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Gulf Downstream Association

International
Downstream Conference
& Exhibition

23rd – 25th October 2018
Kingdom of Bahrain

K-SAAT – A Break-through Solid Acid Alkylation Technology

EDWARD GRIFFITHS

KBR
TECHNOLOGY

Agenda

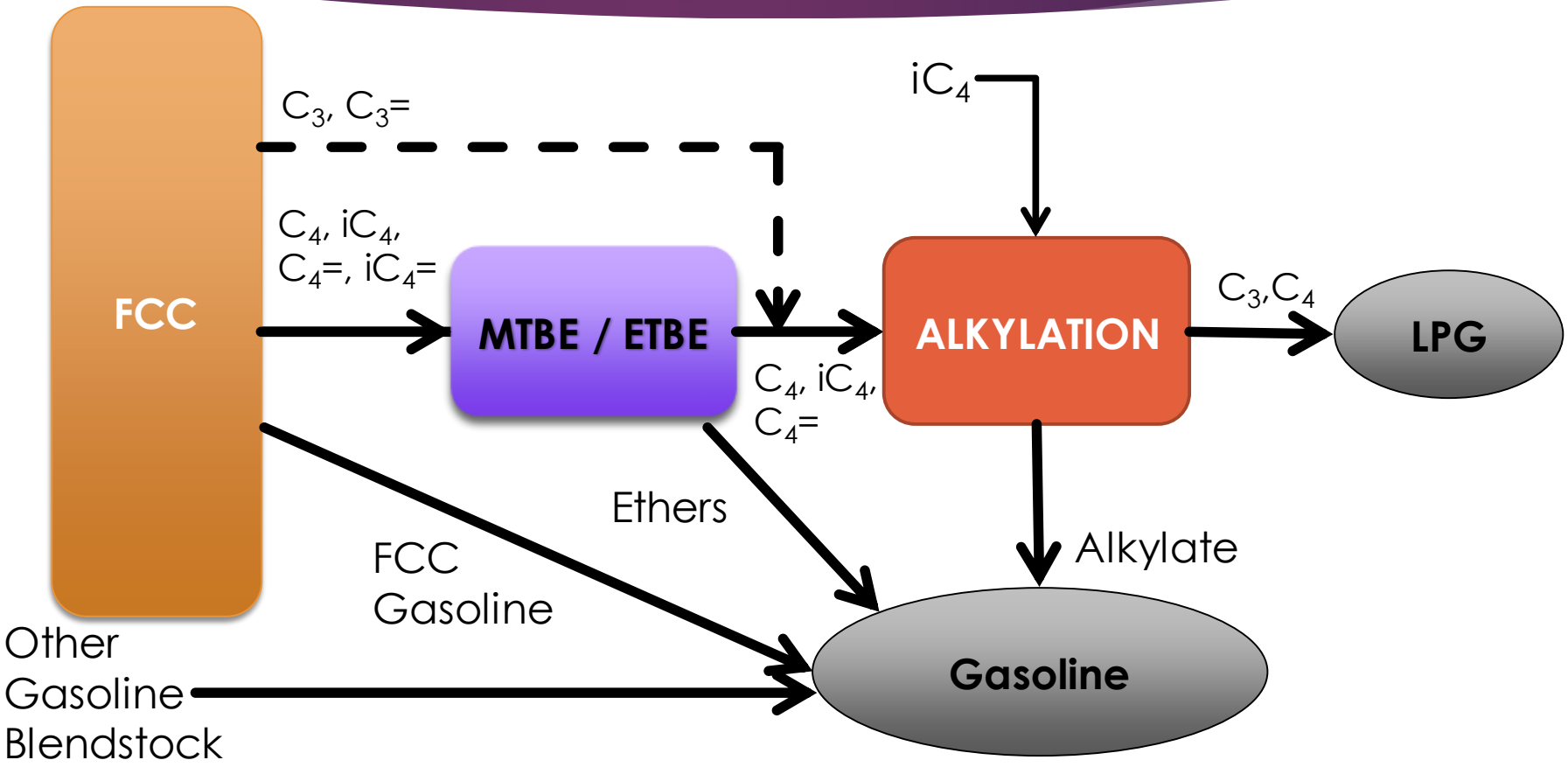
- Alkylation Overview
- Moving Beyond Liquid Acids
- K-SAAT Overview
- Benefits of K-SAAT
- Commercialization

Gasoline Blend Components

	C4	LSR	Isomerate	Other Naph	FCC Light Naph	FCC Heavy Naph	Alkylate	Reformate	Ethers	Ethanol
RON	-	- -	- -	?	+	-	+ +	+ +	+ +	+ +
MON	+	- -	- -	?	-	- -	+ +	+ +	+ +	+ +
RVP	- -	- -	- -	?	- -	+ +	+ +	+ +	+ +	- -
E70	- -	- -	- -	?	- -	+ +	+ +	+ +	+	- -
FBP	+ +	+ +	+ +	?	+ +	-	+ +	-	+ +	+ +
Olefins	+	+ +	+ +	?	- -	-	+ +	+ +	+ +	+ +
Aromatics	+ +	+ +	+ +	?	+ +	+	+ +	- -	+ +	+ +
Benzene	+ +	?	+ +	?	-	+ +	+ +	?	+ +	+ +
Oxygen	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	- -	- -

Alkylate is the preferred premium gasoline blendstock

Alkylation (in the Refinery)



C3 / C_4 Olefins + iso-Butane ⇒ Alkylate

Moving Beyond Liquid Acids

- Challenges of Liquid Acids
  - High maintenance expense
  - Safety, Environmental and liability issues
- Solid Acids offer a new opportunity
  - Reduced Maintenance expenses
  - Lower Chemical Inventory
  - Inherently Safe Technology
  - Tunable (Resemble FCC Catalysts)

Solid Acids surpass Liquid Acids in many aspects

Solid Acid Catalyst Advantages

Catalyst	Tunable Parameters	Advantages
Liquid Acid	None	

Solid Acids	• Chemical Variables
	  • Acid Site Strength
	  • Acid Site Density
	  • Acid Site Type
	• Physical Variables
	  • Pore Size
	  • Pore Configuration
	  • Particle Size
		• Increase Octane
		• Decrease Olefin polymerization
		• Eliminate ASO
		• Reduce RVP

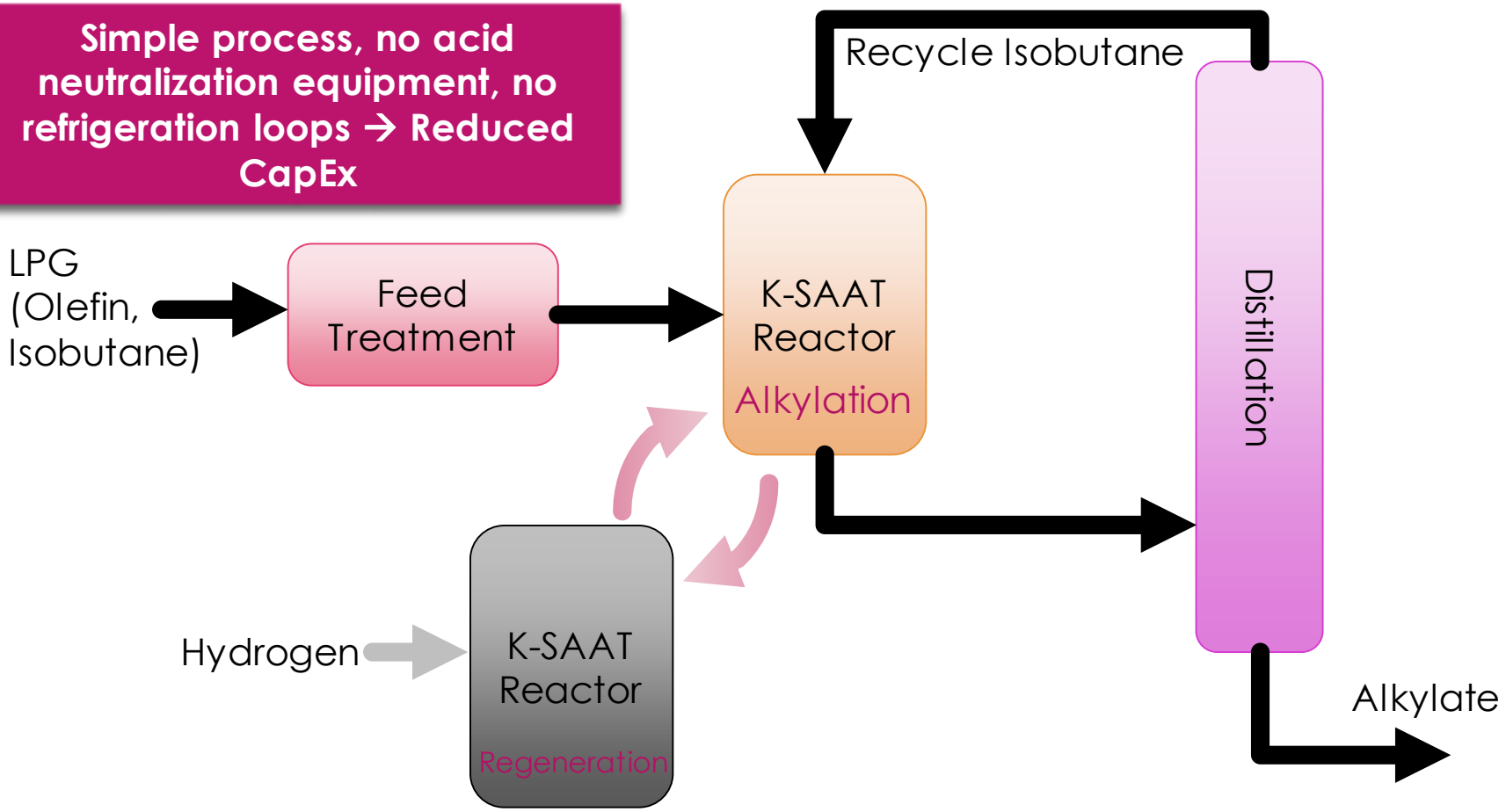
>> Improved control & safety, improved product & reliability <<
>> improved economics <<

ExSact Catalyst

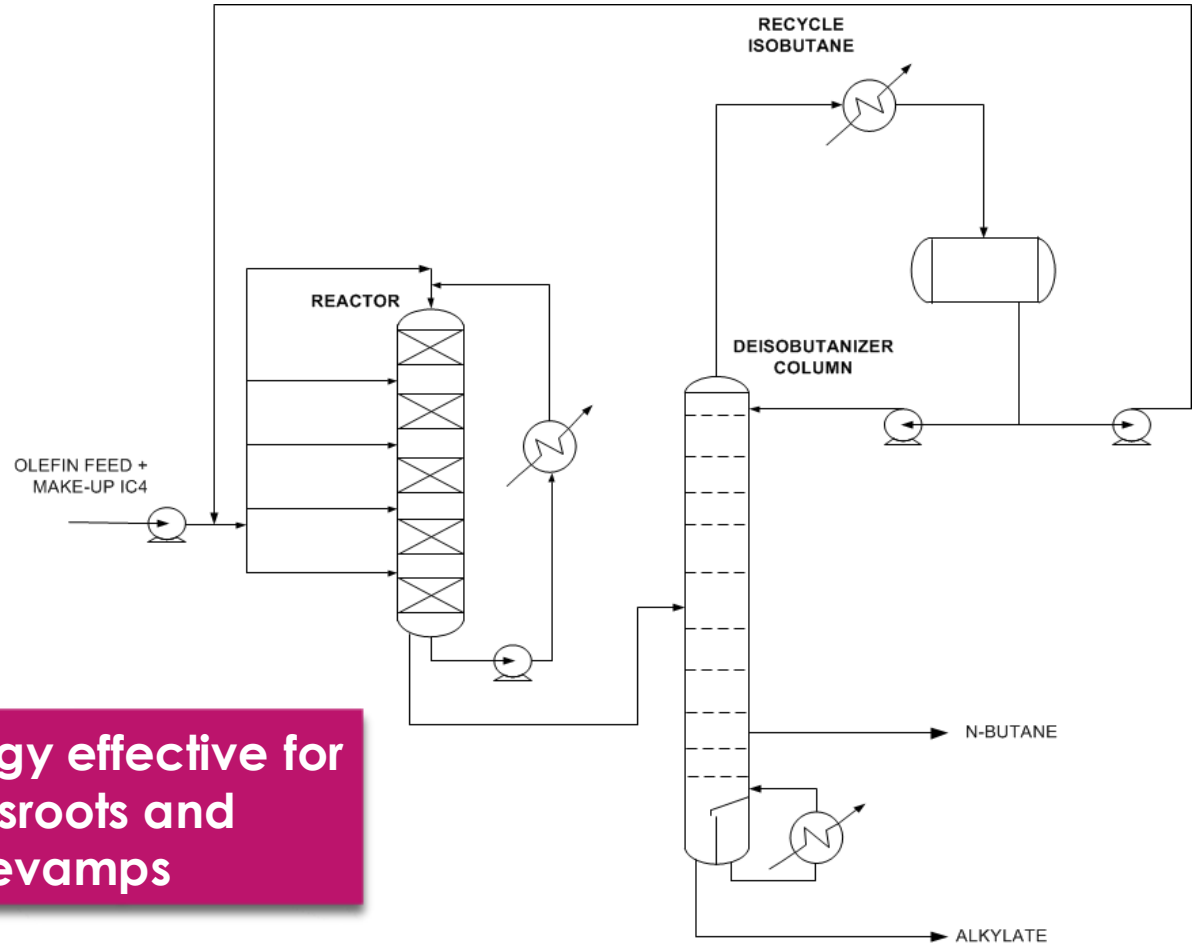
- Zeolite catalyst
- Precious Metal Free Catalyst
- Produces high octane alkylate
- Eliminates Acid Soluble Oils (ASO)
- Regenerated using hydrogen
- 30 times longer Alkylation Cycle than other Solid Acid catalysts

K-SAAT Conceptual Scheme

Simple process, no acid neutralization equipment, no refrigeration loops → Reduced CapEx

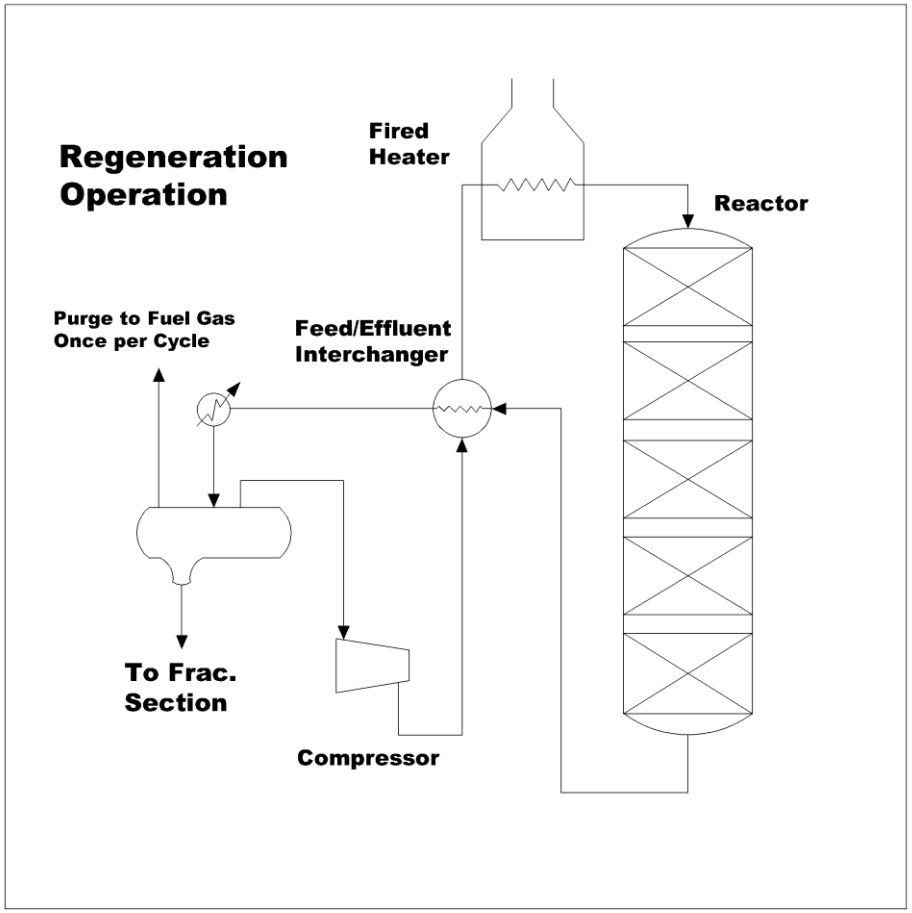


Process Scheme



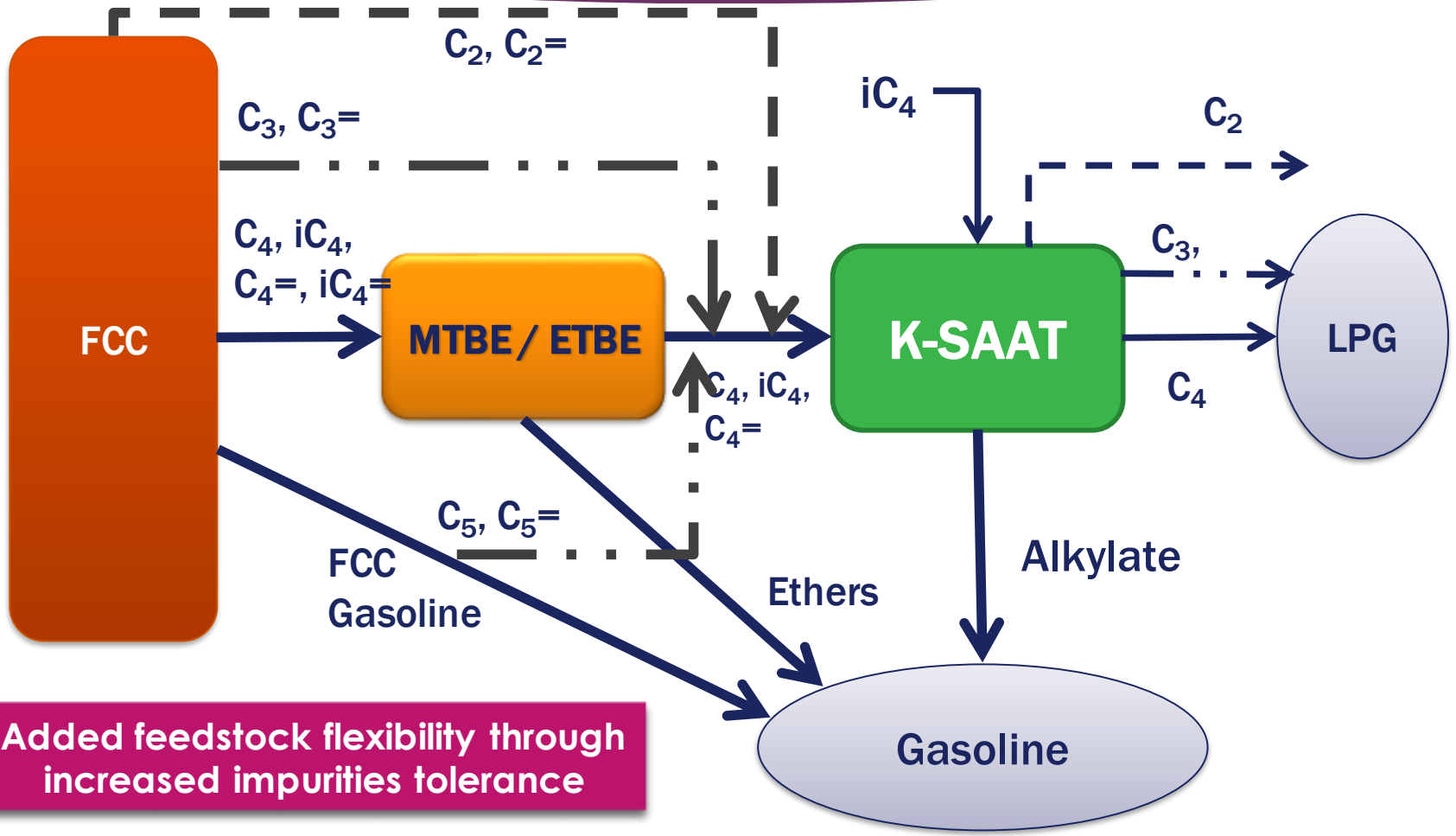
Technology effective for Grassroots and Revamps

Process Scheme - Regeneration



Reformer Grade Hydrogen (~80% purity)

Feed Flexibility with K-SAAT



Added feedstock flexibility through increased impurities tolerance

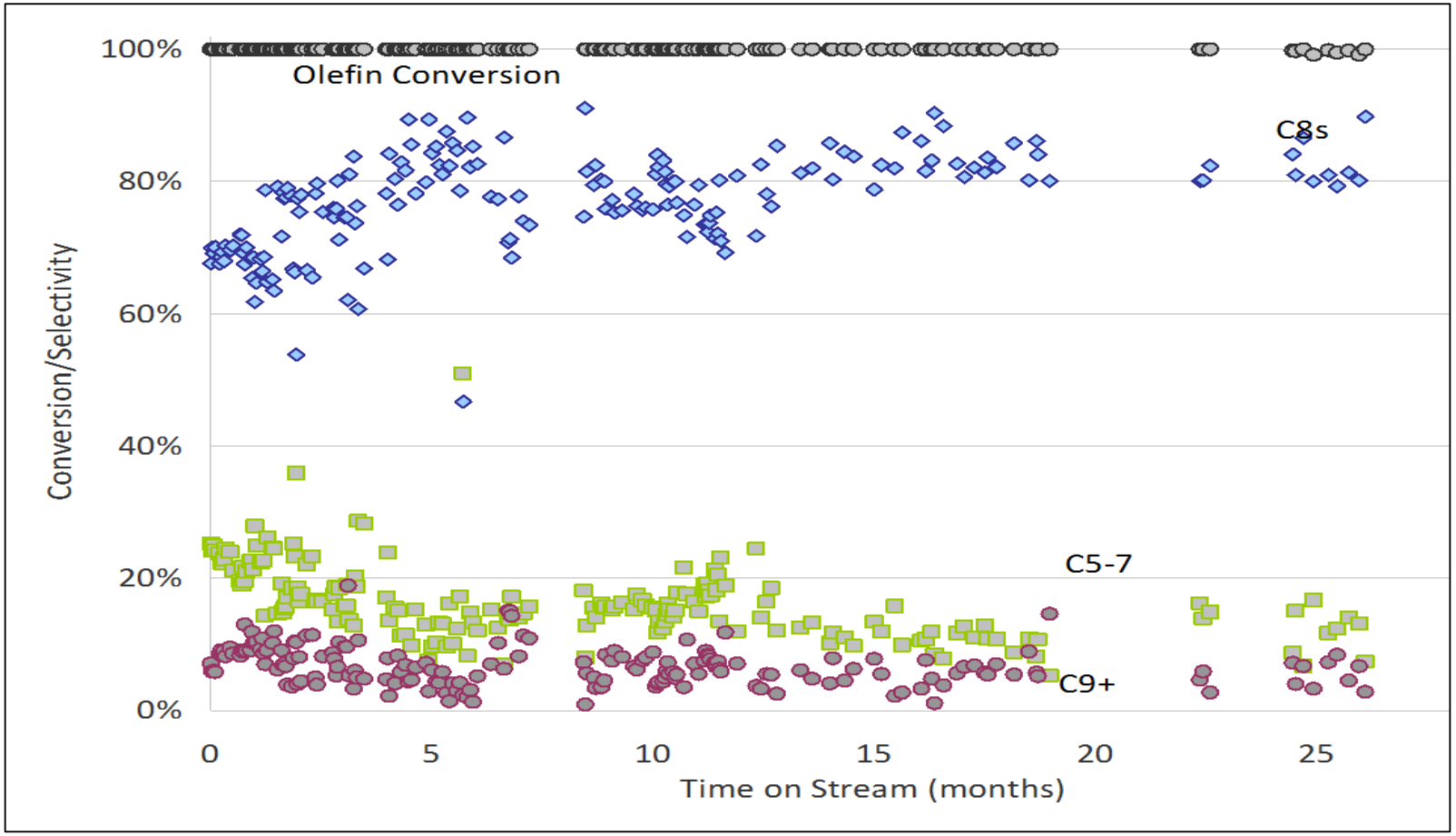
Enhanced Feed Flexibility

- Feedstock flexibility:
  - Ethylene, Propylene, mixed Butenes, Amylenes
- Higher Octane (+1 point of octane):

Feed	Ethylene	Propylene (70% C_3=)	MTBE Raffinate	Butenes (30% i-C_4=)	Amylenes
RON	99	92	99	97	91.0
MON	94.5	90	95	93	89.0

Note: Liquid Acid Catalyst will not alkylate Ethylene

Catalyst Stability



K-SAAT vs. Sulfuric Acid alkylation

	Sulfuric Acid	K-SAAT
Capital Investment	Base*	40% Base
Yields (vol/vol Olefin)		
Alkylate Yield	1.77	1.84
Utilities (per Metric Tonne of Alkylate)		
10 bar steam (kg)	840	973
Power (Kwh)	159	58
Cooling Water (m3)	71	87
Chemicals (kg)	4.4	--
Fuel Gas (MMkcal)	--	0.12
Hydrogen (kg)	--	0.87

>> Lower CapEx, improved yields, reduced OpEx <<

K-SAAT vs. other Solid Acid Catalysts

	K-SAAT	Competition
RON	99+	95-97
RVP (KPa)	<30	<50
Layout	2-3 reactors	3 Reactors
Cycle time	16 - 24 hrs	Less than an hour
Noble metal Catalyst	No	Yes

Commercialization Status

- KBR has signed two K-SAAT licenses
- The first unit
  - Licensee: Dong Ying Haike Ruilin Chemical Co. Ltd
  - Location: Shandong Province, China.
  - Start up: Q2 2018
- The second
  - Licensee: Luoyang Aiyou Chemical Co.
  - Location: Henan Province, China

Summary – K-SAAT

- Superior quality alkylate
  - +1 Higher Octane
  - < 1 ppm Sulfur
- Feed flexibility
- Higher octane barrel yield
- Conventional Refinery operations
- Lower capital and operating costs
- Safer alternative to toxic liquid acids (HF and H_2SO_4)
- Commercial Unit performance exceeds expectations