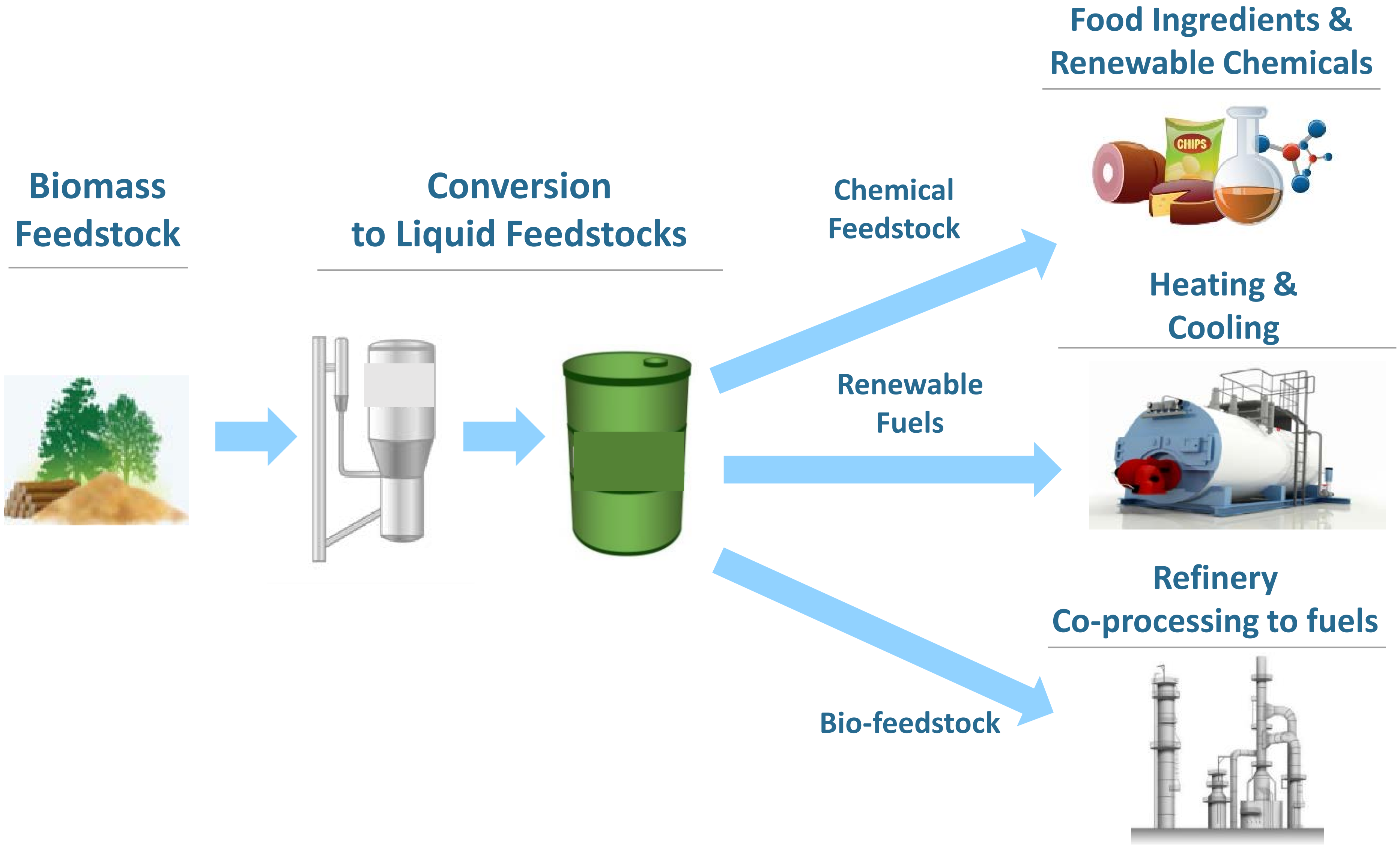
Jeffrey M. Jacobs

Jacobs was President and Chief Executive Officer of Ensyn Corporation from 2015 thru 2018 and a member of the company's board of directors. During this period Ensyn financed, constructed and brought into commercial production the world's largest fast pyrolysis plant. With its refinery partners, Ensyn also successfully demonstrated the co-processing of its renewable bio-feedstock with conventional petroleum feeds in fluid catalytic cracking units. Founded in 1984, Ensyn is a leader in the production of renewable, low-carbon chemicals and fuels and maintains direct operations in New York and Canada; and joint venture interests in the U.S., Brazil and Canada.

Previously, Jacobs spent more than 20 years with Chevron Corporation and its predecessor companies progressing thru the energy value chain from oil & gas production to refining. He retired as vice president of Chevron Technology Ventures and, in this capacity, identified, sponsored and demonstrated emerging technology and championed its integration into Chevron. Jacobs led strategic collaborations for developing advanced biofuels and championed their adoption into Chevron's refining and fuels assets. He led the formation of Catchlight Energy LLC and served as one of its Chairmen. The joint venture was launched by Weyerhaeuser and Chevron in 2008 to develop advanced biofuels from forest-based biomass. Jacobs was previously responsible for the development of Chevron's hydrogen business and evaluated technologies and business models that enabled its use as a transportation fuel.

Jacobs is currently Chairman of the U.S. Department of Energy's National Renewable Energy Laboratory's BioEnergy Technical Review Panel. Until his retirement from Chevron, Jacobs was a member of the Executive Steering Group for the Department of Energy's U.S. Drive Initiative. Jacobs was previously a member of the Board of Directors of the National Hydrogen Association and Fuel Cells Canada. In addition, he served as the Chairman of the Commercial Advisory Board for the U.S. Department of Energy's Algae Testbed Public-Private Partnership centered at Arizona State University.

Biomass Densification Can Supply Renewable Chemicals, Heating Fuels and Bio-feedstocks for Refineries



For Example, Properties of Solid & Liquid Wood Are Similar

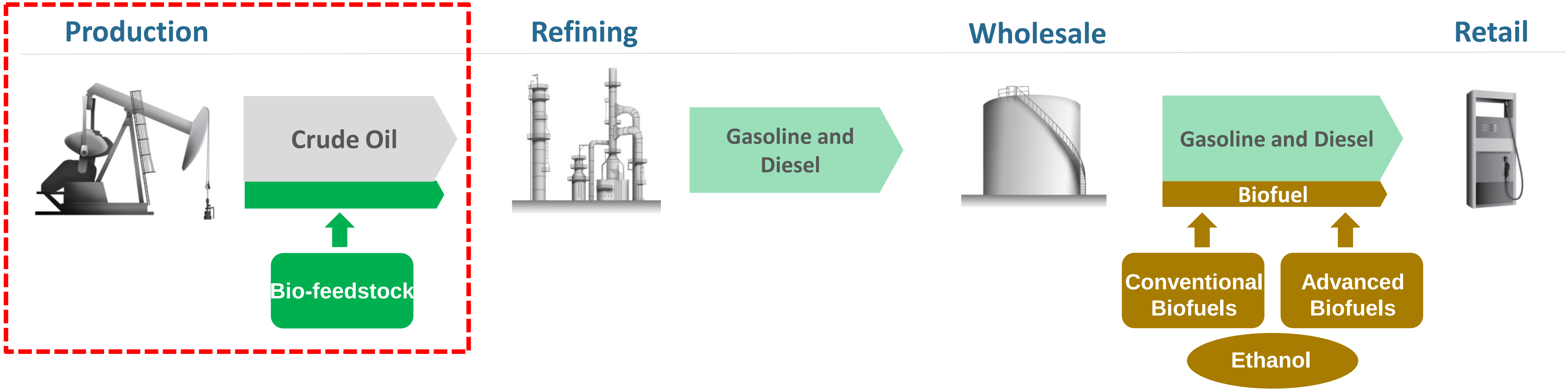
Property	Wood	Liquid Wood
Heating Value (MJ/kg)	17.9	18.1
Molecular Mass	162	164
Empirical Formula	$C_6H_{10}O_5$	$C_6H_{12}O_5$
Phenolic Content (lignin)	20-30%	20-30%

Co-processing Can Meet the Demand for Billions of Gallons of Cellulosic Fuels

- ✓ **Leverages industry know-how and existing installed capacity**
- ✓ **Enables the petroleum industry to participate in the economic expansion of renewable fuels bases**

By supplying renewable bio-feedstocks to the refinery sector, we can leverage existing installed capacity to produce billions of gallons of cellulosic fuels

Refinery Co-processing Overview

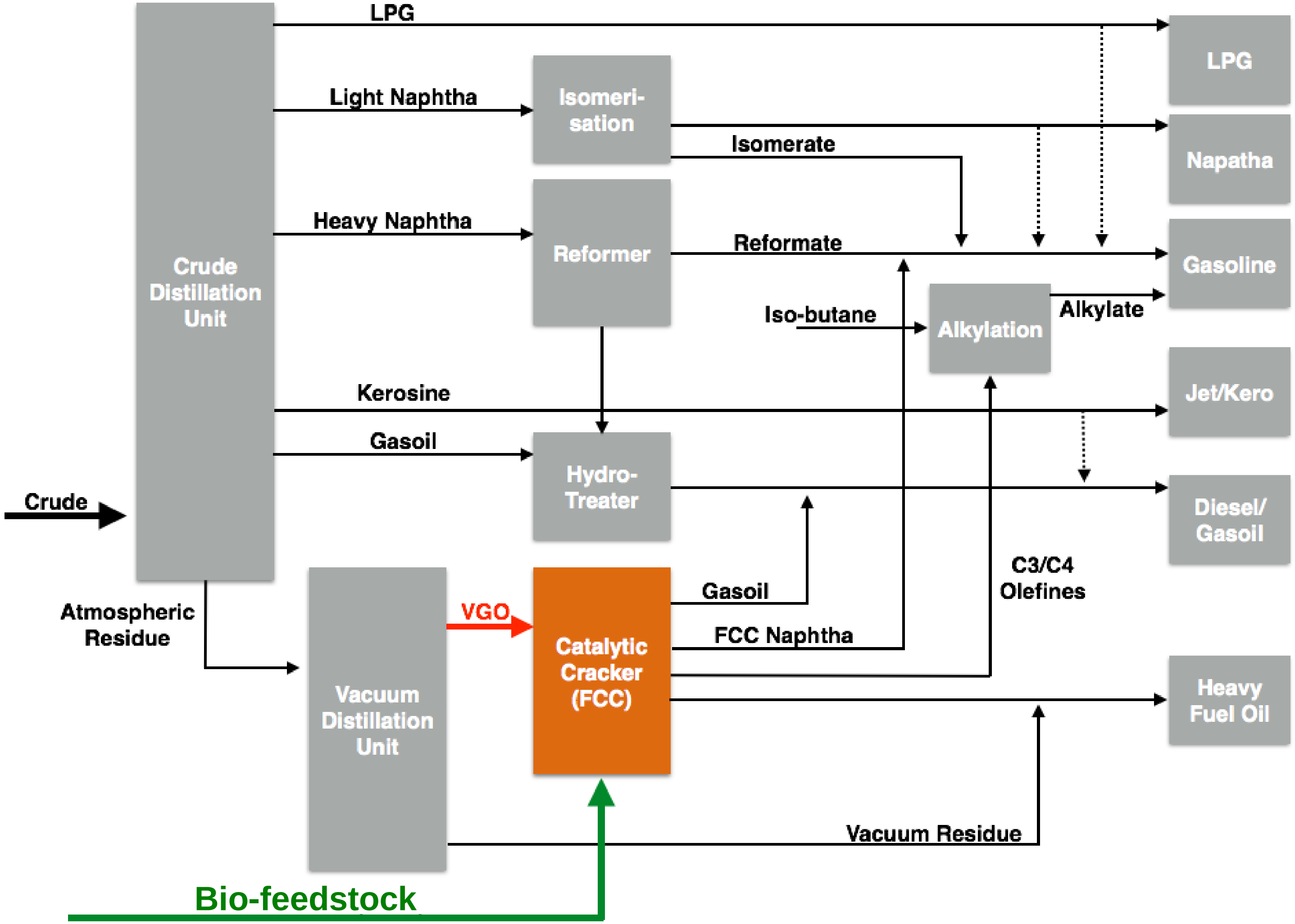


Advantages of Co-processing Bio-feedstocks

- ✓ Leverages existing fuels infrastructure in refining and distribution – pipelines, terminals and retail facilities
- ✓ Reduces GHG emissions of transportation fuels by up to 90%
- ✓ Does not compete with refining sector for share of gasoline and diesel markets, yet continues to allow for downstream blending
- ✓ Generates significant financial returns for refiners by reducing their regulatory compliance costs
- ✓ Requires limited capital investment by refiners to implement
- ✓ Limited or no effect on refinery production yields and operating costs

Co-processing of bio-feedstocks can bring volumes of cellulosic fuels quickly and cost-effectively to market, enabling the refining industry to be part of the solution

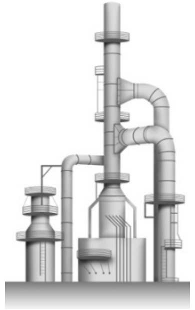
One Example of Refinery Co-processing



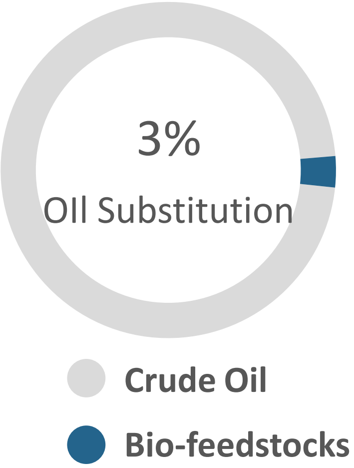
Source: Meyers' Handbook of Petroleum Refining Processes

Advantages to Scale via Refinery Co-processing

U.S. Fluid Catalytic Cracker Market



93 FCC Units
5.5 million barrels / day
84.4 billion gallons / year



Bio-feedstock Required to Supply 3% of U.S. FCC Capacity

127 20 mmgpy Units
165,267 barrels / day
2.5 billion gallons / year

With commercial scale operations and low production costs, the existing fuels production infrastructure represents the fastest way to scale cellulosic biofuels

Source: 2017 O&G Journal Refining Survey.

Benefits for Multiple Industries and Stakeholders

Domestic bio-feeds co-processed with crude oil in refineries

Improves forest management and reduces wildfire risk

Provides economic growth in rural and underemployed regions

Up to 90% reduction in GHG emissions

Does not compete with the food supply chain

One Significant Barrier to Market Entry Remains

- ✓ Refiners cannot currently obtain a RIN by co-processing qualifying bio-feedstocks produced at a different location with conventional petroleum feeds at their refineries
- ✓ EPA staff has expressed concerns that the co-processing of bio-feedstocks produced at a location different from the finished renewable fuels poses a compliance concern and are not expressly permitted under the current RFS regulations
  - Staff view that enablement of their “REGs rule” is required to correct the situation
  - Resolution of this interpretation is not an identified priority task for staff
- ✓ *In the interim, why not allow individual applicants for Part 80’s for co-processing to meet the same documentation criteria as that proposed in the REGs rule?*

Removing this barrier will unlock billions in investment and bring cellulosic fuels to market at the scale contemplated by the RFS

Summary

- ✓ Co-processing is a technology breakthrough to produce sustainable cellulosic transportation fuels
  - Demonstrated on a commercial scale in U.S., Canadian and Chinese refineries
  - Full commercial implementation in the U.S will occur when the regulatory barrier to entry is resolved
- ✓ Provides obligated parties with a pathway to generate and satisfy the EPA cellulosic RVO / RINs
- ✓ Low cost technology revamp solution that can be easily implemented in existing refining units
- ✓ Determination of the percentage of modern carbon in co-processed fuels best done through the statistical mass balance methodology currently in use within refinery units
- ✓ Mass Balance avoids the =/- 3% analysis error and the lack of repeatable results associated with 14C
  - Controlled ASTM inter-lab testing shows error to be+/- 3 pmC (absolute), (with application of natural abundance correction), in the range 8-100 pmC
  - Data confirmed by Norton and Devlin, Bioresource Technology, 97, (2006), pp 2084-2090.
  - ASTM warns for additional and unquantified error when complex mixtures of aquatic and terrestrial materials are used