Ethanol to Ethylene Conversion, Hummingbird Technology

July 2018

TechnipFMC Process Technology

TechnipFMC Process Technology (PT)

- A global technology licensing business that combines leading proprietary process technologies from TechnipFMC, Badger, Zimmer and others
- Offers a market-leading portfolio of technologies, proprietary or through alliances in Refining, Syngas, Petrochemicals, Polymers and Gas Monetization
- In line with TechnipFMC's strategy to focus on technology to differentiate us from our competitors
- Headquartered in Houston with centers around the world
- R&D and piloting facilities in US and Europe

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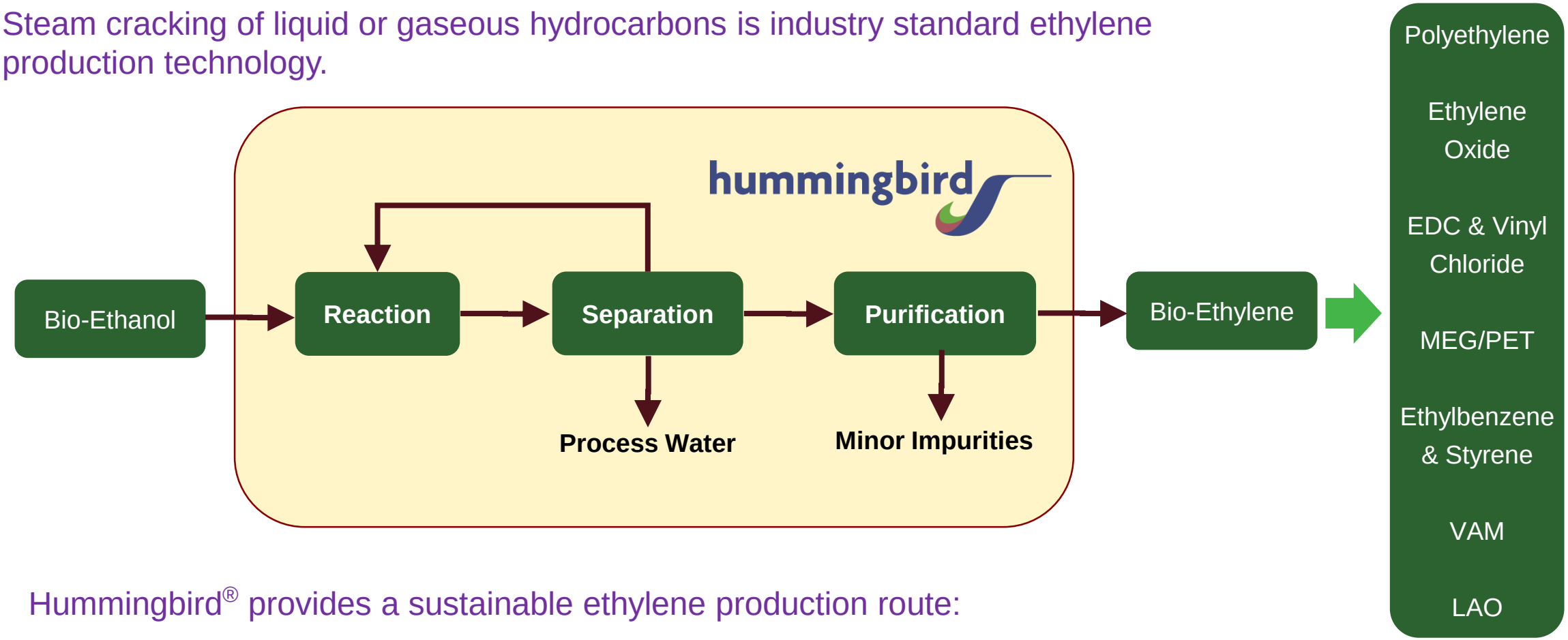
Ethylene Production From Sustainable Feedstock

Steam cracking of liquid or gaseous hydrocarbons is industry standard ethylene production technology.



Hummingbird® provides a sustainable ethylene production route:

Bioethanol dehydration to produce bio-ethylene

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Ultra-Selective Ethylene Production Process

Hummingbird® is an IChemE award winning gas phase reaction process, using a proprietary hetropolyacid heterogeneous catalyst.

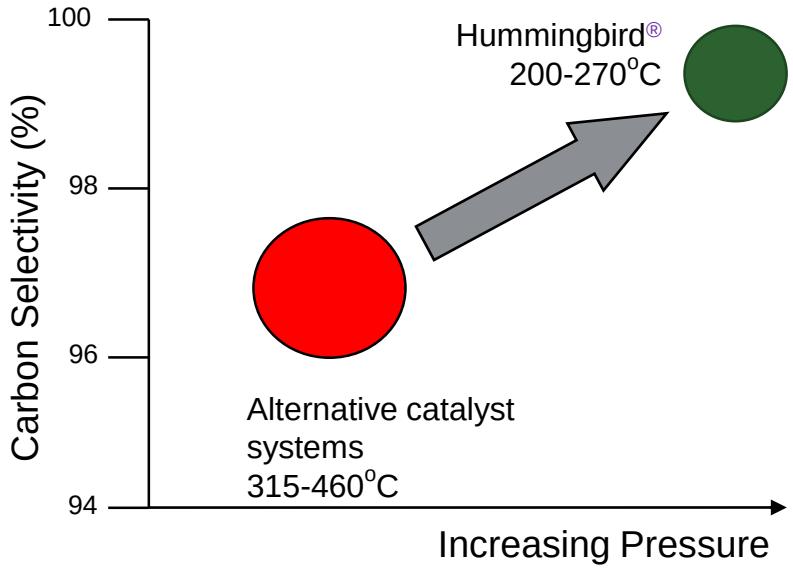
Ethanol → Ethylene

$$C_2H_5OH \xrightarrow[\text{via DEE}]{H^+} C_2H_4 + H_2O$$

The reaction occurs via diethyl ether [DEE] intermediate, with

Ultra-selective performance:

- With over 99% carbon conversion of ethanol to high grade ethylene.
- Low temperature operation.
- Simple separation and purification.
- Reduced utility requirements.



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Demonstrated Technology

The process has been **demonstrated in a fully recycling facility** with purification columns similar to a commercial plant.

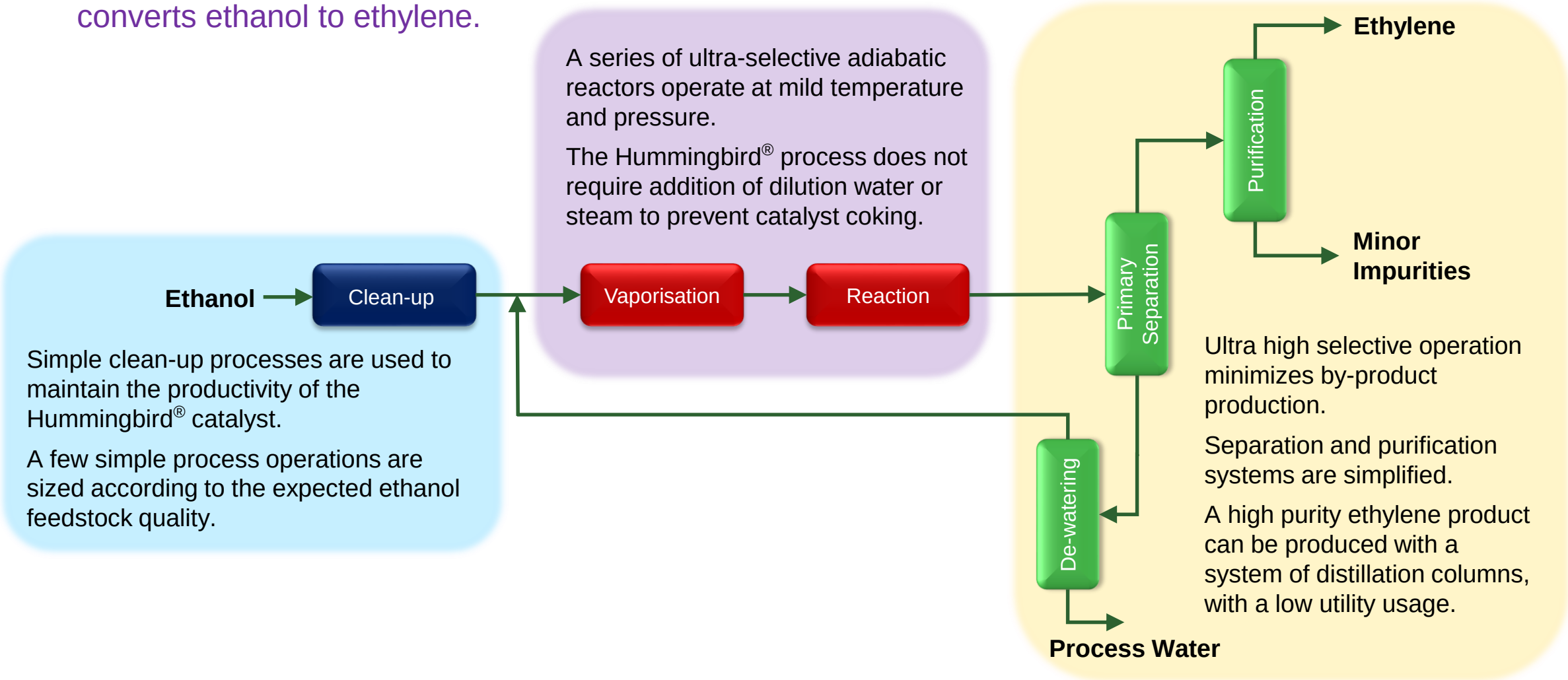
- The plant was operated from 2009 to 2015 for over 36,000 hours.
- Gained understanding on start-up, shutdown, and steady state operations.
- Catalyst lifetime was proven for 2 years operation.

The programme completed by producing commercial grade ethylene product using commercial grade ethanol feed and commercially produced Hummingbird® catalyst.

Hummingbird® Process Configuration

A simple Process Flow Scheme

converts ethanol to ethylene.



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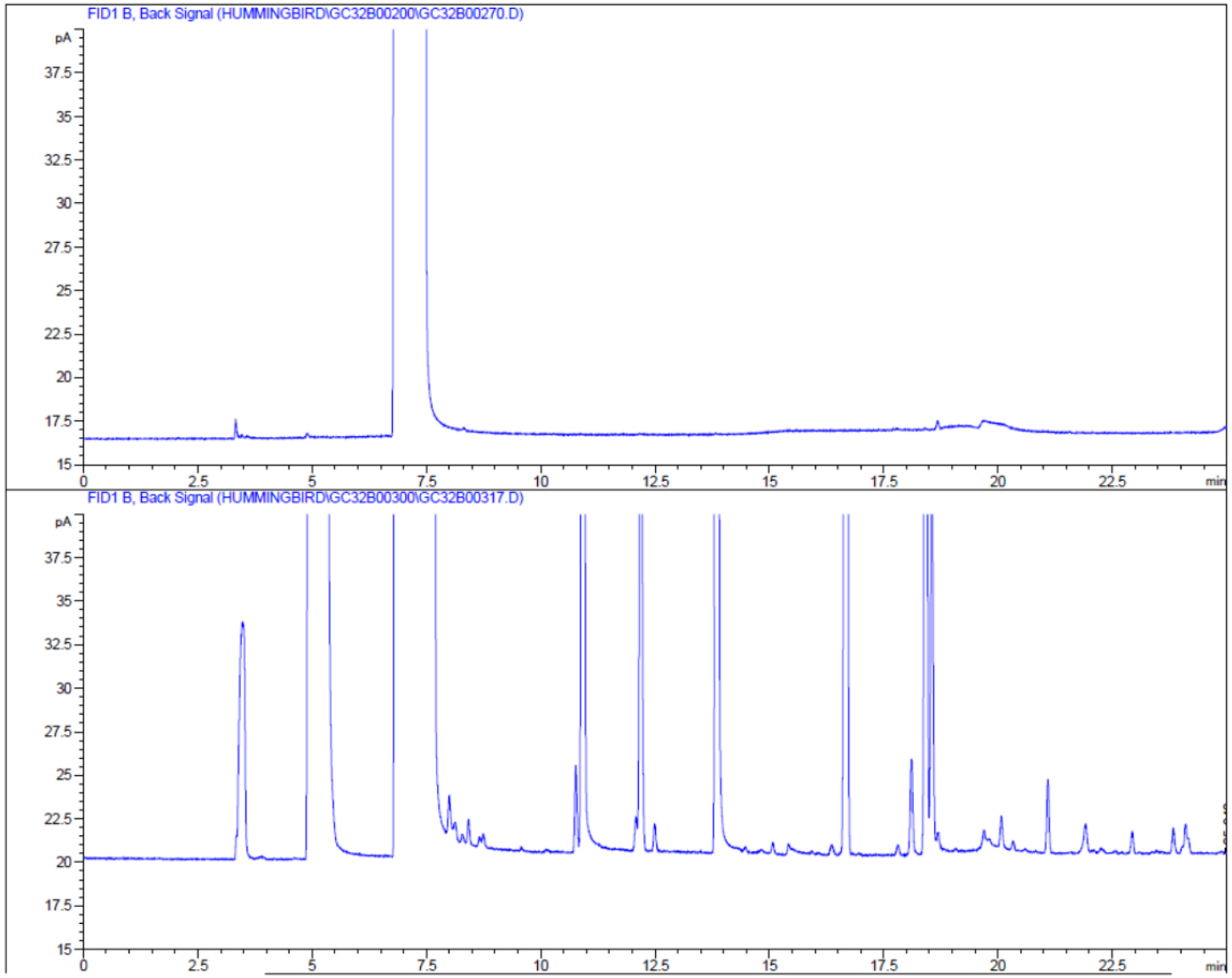
Typical GC Analysis Output

Bioethanol #1

- A typical high purity 1G Ethanol

Bioethanol #2

- A potential fuel grade ethanol



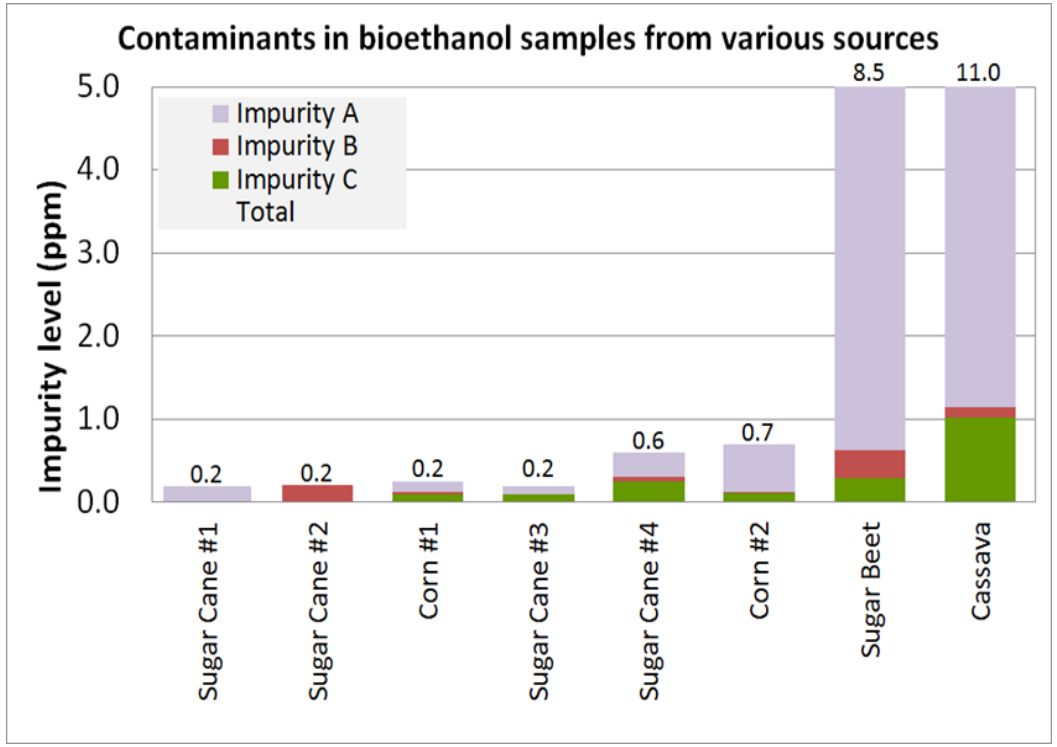
Designing for Bioethanol Impurities

Hummingbird® technology includes an bioethanol clean-up ‘toolkit’:

- Bioethanol is analysed for certain trace chemicals.
- Design of pre-treatment unit and E2E process is tailored to analysis.
- Growing reference library of commercially available bioethanols, with over 60 ethanol samples already tested.

Process designs can accommodate a variety of bioethanol feedstocks.

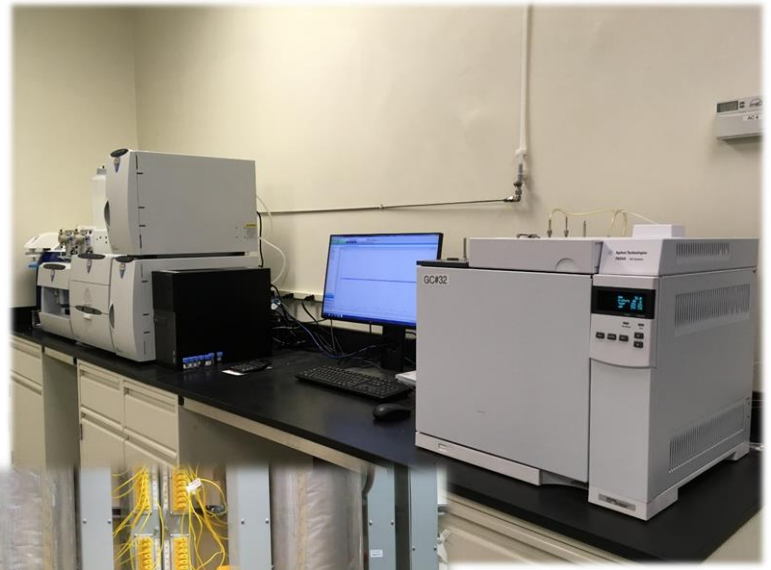
- Process design to characteristics of specific bioethanol feedstock.
- Opportunity to process less expensive bioethanols.



Ensuring Process Performance & Development

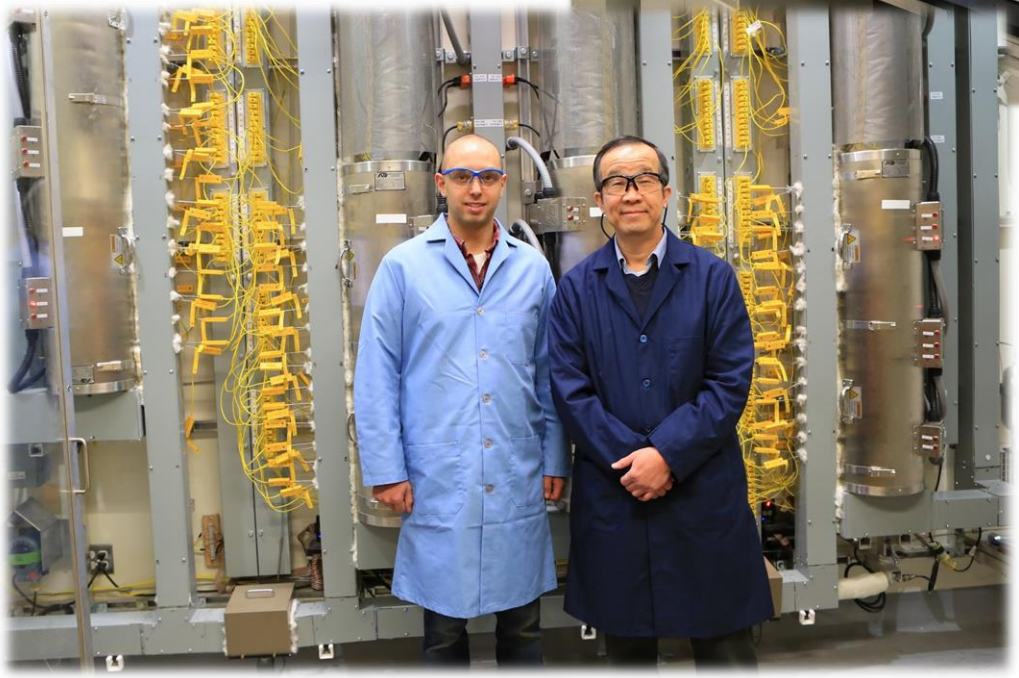
The process can use a variety of bio-ethanol feedstocks.

- Hummingbird® was developed to use fuel grade bio-ethanol feedstock, which has variable quality.
- Bioethanol is analysed for certain trace chemicals.
- Design of the process is tailored to the bioethanol analysis.



TechnipFMC pilot plant

- Providing an accurate platform for process design and performance guarantees.
- Assures Hummingbird® catalyst manufacturing quality.
- And is used to develop technology improvements.



Thank you.

Paul Langston

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