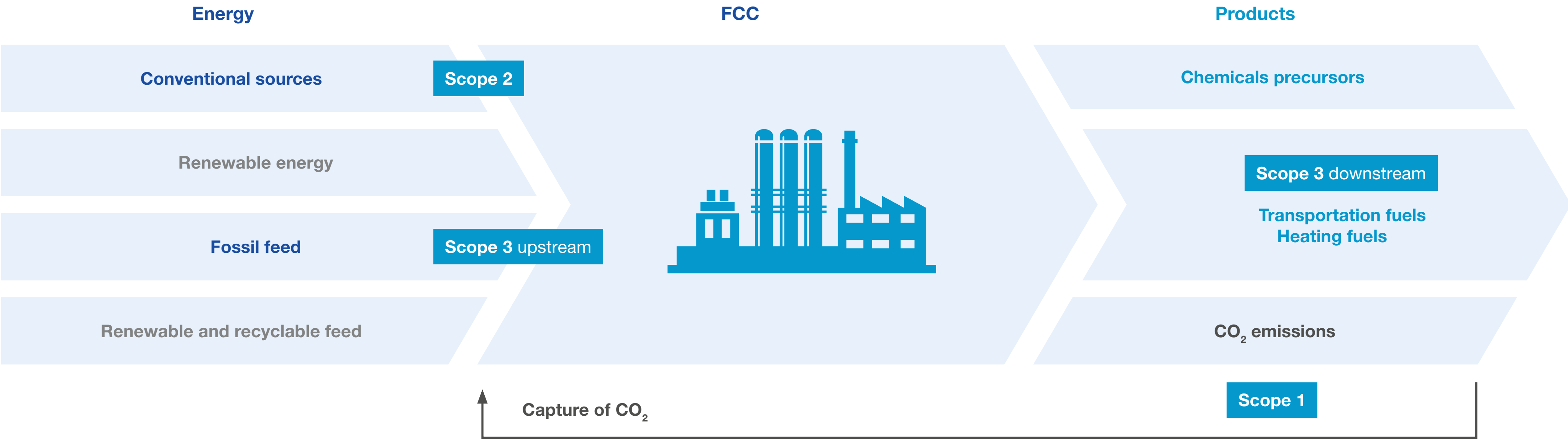
We create chemistry

Operating FCCs more sustainably by supporting the co-processing of alternative feeds

Introduction and need

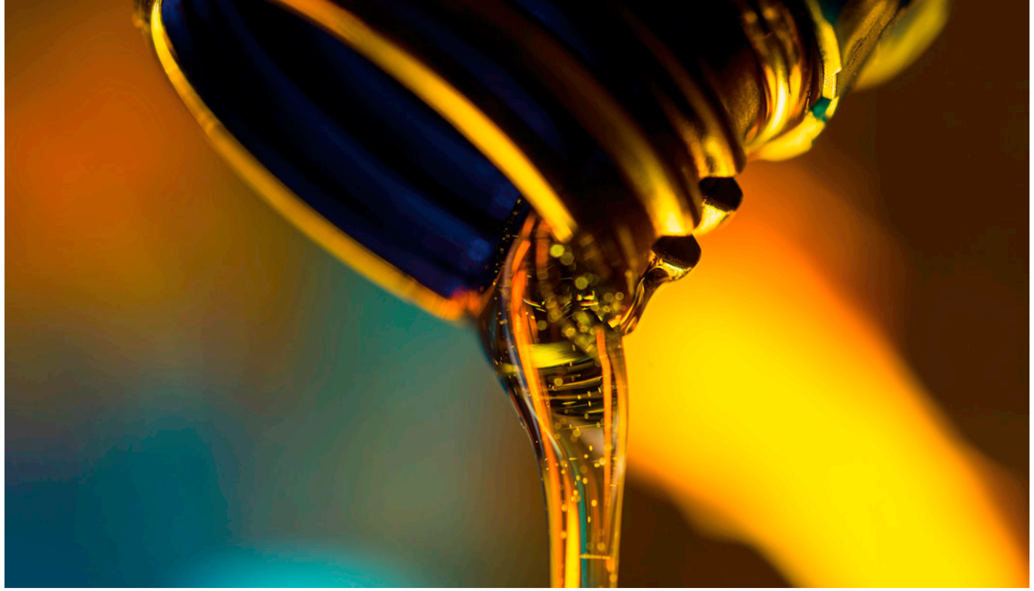
Vision of low carbon FCC of the future

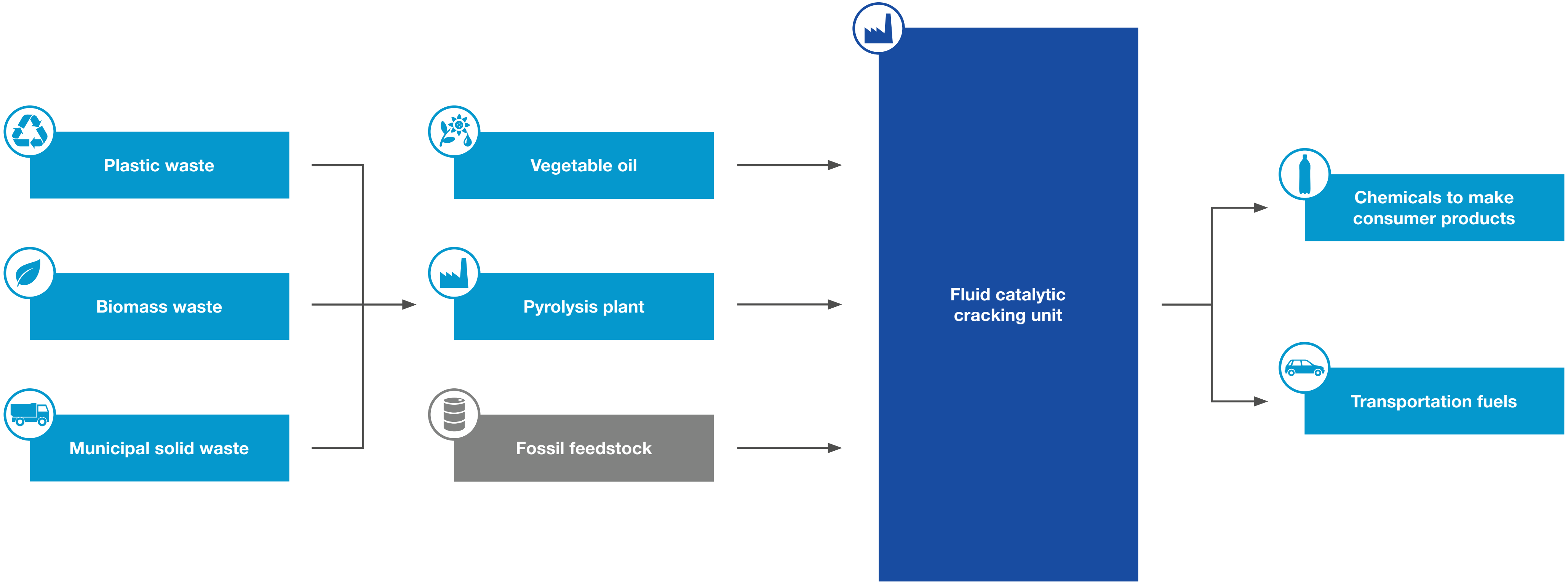


- To live in a more sustainable world, refiners are exploring ways to lower their carbon footprint
- Sources of FCC Carbon emissions FCC
  - **Scope 1** emissions from burning coke
  - **Scope 2** emissions related to energy inputs (fairly small for FCC)
  - **Scope 3** Upstream emissions for production and transport of feed
  - **Scope 3** downstream for combustion of transportation fuels made from FCC

BASF Refining Catalyst enables the partial replacement of fossil-based feedstocks with waste or renewable streams to ensure a sustainable future

- With feeds from waste, plastics, or biological sources that have lower CO_2 footprints over their life cycle
- Co-processing of these feeds in FCC offers a real opportunity to lower Scope 3 emissions associated with refineries





We are combining learnings from our customers, partners, and collaborators to build the solid technical foundation for future work

Customers, Collaborators and Partners

Realistic Feedstocks

Very diverse, varying composition & contaminants

Pro	Provides us broad experience
Con	Fundamentals can be obscured by complexity of feed & processing unknowns

Model Feedstocks

Controlled preparation of renewable feedstock

Pro	Allows for methodical experimentation
Pro	Allows exploration of nontraditional applications of catalytic cracking

Our "library of feedstocks" is used to identify challenges and select topics to explore in greater depth

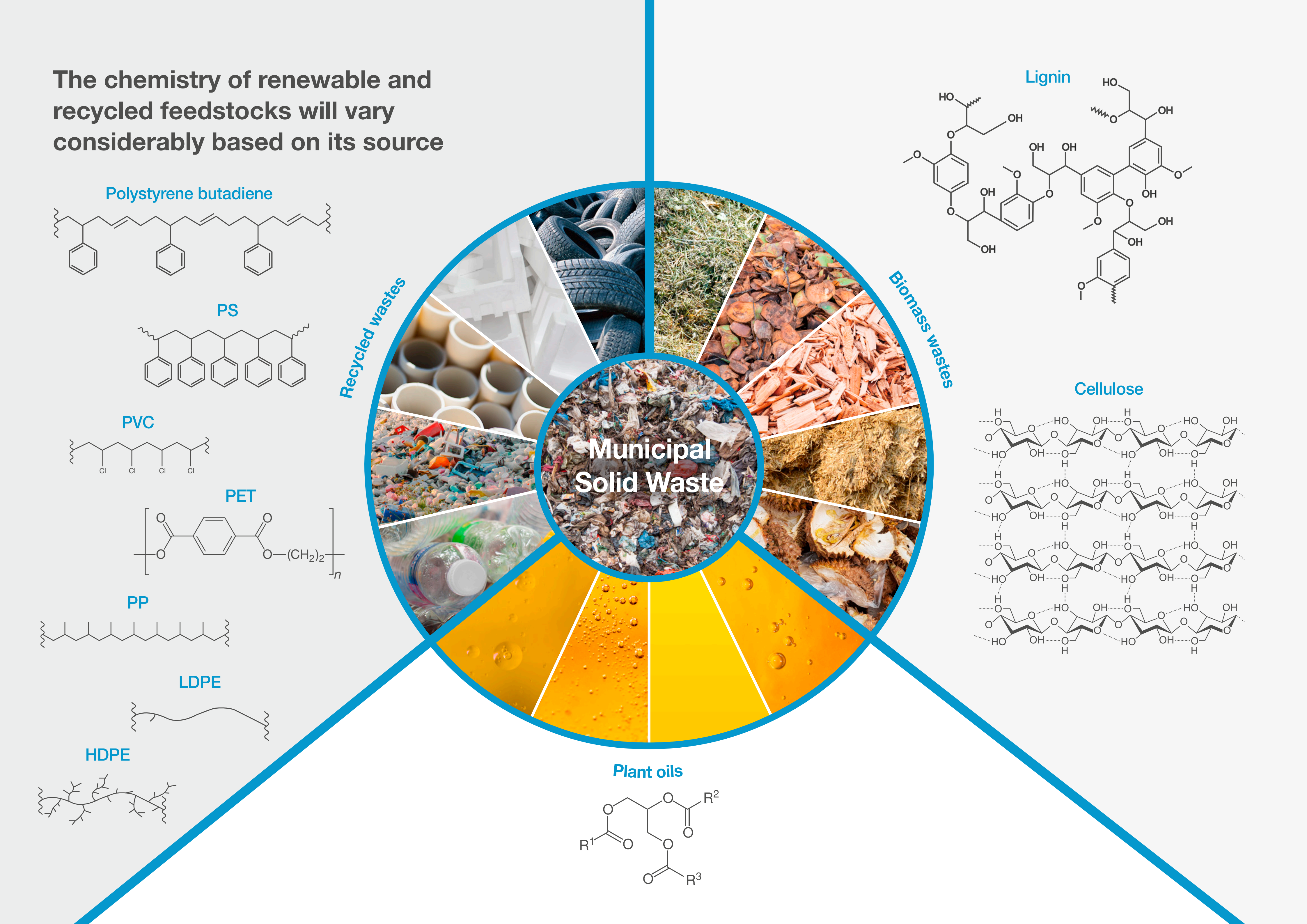
Topics explored in greater depth →

Co-processing vegetable oils in FCC

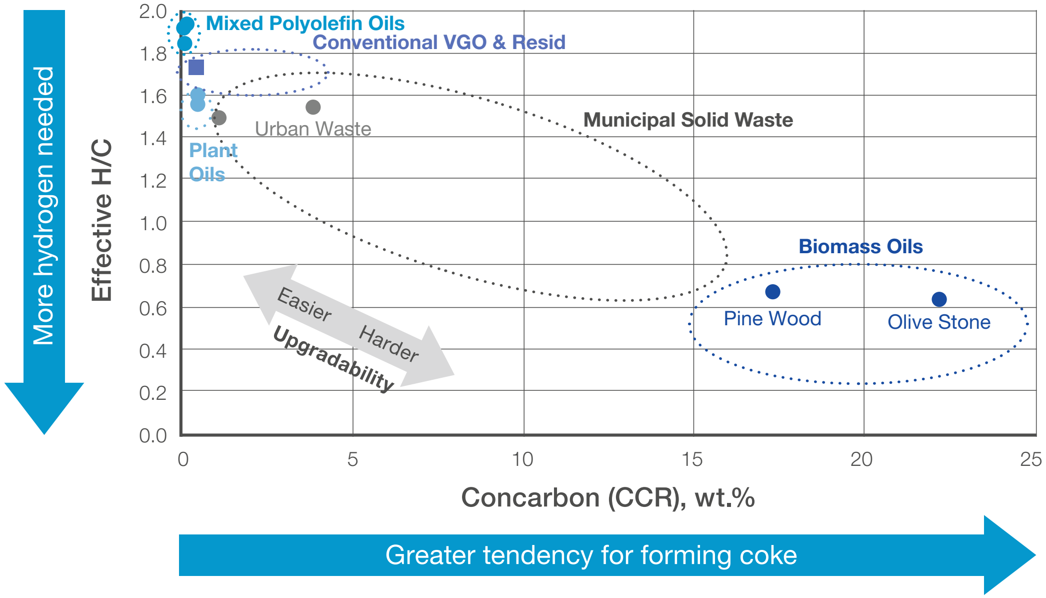
Model v. realistic mixed plastic waste

Strategies for upgrading plastic waste

Upgrading biomass (& MSW)


The chemistry of renewable and recycled feedstocks will vary considerably based on its source
Polystyrene butadiene
PS
PVC
Cl
PET
O—(CH2)2
n
PP
LDPE
HDPE
Recycled wastes
Municipal Solid Waste
Biomass wastes
Lignin
HO
OH
Cellulose
Plant oils
R1
R2
R3
O

Ability to crack feeds in FCC will vary depending on the source of the feed



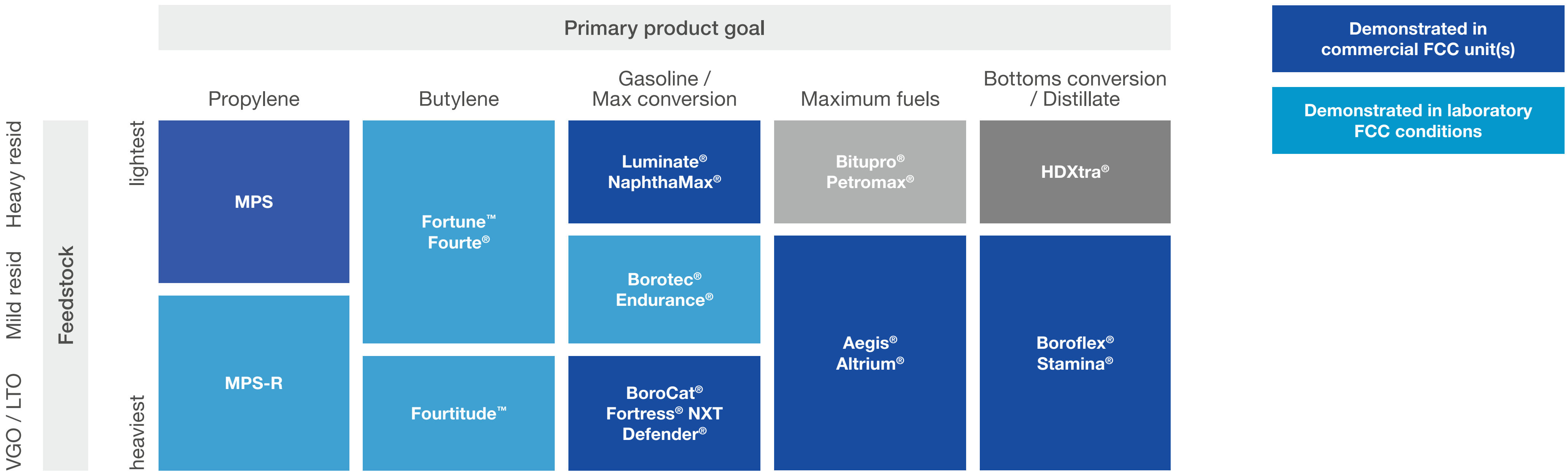
Alternative feeds are challenging due to contaminants

Feedstock	V ppm	Na ppm	K ppm	Fe ppm	Ca ppm	Mg ppm	P ppm	Zn ppm	Al ppm	Mn ppm	Cl ppm
Vegetable oil	0.5 – 1	0 – 5	1 – 130	0.2 – 12	0 – 60	0 – 1	0 – 250	0 – 2.5	0.1 – 0.2	<0.1	
Used Cooking oil	0.5 – 1	0 – 5	1 – 130	0.2 – 12	0 – 60	0 – 1	0 – 250	0 – 2.5	0.1 – 0.2	<0.1	
Animal fat	0.5 – 1	0 – 5	1 – 130	0.2 – 12	0 – 60	0 – 1	0 – 250	0 – 2.5	0.1 – 0.2	<0.1	
Biomass pyoil		5 – 500 (Na + K)			4 – 600	0.7 – 12					
Plastic pyoil	0.1	0.7		<0.1	300 – 400			100 – 200	<0.5		400 – 500

Catalytic mitigation strategies for each co-processing challenge

Challenge	Vegetable oils	Plastic pyoils	Biomass pyoils	MSW pyoils	Mitigation strategies
High chlorides		⚠	⚠	⚠	Use catalysts without Cl-binders to increase tolerance to Cl deposit issues.
High alkali metals / low conversion	⚠	⚠	⚠	⚠	Minimize fresh catalyst Na to give highest tolerance to added alkali metals. Use Valor technology to maintain conversion.
Dehydrogenation metals		⚠	⚠	⚠	Use advanced metal passivation technology such as Boron Based Technology (BBT) to reduce coke and hydrogen.
High coke / CCR			⚠	⚠	Use BBT / Valor® technologies. Use in situ high zeolite surface area to maximize coke selective cracking.
Impacts in LPG / gasoline split	⚠	⚠	⚠	⚠	Use ZIP to offset any LPG olefins impacts. Increase catalyst acid site density.

BASF catalysts have been used in FCCU co-processing



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About us

BASF's Catalysts division is the world's leading supplier of environmental and process catalysts. The group offers exceptional expertise in the development of technologies that protect the air we breathe, produce the fuels that power our world and ensure efficient production of a wide variety of chemicals, plastics and other products, including advanced battery materials. By leveraging our industry-leading R&D platforms, passion for innovation and deep knowledge of precious and base metals, BASF's Catalysts division develops unique, proprietary solutions that drive customer success.

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