WORLD SCALE CRUDE TO OLEFINS

Integrated Olefin Suite

Honeywell
UOP

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ABSTRACT

The Crude-to-Chemicals project is designed for world-scale petrochemicals production to deliver a flexible, bankable, and sustainable free-market investment. Through strong cooperation with the customer, Honeywell UOP has developed a configuration that enables 100% net olefins derived products. The Molecular Management Solution, also called the Integrated Olefin Suite (IOS), leverages commercially demonstrated and proven UOP technologies deployed in a way to optimize the Steam Cracker yields and margin cost-effectively to produce this bankable solution.

INTRODUCTION

1

The global ethylene market is the largest petrochemical market by volume and value, and it influences the economics of many downstream petrochemical derivatives.

The global ethylene market consumes approximately 178 million metric tons per annum and is forecast to grow at a CAGR of 3-3.5%, which is about 6 MM tons per year of new production capacity needed to meet the growing demand.
The consumption of ethylene within the ethylene derivatives chain is as follows:

- 62% of ethylene is consumed in polyethylene (PE) manufacturing.
- 16% of ethylene is consumed in ethylene oxide (EO)/ethylene glycol (EG) manufacturing, with 70% of all EO ending up as monoethylene glycol (MEG); and,
- 5% of ethylene is consumed in styrene manufacturing.

If we overlay the amount of ethylene consumed per ton of derivative product made: 0.92-1.01 tons of ethylene per ton of polyethylene produced, 0.6 tons of ethylene per ton of MEG produced, and 0.29 tons of ethylene per ton of styrene produced, the economics of ethylene production will have the greatest effect on the PE market overall. More than 95% of the global ethylene production comes from steam cracking technology and is roughly split equally between ethane and naphtha steam crackers.

Ethane is a regionally available feed source, mainly in North America and the Middle East, and is not in sufficient supply to meet the global demand, while naphtha is readily available globally. It's the economics of steam cracking technology that drives the economics of ethylene derivatives, with the two main factors being feed stock costs and selectivity to light olefins and are reflected in the Cash Cost of Production (CCOP).

If we look at the world 2020 CCOP curve (Figure 1) for ethylene from IHS Markit we can see that the Naphtha Steam Crackers tend to be the "price setters" for the ethylene market due to the $200-$400 per metric ton cost disadvantage, the green squares that are on the right side of the curve below, versus and ethane steam crackers, which are the red diamonds on the left-hand side if the curve.

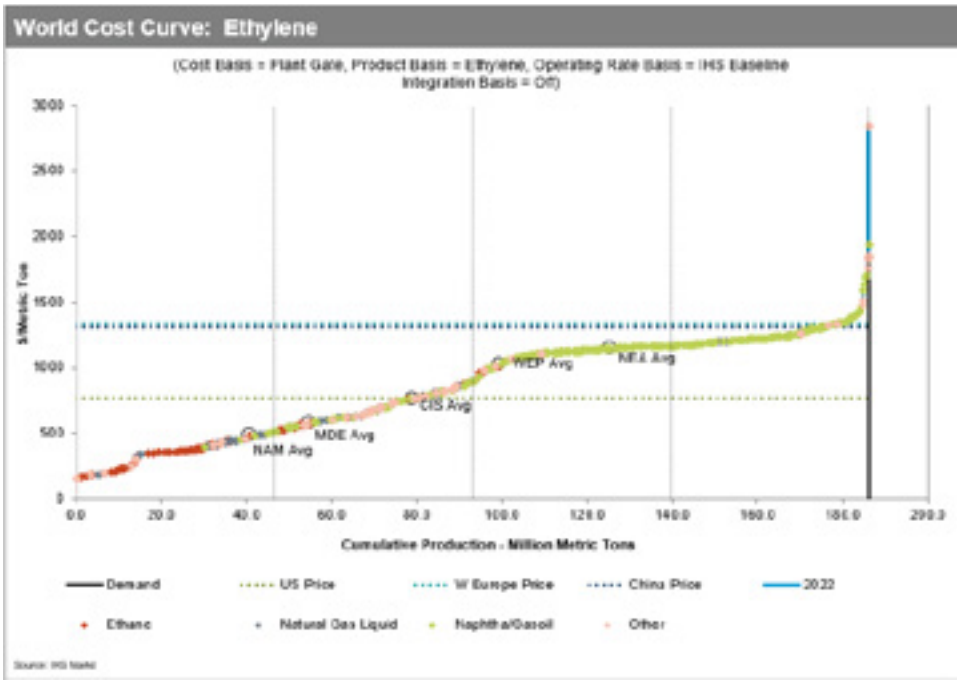


Figure 1: Steam Cracker Cash Cost of Production

How do we unlock the potential of a naphtha steam cracker and improve the competitiveness of naphtha crackers? The key is looking at the selectivity to ethylene and propylene of the different molecules that are fed to the steam cracker, or what Honeywell UOP calls Molecule Management.

In a dynamic and competitive global market, a steam cracking unit should no longer be treated as a "garbage" processor of the leftover streams. Steam cracking investors and operators need the most efficient technology available to ensure profitable operations. A steam cracking unit can be designed to process a range of molecules from ethane to diesel. However, the profitability of the unit varies greatly with different feeds due to yield differences. The production of lower value by-products such as fuel gas, pygas, and pyoil creates a drag on operating margins, requires incremental CAPEX and OPEX, and creates additional market risk for the investor.

As shown in Figure 2, a steam cracking unit that is fed ethane (C2) yields about 80% of the target product ethylene; with light naphtha (SR LN) it yields less than 40% of the target product; or with heavier feedstocks such as heavy naphtha (SR HN) and diesel – it produces an even greater proportion of low-value by-products.

In other words, heavier feed or unoptimized feed results in poor carbon and hydrogen efficiencies. A higher return on investment can be achieved with an innovative solution that maximizes the production of high-value ethylene and propylene products, minimizes the production of undesirable pygas and pyoil by-products, and optimizes opportunistic products such as butadiene.

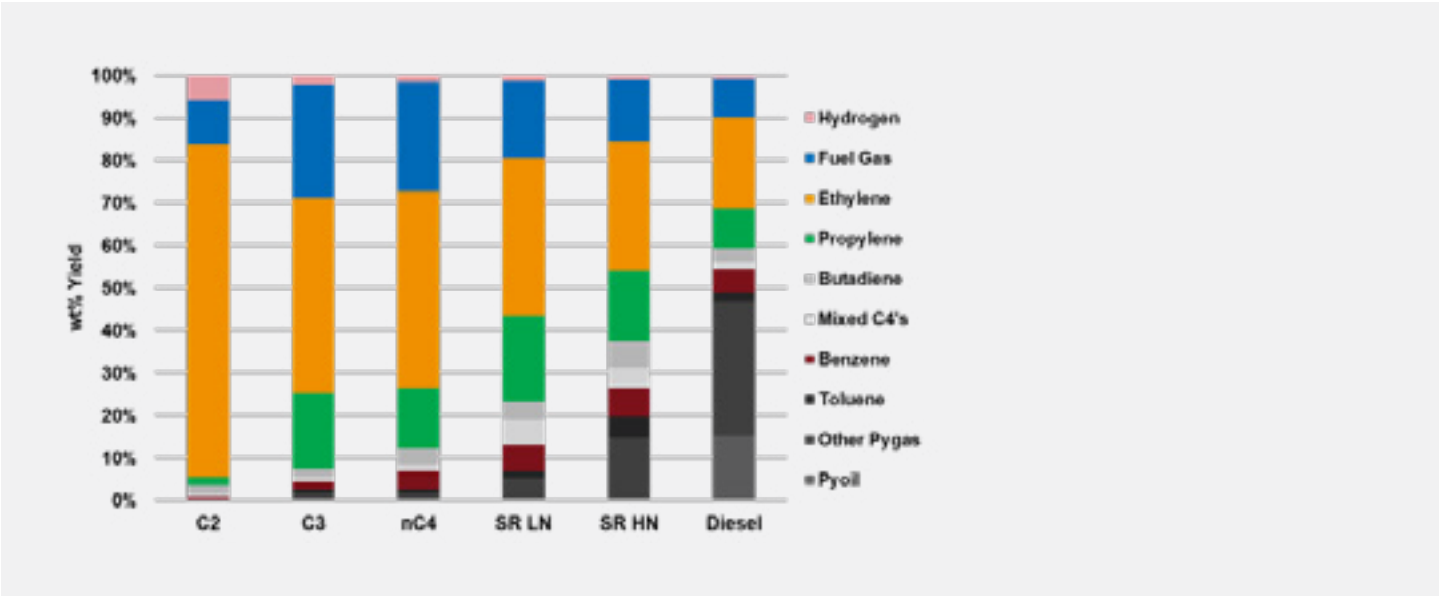


Figure 2: Steam Cracker Yields and Hydrocarbon Fraction

When processing naphtha range feed in the steam cracker complex, it is well-known that feeds richer in n-paraffins are a preferred feedstock. As shown in Figure 3, normal paraffins have a superior cracking yield pattern versus iso paraffins. Due to the improved yield of ethylene from normal paraffins, both Carbon Efficiency and Hydrogen Efficiency improve. Naphtha feeds rich in normal paraffins have the following benefits relative to iso paraffins:

- Increase ethylene yield by more than 100%
- Reduce C4 by-product yield by more than 50%
- Reduce pygas yield by more than 50%
- Reduce pyoil yield by more than 60%
- Reduce furnace coking resulting in fewer decoking cycles and improved operability

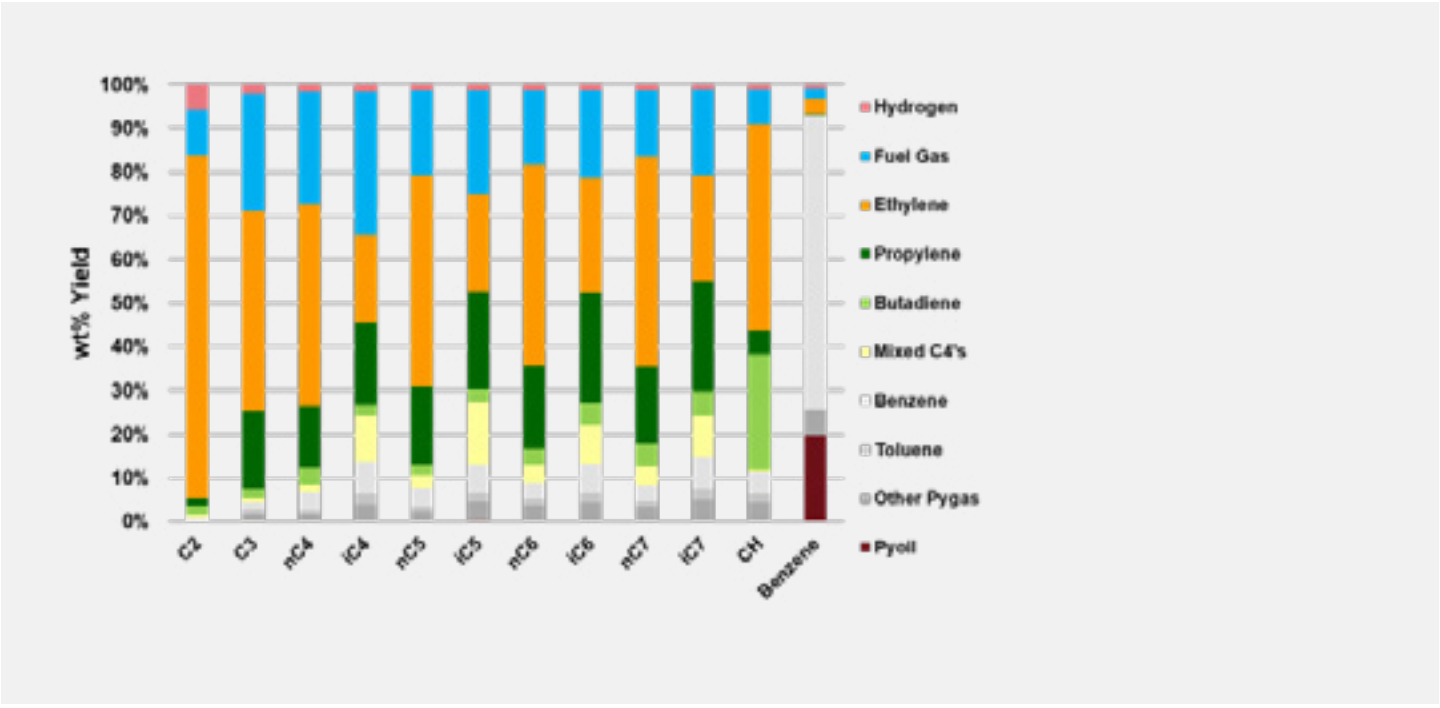


Figure 3: Steam Cracker Yields and Efficiencies by Molecule

COMMERCIAL CONFIGURATION STUDY

2

Honeywell UOP's Integrated Olefin Suite (UOP IOS) employs a collection of flexible, proven technologies to maximize normal paraffin in the feed to the steam cracker, co-process certain molecules more efficiently, and manage lower-valued by-products to enable the following:

- **Make more light olefins with the same amount of feed**
- **Make the same amount of light olefins with less feed**
- **Target high-value by-products to match strategic objectives**
- **Reduce or eliminate low-value products with market risk**
- **Improve profitability and ROI**
- **Reduce environmental footprint per MT of light olefin**

Let's take a look at Honeywell UOP's IOS capability through a commercial configuration study. A customer is planning a grassroots crude to light olefins complex from 100 kBPSD (4500 KMTA) of crude. Based on a conventional configuration, as shown in Figure 4, the project would produce ethylene, propylene, butadiene, benzene, mixed aromatics, and fuel oil. The LPG and naphtha streams from crude distillation column are processed in the steam cracker complex.

The heavier streams (kerosene, light gas oil, and atmospheric resid) are processed in a combination of Solvent Deasphalting (SDA) unit and Hydrocracking (HCU) unit to convert to lighter components that are also routed to the steam cracker complex.

A traditional steam cracker complex is configured to produce ethylene and propylene, while it also produces undesired by-products of butadiene and mixed aromatics.

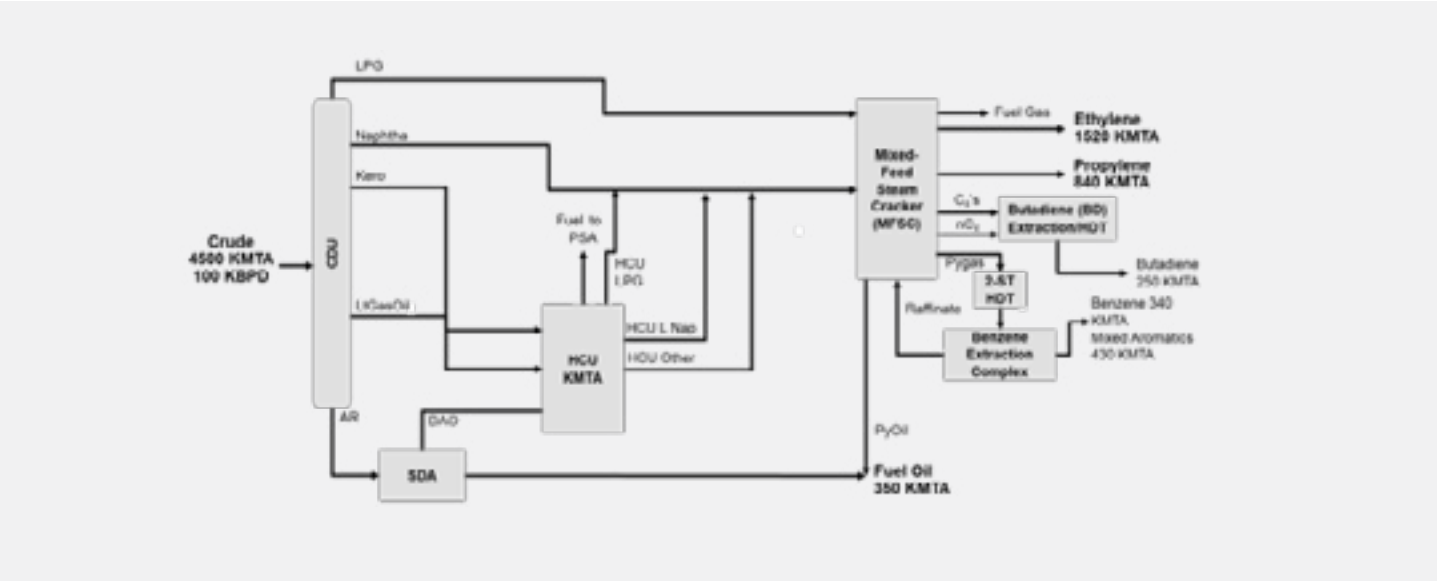


Figure 4: Conventional Configuration

After a third-party market study and financial model review, the typical crude-to-olefins configuration yielded only 52% light olefins on feed and 48% of non-strategic by-products the customer wasn't interested in. The customer was encouraged to maximize ethylene and propylene, minimize fuels, and eliminate by-products of aromatics and C4 olefins. The elimination of the by-products makes the project more attractive by increasing ROI, aligning with the local market demand, and simplifying the product value chain to reduce exposure from by-products to be sold in an uncertain market. UOP worked closely with the customer to develop the crude to olefins configuration shown below in Figure 5. The selected crude-to-olefins configuration first processes the crude in a conventional crude distillation column with a saturated gas plant. The propane (C3) from the crude, from the conversion units and from the Feed Optimization processes are Co-Processed in the highly selective UOP Oleflex™ propane dehydrogenation (PDH) unit to produce propylene. The straight run naphtha and hydrocracking naphtha is processed in the UOP IOS Feed Optimization Section to maximize the normal paraffins to the steam cracker to increase ethylene production while minimizing all byproducts by converting the iso paraffins and naphthenic components to normal paraffins. The remaining heavies in the crude are selectively converted to naphtha and LPG in a combination of SDA + Retuned Unicracking™ units. The already reduced steam cracker by-products are reduced to zero by hydrogenation technologies and recycled back to the steam cracker to upgrade them to light olefins. A small amount of SDA pitch and pyoil is burned on-site to meet utility needs, and only light olefins are sold to market.

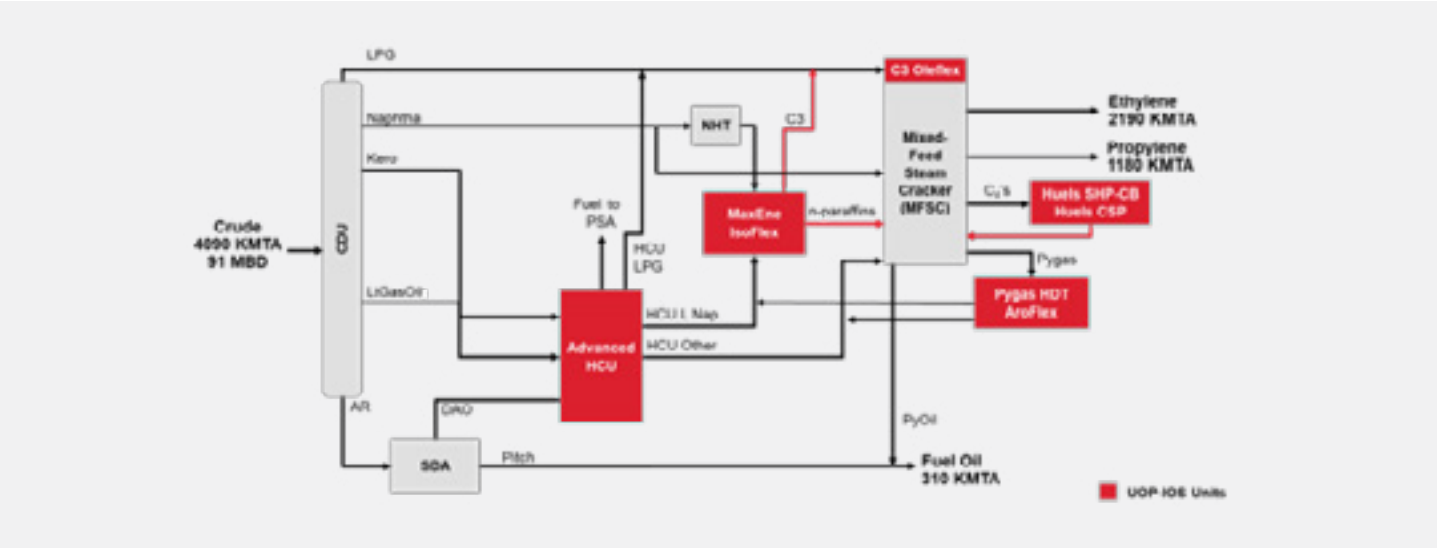


Figure 5: Crude to Olefins Configuration: UOP IOS Solution

By integrating the UOP IOS units around the steam cracker complex in the revised configuration compared to the conventional configuration, UOP IOS enabled the project to deliver the following results:

- Increased light olefins yield from 52% to 82% of total crude processed;
- Eliminates several undesired by-products such as butadiene, benzene, and mixed aromatics;
- Reduced the crude feed to 91 MBD from 100 MBD;
- Increased NPV of the project to $3.7Billion from $1.4Billion; and,
- Increased the project IRR to 19.7% up from 16.3%.

An additional key benefit of UOP IOS is the positive impact on the overall CO_2 footprint of the project. Honeywell UOP performed a very basic CO_2 footprint analysis (not a complete Lifecycle analysis) of a typical 100 MBD refinery producing 80% ULSD, 10% gasoline and 10% LPG, the base 64% net petrochemical site in Figure 4, and new 100% net petrochemical site in Figure 5. These results are presented in Figure 6.

	HYPOTHETICAL REFINERY [1]	BASE CASE	UOP-IOS CASE
Crude Rate, KBPD	100	100	91
Net export of petrochemicals	0%	64%	100%
CO_2 from operations + imported utilities[2]	8,420	26,304	34,422
CO_2 from fuel by-products combusted[2]	56,746	16,313	0
Subtotal CO_2, TPD[3]	**63,682**	**42,617**	**32,422**
CO_2 reduction from carbon capture on H_2 SMR unit	(1,304)	(2,072)	(4,326)
Total CO2 TPD[3]	**63,682**	**40,545**	**28,096**
MT CO^2 per MT of light olefin[3]	N/A	6.0	2.9

Figure 6: UOP IOS Sustainability Effect

CONCLUSION

As we can see, the base refinery has the lowest Scope 1 & 2 emissions merely upgrading the crude to fuels that are burned elsewhere. However, these Scope 3 emissions are the highest for that base refinery.

As more processing is required to upgrade these transportation fuels to light olefins, the CO_2 emissions from that base refinery increase, and there is a corresponding significant reduction in the fuels burned, Scope 3, emissions, all the way to zero in the final configuration. It is also clear that with the use of UOP IOS the overall emissions versus the base petrochemical configuration can be reduced by 31%, due to the greater carbon efficiency of molecule management.

For more information
uop.honeywell.com

UOP LLC, A Honeywell Company
25 East Algonquin Road
Des Plaines, IL 60017-5017, U.S.A.
Tel: +1-847-391-2000

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