Next generation catalysts for sustained growth

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March 21-22, 2023 | Seminar on “Recent Developments in Catalysis in Process Industry”
IIChE-NRC Auditorium, New Delhi.

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Ethylene background

- Ethylene is the largest petrochemical market (186M MTA with CAGR of ~3%)[1]
- Steam cracking produces >96% of the world's ethylene[1]
- Ethane and naphtha are most common feeds with each supplying ~45% of globally[1]
- Ethane supply is regional and insufficient to meet global ethylene demand
- Naphtha used in most other regions
- Naphtha cracking has several disadvantages

Naphtha Cracking Disadvantages

- **Cost disadvantaged feedstock**
- **Low ethylene yield (~35%)**
- **Large number of by-products with range of value**
  - **High value (e.g., propylene, butadiene)**
  - **Medium value (e.g., butenes, BTX)**
  - **Low value by-products (e.g., fuel oil, fuel gas)**
- **By-products may or may not be strategic but consume valuable CAPEX and operating resources**
- **Tend to be price setter for ethylene**

How can the efficiency of naphtha crackers be improved?

1. IHS Markit

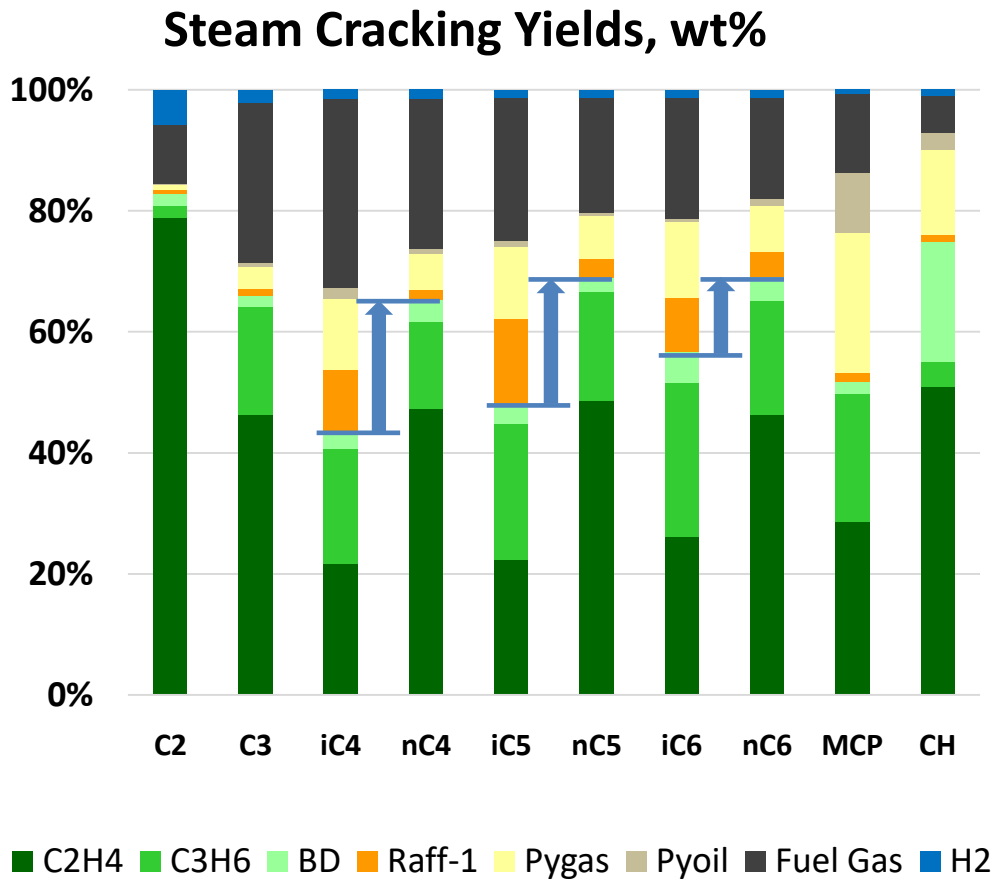
Ideal steam cracker feeds

***n*-paraffins are preferred feed stock**

Benefits include:

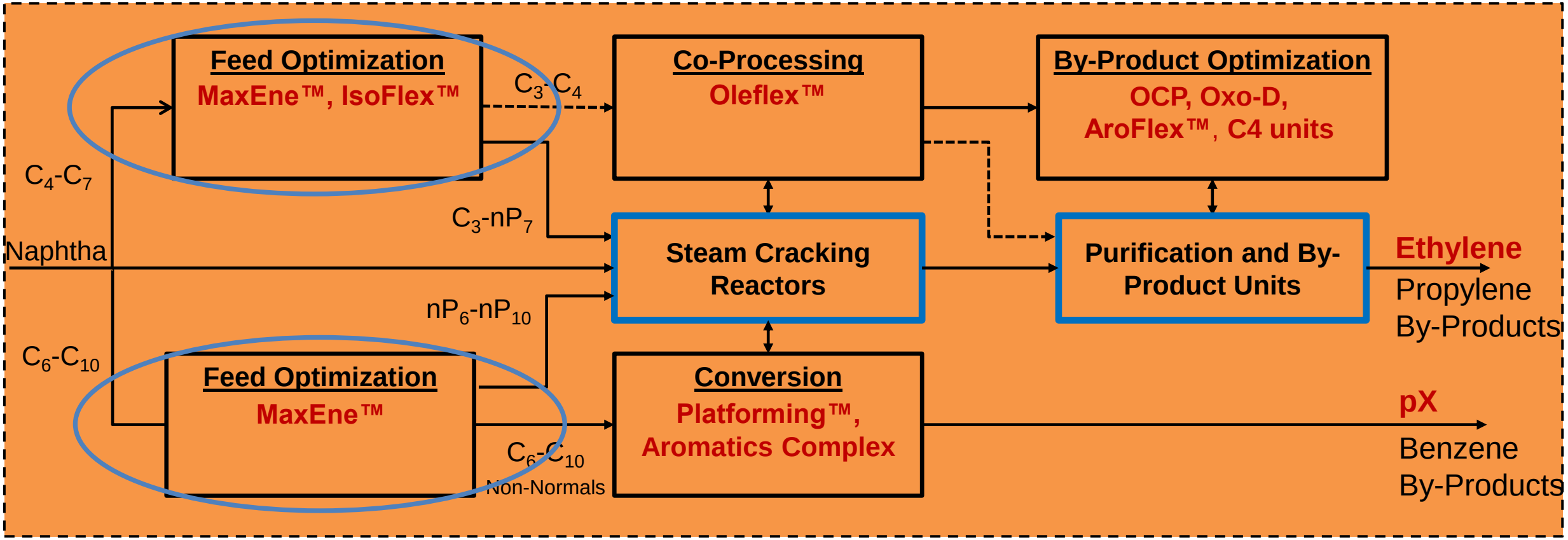
- **~2x yield of ethylene and >30% higher yield of ethylene+propylene vs. i-paraffins**
- Lower yield to lower-value by-products such as pygas, fuel gas, heavy residues and coke
- Longer operating cycles
- Lower operating severity
- Lower utilities/MT of olefins
- Low CO_2/MT of olefins
- Lower CAPEX/MT of olefins

Difficult to purchase feeds with high *n*-paraffins



The UOP-IOS includes technologies for generating high *n*-paraffin streams

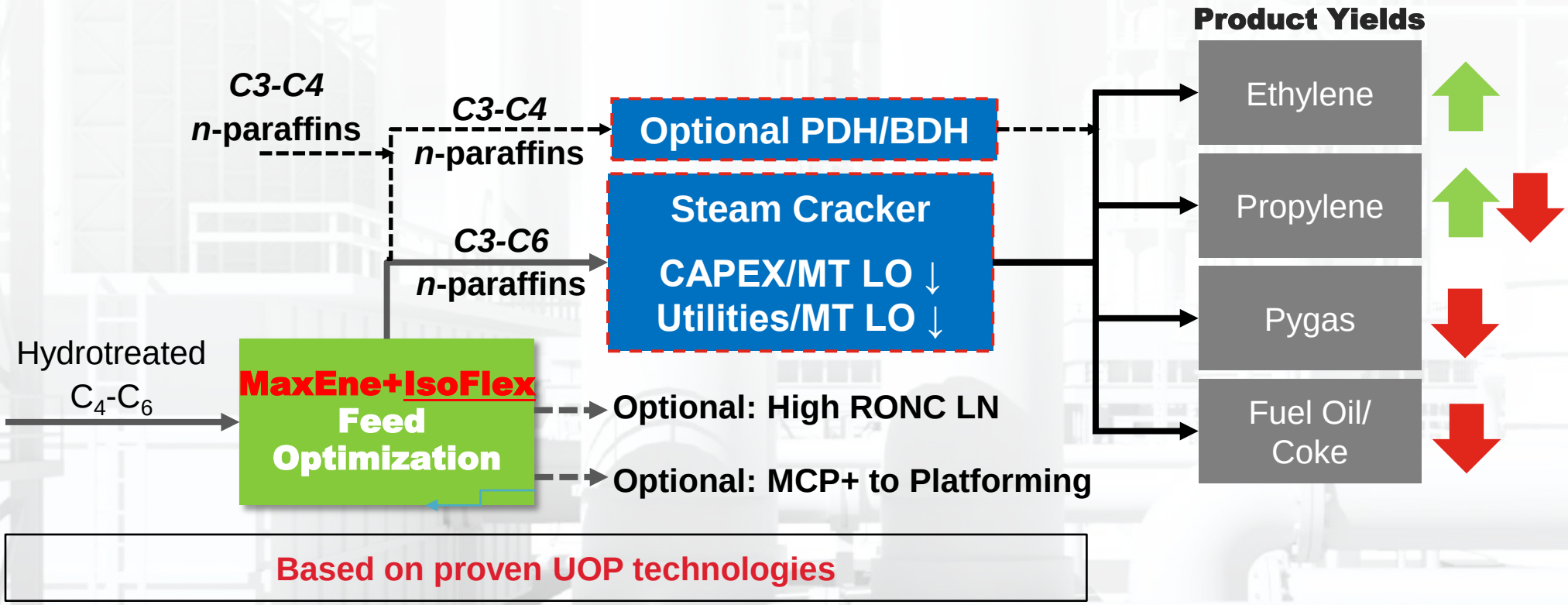
UOP INTEGRATED OLEFIN SUITE



UOP **Integrated Olefin Suite** is an innovative take on proven technologies that gives steam cracking investors and operators **the ability to meet their needs to improve ROI, increase operating profits, reduce CO_2 footprint and enjoy an unprecedented level of control over by-products**

Next Gen Catalysts and Process Integrations Maximizing Benefits

light Naphtha Optimization



Key Benefits

Increase C2= yield up to 50% & tune E/P ratio <1:1 to >3:1

Reduce pygas up to 60%

Reduce pyoil up to 95%

Option to increase benzene from Platforming up to 60%

Based on proven UOP technologies

- ***Increase concentration of n-paraffins to steam cracker***
- ***Increase ethylene yield up to 50% versus traditional naphtha cracker***
- ***Increase or decrease the production of by-products (fuels, BD, butenes, benzene)***

Improved economics vs. traditional naphtha cracker - make the products you need!

INTEGRATED SOLUTIONS FOR HEAVY NAPHTHAS

Commercially proven at Sinopec's YPC facility
Also licensed by PKN (Poland)

Extract *n*-paraffins

Hydrotreated C_5-C_{10} Naphtha

MaxEne Unit

Raffinate *non*-normals ↑ N+2A

Naphtha Cracking Feed

- *n*-paraffins

CCR Reforming Feed

- Naphthenes
- Aromatics
- Iso-paraffins

Product Yields

Product Yields		Key Benefits
Ethylene	↑	Increase light olefin yield up to 30%
Propylene	↑	
Pygas	↓	Reduce pygas up to 50%
Fuel Oil/ Coke	↓	Reduced low value by-products
Aromatics	↑	Increase aromatics yield up to 16%
Light Ends	↓	Reduced lower value by-products
Catalyst Coking	↓	Debottleneck Platforming unit

Typical capital payback times < 3 years, may require incremental heavy naphtha

CCR platforming Process

Why CCR Platforming

•Turn low octane naphtha feeds into high-octane reformate for use in both the gasoline pool and as a source for BTX aromatics, while producing a continuous source of high purity hydrogen and HP Steam for refinery use.

Key Features of UOP CCR PLATFORMING TECHNOLOGY

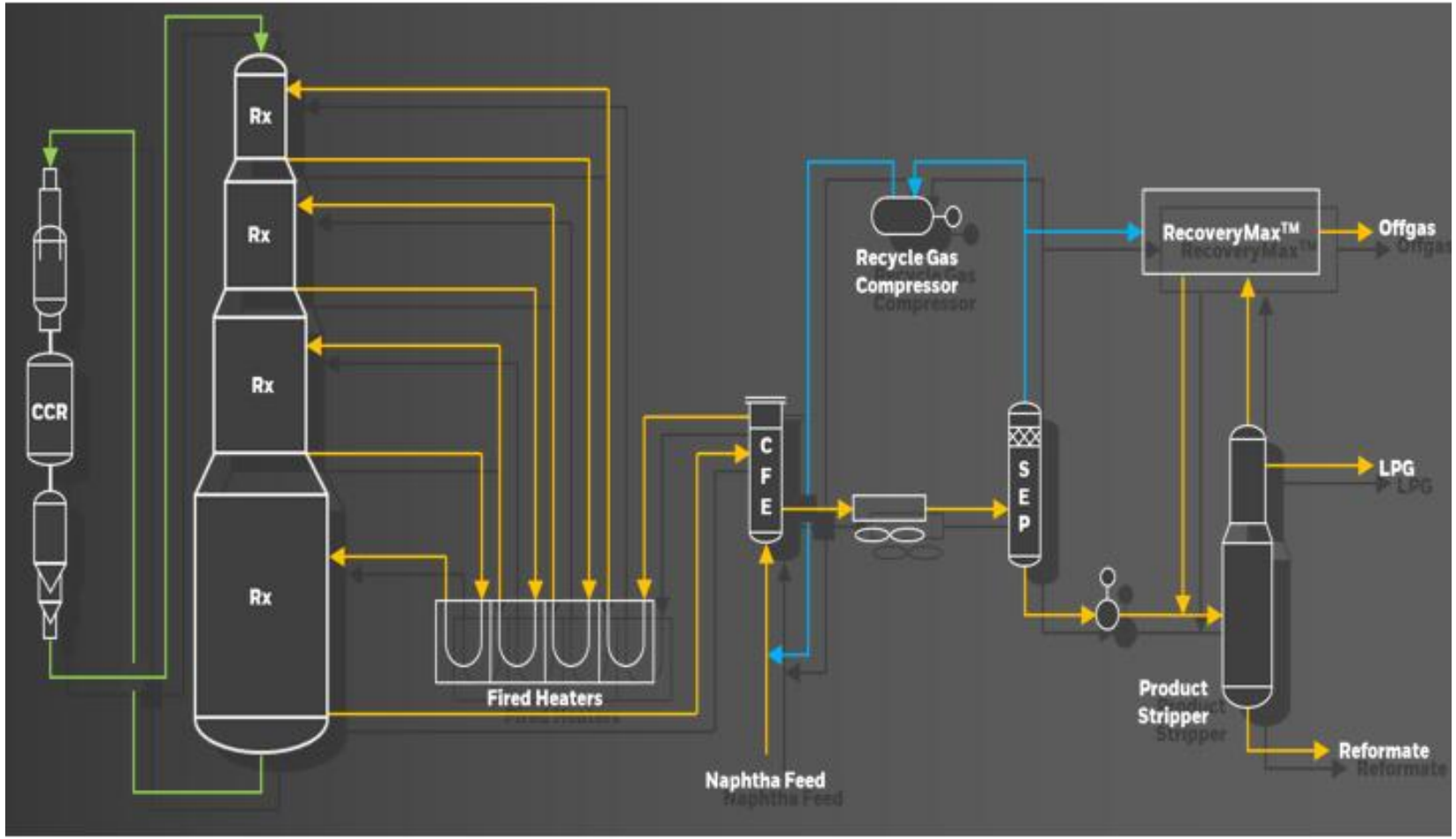
•Higher liquid yield and no drop in yield during entire life of catalyst.

•The UOP stacked reactor design requires less plot space than side by side reactor design.

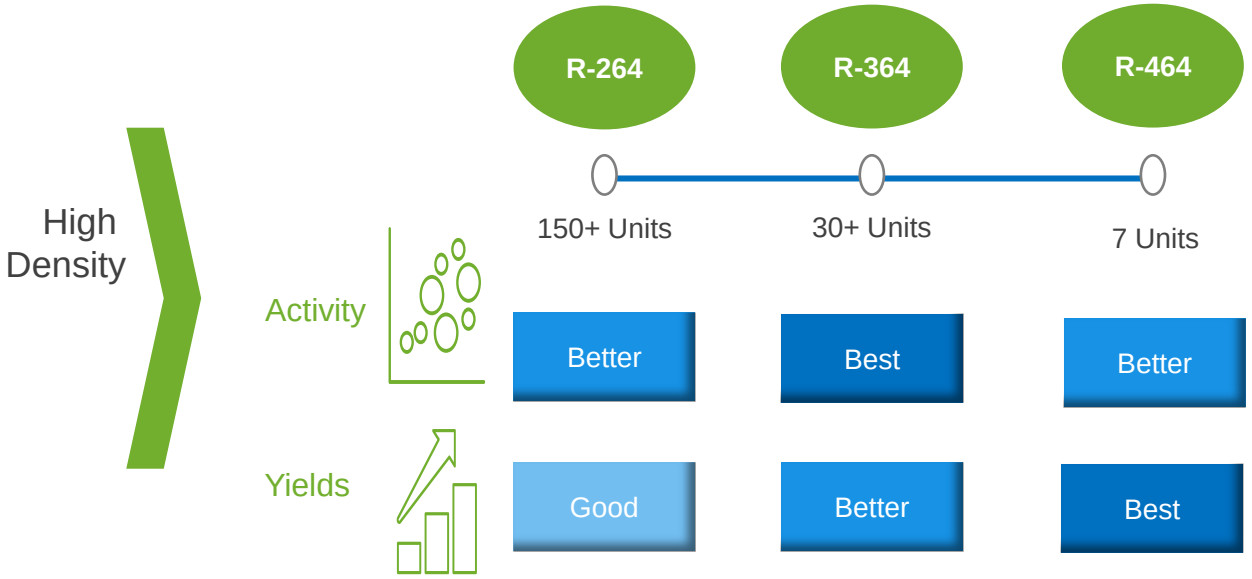
•8 ~ 10 years of Continuous operation without catalyst changeover.

•CycleMax CCR Regenerator design (Modular design)

•Zero Caustic solution.



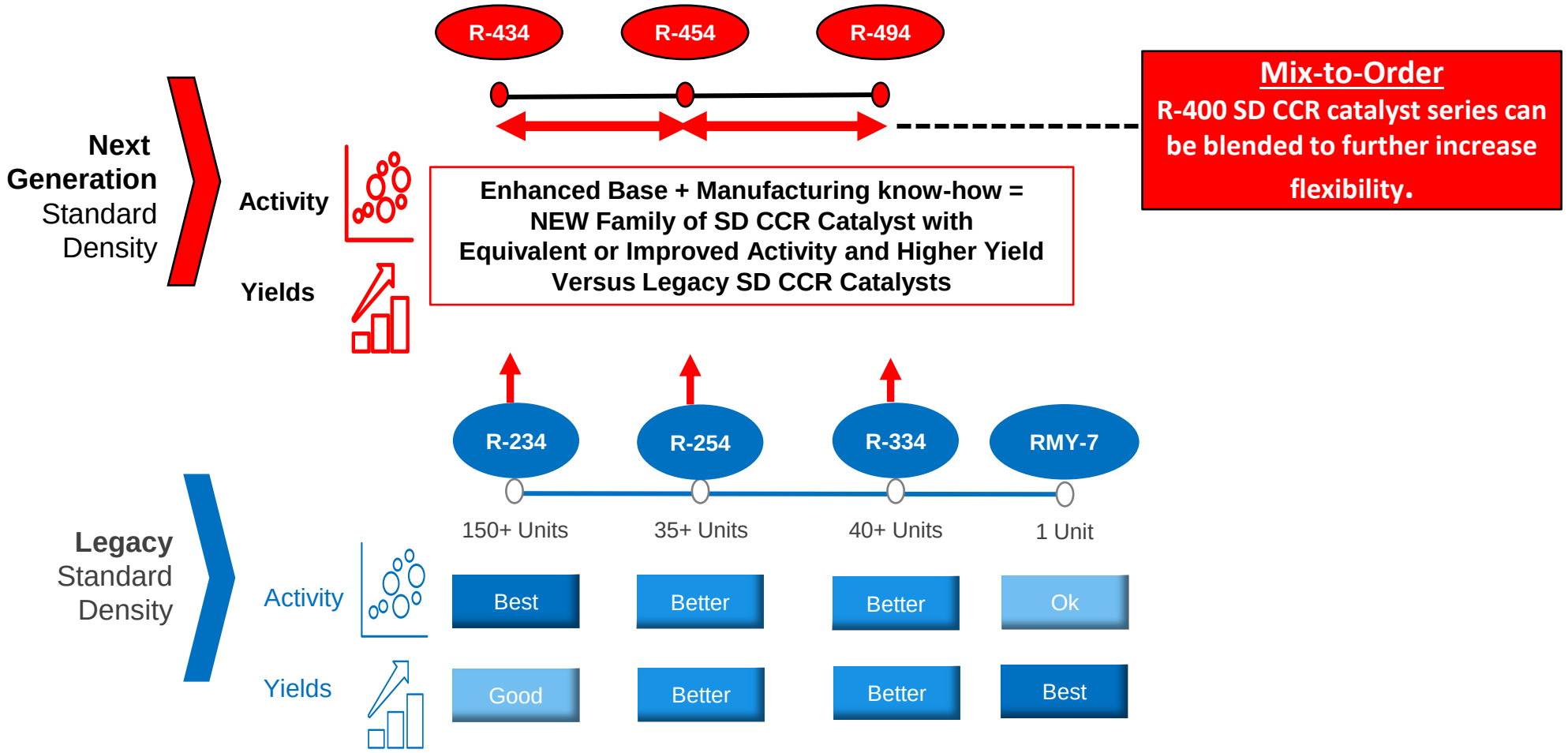
Honeywell UOP CCR Platforming™
High Density Catalyst portfolio



Catalyst	R-264	R-364	R-464
WAIT	Base	Best HD	Base
Aromatics Yield	Base	Better	Best HD
C5+ Yield	Base	Better	Best HD
H2 Yield	Base	Better	Best HD
Coke Make	Base	Best HD	Best HD
When to Select	When more catalyst **activity** is required and when **pinning** is a concern	When needing to **debottleneck** a unit that has **R-264**	When needing **maximum yield** in a unit loaded with R-364

UOP's Portfolio Can Meet a Variety of Applications and Needs

Honeywell UOP CCR Platforming™
Standard Density Catalyst portfolio



UOP's Portfolio Can Meet a Variety of Applications and Needs

FUELING THE FUTURE FOR CLEANER SKIES

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Take off with UOP's ethanol to jet (ETJ) process technology. The next generation of renewable fuels.

5. SUSTAINABLE AVIATION FUEL (SAF)

BENEFITS OF ETJ

- High jet yield output
- Lower CAPEX & OPEX
- Reduced GHG emissions
- Higher profit margins

4. FUEL BLENDING

2. ETHANOL PLANT

3. ETHANOL TO JET

1. FEEDSTOCK SUPPLY

Reduced GHG emissions is based on UOP analysis derived from a 3rd party LCA for 1G low carbon ethanol production with locally sourced feedstock used in comparison to fossil fuels.

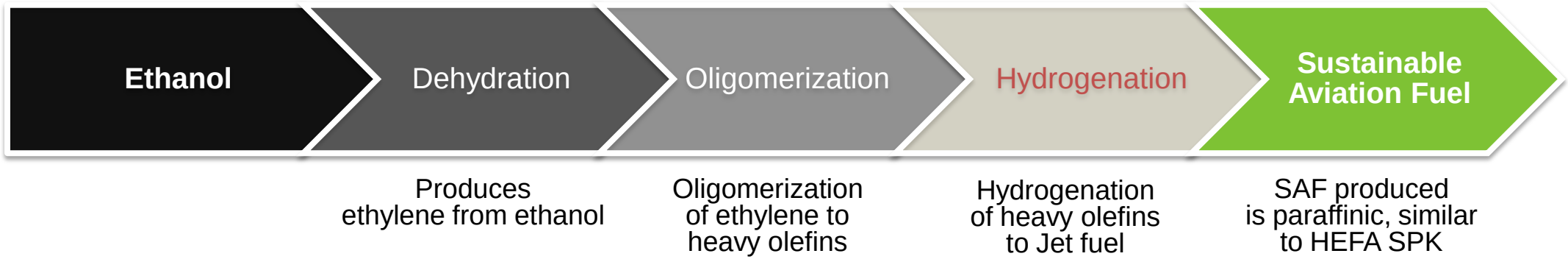
World SAF Opportunity

Mandates are limited today but coming in EU and the US[1]	ICAO CORSIA program to reduce international aviation emissions 50% by 2050[2]	Aviation Fuel demand increased from 5.1 mil BPD (2021) to 9.1 mil BPD (2050)[3]
• US DOE targeting 3B gallons SAF (>200k BPD) by 2030, 35B by 2050 • "Fit for 55" proposal in EU requires 2% 2025, 5% 2030, 63% 2050[1] • Inflation Reduction Act (IRA) blender tax credits (BTC) & clean production tax credit (CPTC) up to $1.75/gallon through 2027 in US	• Voluntary today, Mandatory in 2027 • SAF is the primary emission reduction method without an engine change	• Current production ~ 10,000 BPD worldwide, with potentially ~70k BPD online by 2025 • SAF forecast ranges up to 3.0 mil BPD by 2050

SAF is the #1 Topic in new Projects

1 – EU countries with legislated mandates include Norway, Sweden and France
2 – ICAO CORSIA Program
3 – IHS Markit 2021 Annual Long-Term Strategic Workbook

UOP's approach
ethanol conversion to jet



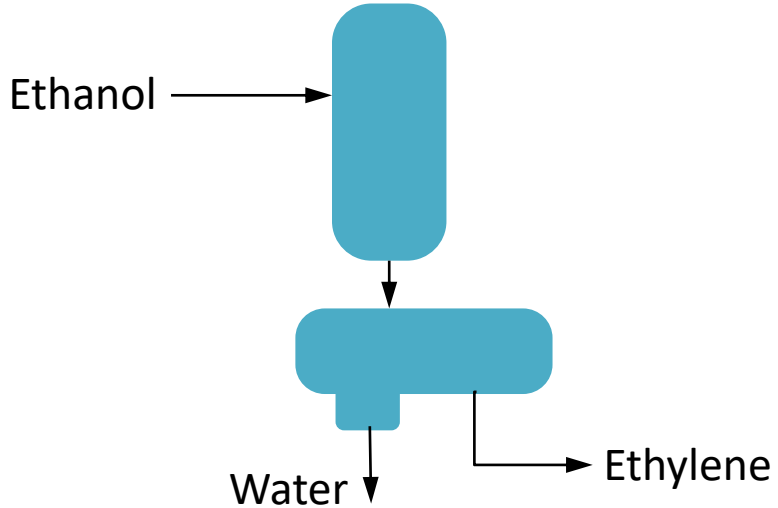
Key Features

- High yields to jet and diesel from UOP's ETJ process
- Reduce greenhouse gas (GHG) emissions by 80% on a total lifecycle basis[1]
- Compatible with hydrous or ASTM D4806 anhydrous ethanol
- Advanced heat integration for lower carbon intensity route
- Based on commercially demonstrated technologies – enables fast scale-up and quicker time to commercialization
- Option to purchase full scope catalyst and process design to provide a single point of guaranteed accountability

1- Based on the EPA's summary LCA of GHG emissions for sugarcane

Step 1:
Ethanol dehydration

Ethanol to Ethylene



- Ethanol is dehydrated to ethylene and water
- Process based on adiabatic reactor design with extensive commercial validation
- Proprietary high activity and selective catalyst ensures low carbon intensity, CAPEX and OPEX
- Performance thus far demonstrated at laboratory scale

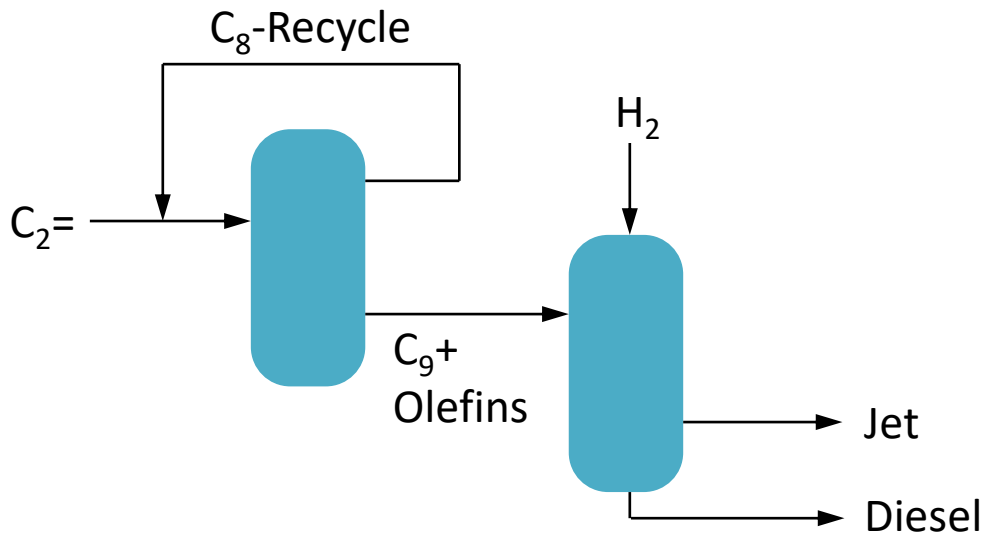
Relevant commercial experience:

- 50+ yrs manufacturing catalysts and optimizing performance in the presence of expected contaminants
- 10+ yrs processing olefins in the presence of oxygenates and handling challenges around fouling and contaminants through the Methanol To Olefins (MTO) process
  - 12 MTO units have been licensed. 7 units on-stream with first commercial design for 700 KMTA of feed
- 30+ yrs designing reactors for endothermic processes e.g. Oleflex
  - 95 Oleflex units have been licensed. 35 units on-stream

Established process and improved catalyst for ethanol dehydration

Step 2&3:
Olefin conversion to jet fuel

Ethylene to Jet



- Ethylene oligomerization and hydrogenation to jet-range, branched molecules
- UOP is leveraging its own commercial experience with similar technologies to fine-tune this process for jet fuel production
- UOP's proprietary design knowledge allows for a low CI process[1]

Relevant commercial experience:

Catalytic Condensation ("Cat Poly") Process Technology:

- Oligomerization of C_3/C_4 olefins for gasoline blending and to nonene and tetramers for specialty chemicals
- Over 400 units licensed and designed

InAlk Technology:

- Oligomerization and hydrogenation of C_4 olefins to C_8-C_{12} hydrocarbons for gasoline blending
- Commercialized in 2001, 22 units were licensed and designed

Catolene technology

- Oligomerization of C_3-C_5 olefins from FCC to diesel range hydrocarbons
- Commercialized in 2016

Leveraging deep experience in oligomerization technology

1 - Proprietary catalyst design and engineering tools result in low carbon intensity

THANK YOU

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