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New Pathways for Decarbonization Creating Greater Value with Fewer Resources

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Four pillars for CO_2 Reduction

make lower CI Products → configurations , technologies, & molecule management

- **PIVOT from**
- **FUELS to PETROCHEMICALS**
  - **Sequester carbon** instead of burning it in vehicles
  - **Aligns with demand trends**
  - **Bankable solutions** – very active & evolving space

- **FEEDSTOCK SUBSTITUTION –**
- **NEW CARBON vs OLD**
  - **Renewable fuels & plastics circularity**
  - **Bankable** where credit subsidies are available
  - **New Units, retrofits, and co-processing**
    - Ecofining™
    - Ethanol to Jet
    - E-fuels
    - Upcycle™

- **CARBON CAPTURE, UTILIZATION & STORAGE**
  - **Ready now** - Capture → Transport → Sequester or use for EOR
  - **Ready soon -** Capture → convert to e-fuels

- **TECHNOLOGY & ENERGY IMPROVEMENTS**
  - **Many options available -** new units or retrofits
  - **Examples**
    - RecoveryMax™
    - NViroFCC™
    - CatMax™
    - Energy efficient dual stripper/fractionator
    - Fugitive emissions monitoring & mitigation
    - Dividing Wall Columns

Bankable options position downstream assets for energy transition

CI – Carbon Intensity

NAPHTHA TO ETHANE & PROPANE

NEP IS A NEW SOLUTION FOR PETCHEMS & REFINERS

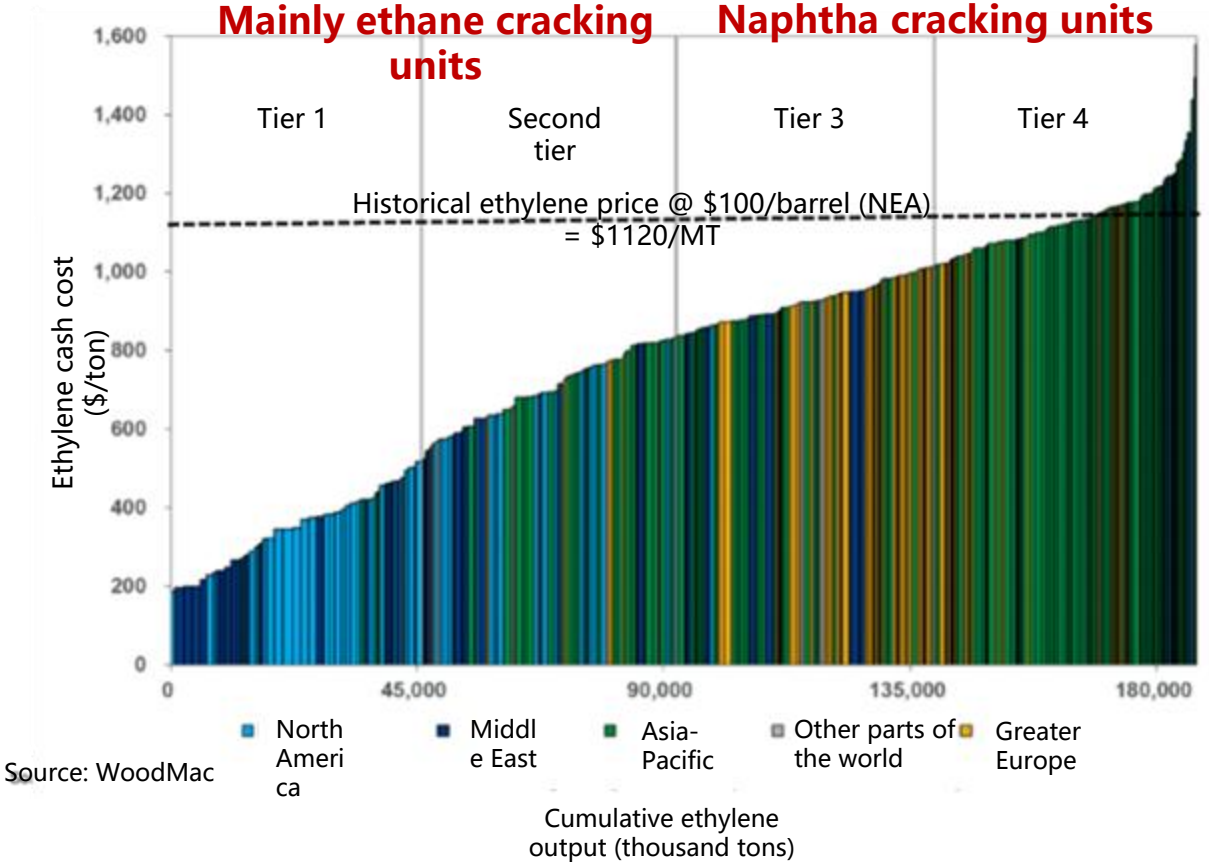


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CHALLENGES FACED BY STEAM CRACKING

- Due to the lack of ethane, Asia mainly relies on naphtha cracking to produce ethylene
- Ethane cracking units outperform naphtha crackers but are constrained by limited ethane supply
- Sustainability is receiving increasing attention
- **Steam cracking units are the largest source of CO2 in the petrochemical industry**
- Demand for liquid fuels is expected to decline—driven by electric vehicles and mandatory regulations
- Geopolitics influence national strategies and alter trade flows

At $100/barrel crude oil, the cash cost curve for ethylene units is high



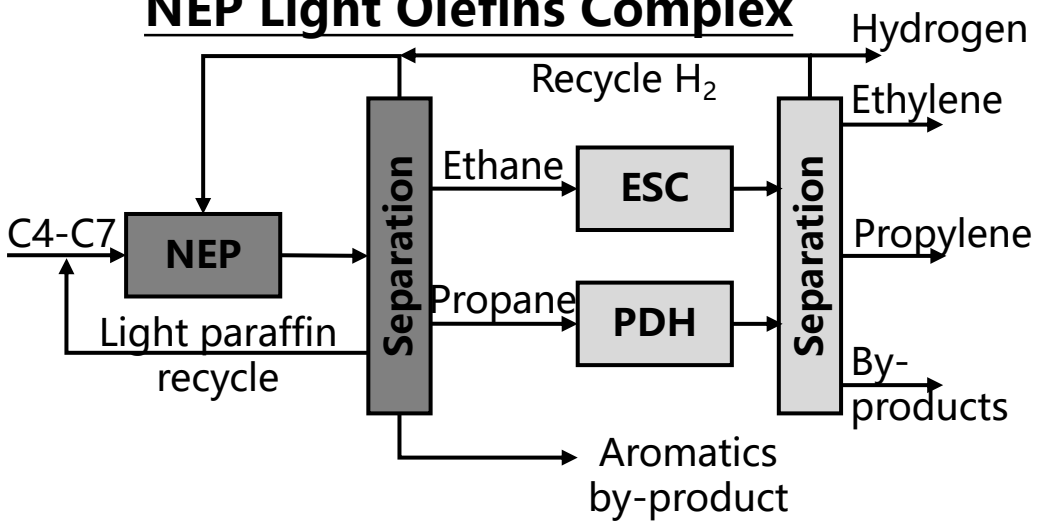
Source: WoodMac

There is an urgent need for an improved method for producing lightweight olefins

NEXT-GENERATION FEEDSTOCK OPTIMIZATION: NEP

- **Convert naphtha (C_4-C_7) to adjustable ethane/propane ratios, favoring either product**
  - **Feed ethane to *ethane cracking (ESC)*** to optimize the ethylene/H_2 ratio
  - **Feed propane to *PDH*** for optimal propylene/H_2 ratio
- **NEP process:**
  - Mild operating conditions
  - Extension of existing catalyst technology
  - Low utility consumption
  - Standard fractionation for product separation
  - Suitable for new units and revamps
- **Purchase naphtha and/or use UOP advanced hydrocracking to produce naphtha from heavy feeds (HN+ to LN and LPG)**

NEP Light Olefins Complex



Benefits

- Higher ethylene/propylene yields, less feed per ton of olefins
- Fewer low-value fuel by-products
- Wide adjustment range for the ethylene/propylene ratio
- Higher maximum ethylene capacity per train than naphtha cracking
- Hydrogen self-sufficiency
- Diverse feed sources (no need to import ethane/propane)

Leading molecular management solutions for light olefin production

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PYROLYSIS GASOLINE

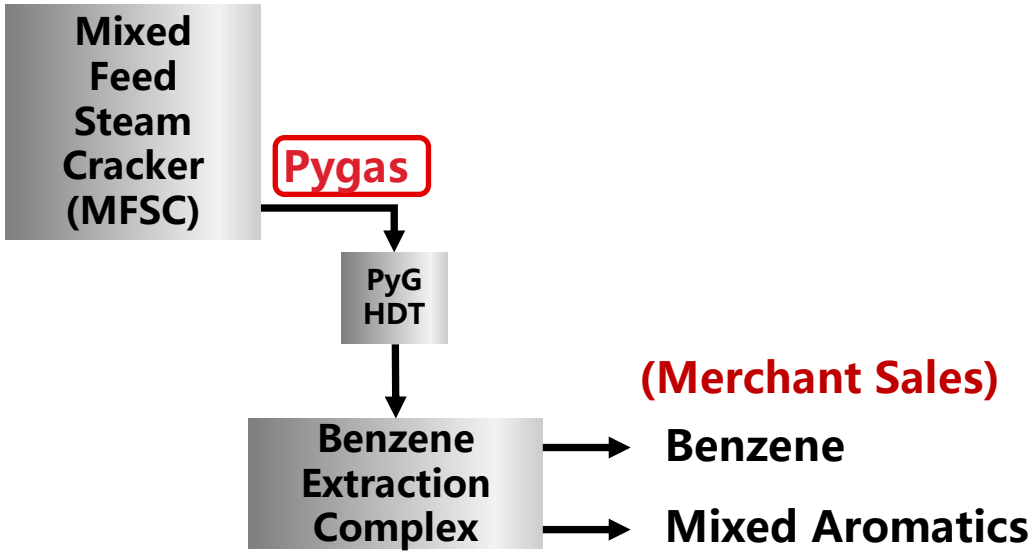
Less pygas means lower CO2 emissions

Process CO2 emissions from pygas are 3.6 times those from reformate

- **Pygas (pyrolysis gasoline): ~53% Aromatics**
- **Reformate: ~80% Aromatics**

Per ton of aromatics, pygas CO2 is 5.5 times that of reformate

- **High CO2 emissions from aromatics**
- **High CO2 emissions from gasoline blendstocks**



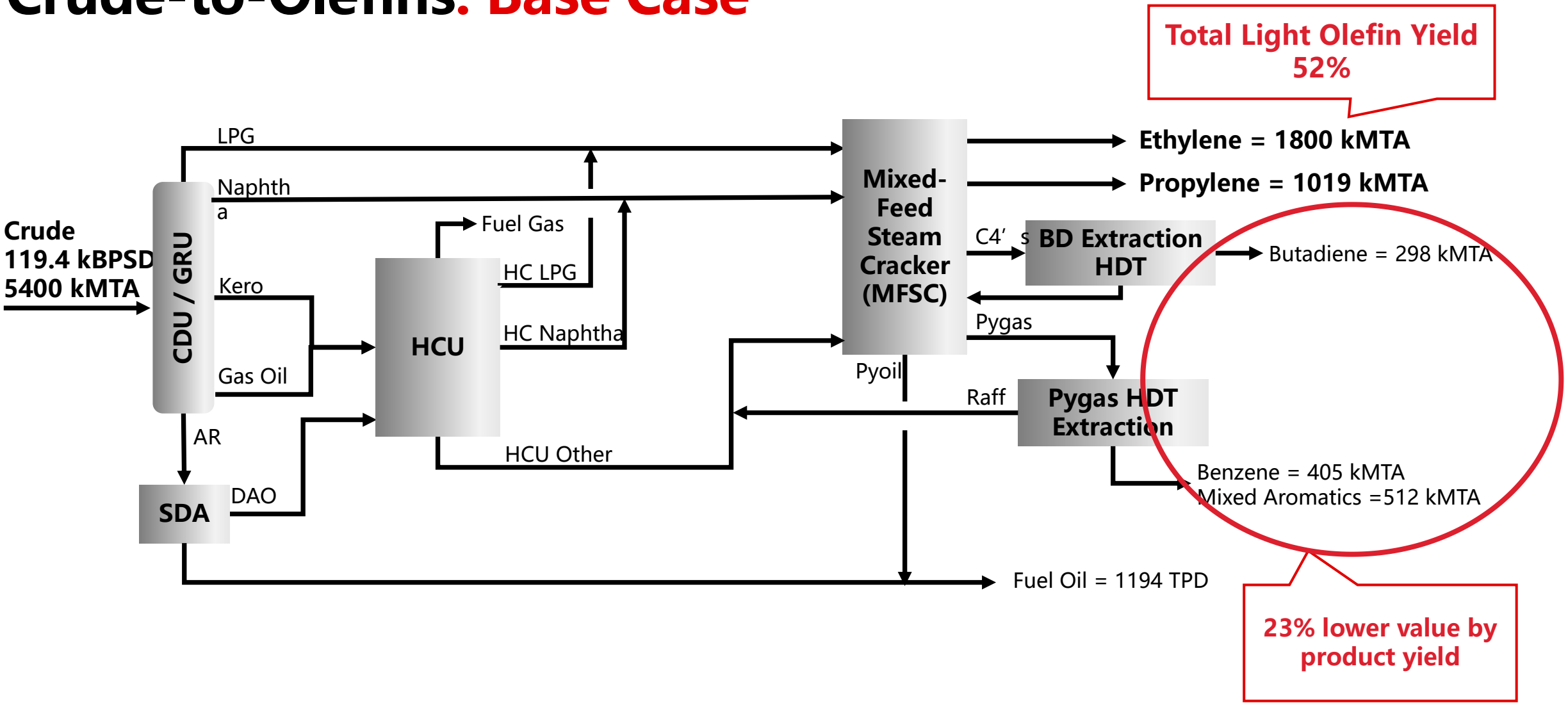
1. Scope 1 and 2 emissions calculated based on net power, fuel gas, steam, cooling water, BFW, and condensate use
2. 5.5 = CO2 ratio for aromatics from pygas: aromatics from reformate = 0.47/0.53 /(0.13/0.8)
3. 1.2 = CO2 ratio for burning cracker methane vs natural gas = (0.47/2205/19000 *1e6+0.058)/0.058 MTCO2/MMBTU

Reforming offers a more sustainable route to aromatics

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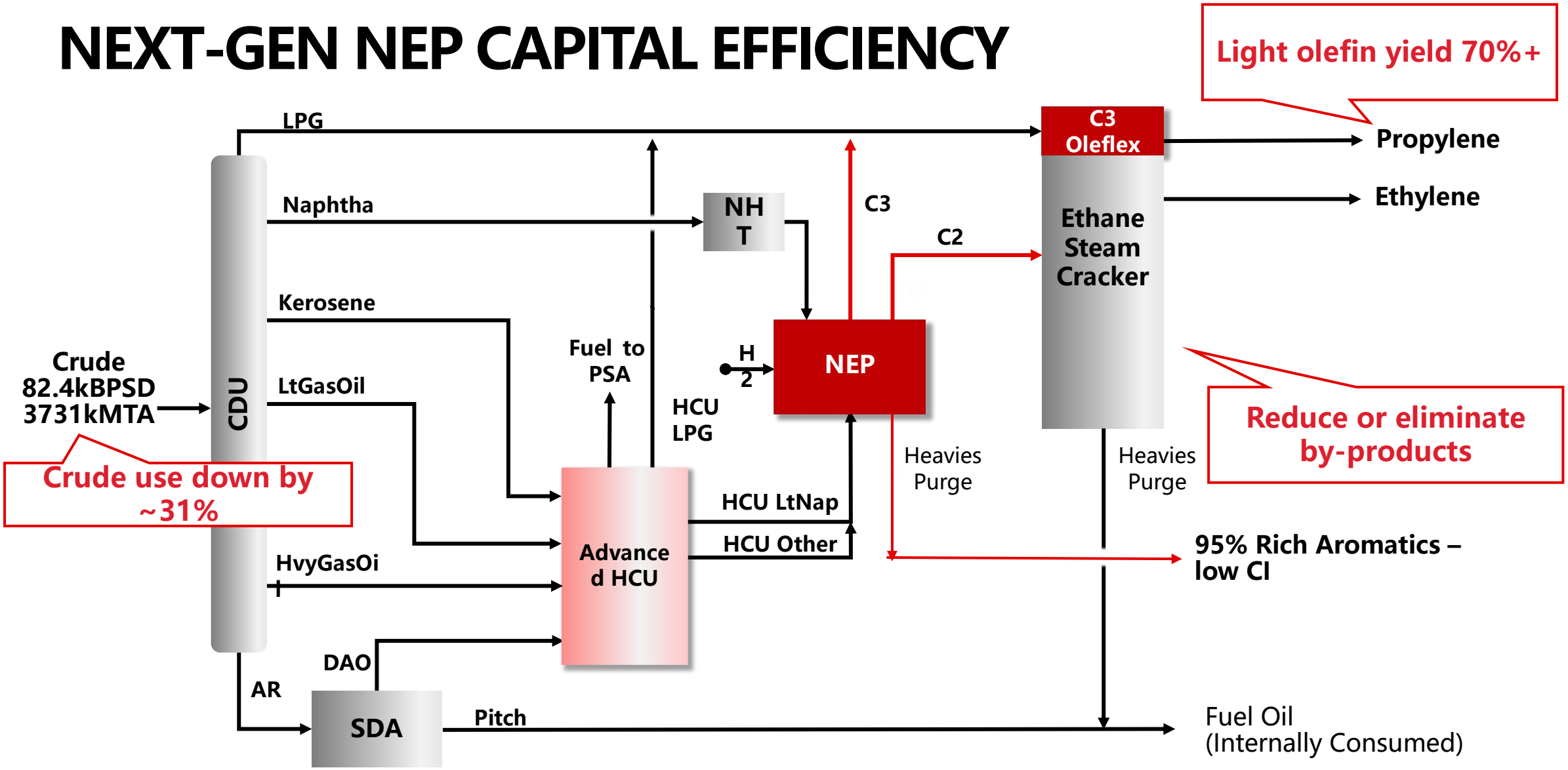
Crude-to-Olefins: Base Case



Conventional crude-to-olefins complexes produce large volumes of by-products

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NEXT-GEN NEP CAPITAL EFFICIENCY



NEP delivers higher light olefin yield with fewer units and no costly MFSC

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UOP NEP Sustainability Credentials

Case study[1]

	Base Case	NEP Case
Total light olefin (Ethylene + Propylene), TPD	8,054	8,054
Crude rate, kMTA	5400	3731
CO_2 from operations + imported utilities[2,3], TPD (Scope 1 and 2)	28,944	27,285
Tonne CO_2 from operations + imported utilities per tonne light olefin[4],	**3.6**	**3.4**
Net export of petrochemicals, %	64	100
Net export of fuel by-products, %	36	0
CO_2 from fuel by-products combusted[5], TPD (Scope 3)	19,484	0
Total CO_2[4], TPD	48,428	27,285
Total CO_2 per total light olefin[4], -	**6.0**	**3.4**

1. Based on customer study (ID000030) using UOP standard Linear Programming methods and customer data
2. CO_2 emissions estimated from refinery based on information from Linear Programing with utilities based on imported natural gas
3. Both cases include carbon capture sequestration on steam methane reforming unit
4. From sources listed above in table
5. CO_2 emissions from fuel byproducts estimated from standard combustion calculations

NEP helps complexes cut carbon emissions per ton of olefins by 40%

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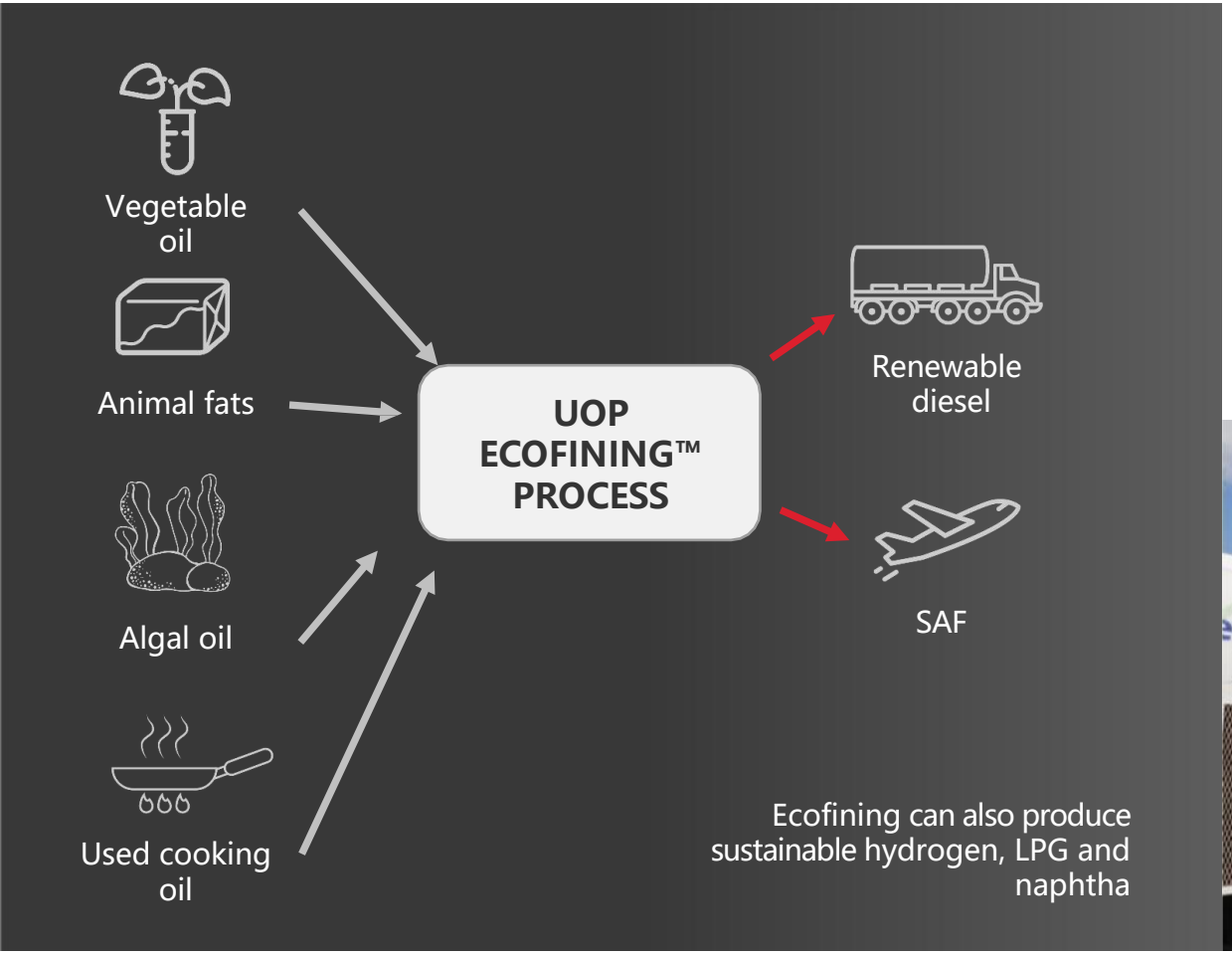
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A TOTAL SOLUTION
FOR LOW CARBON INTENSITY RENEWABLE FUELS

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SUSTAINABLE FUELS
Honeywell UOP Ecofining™ Process Technology

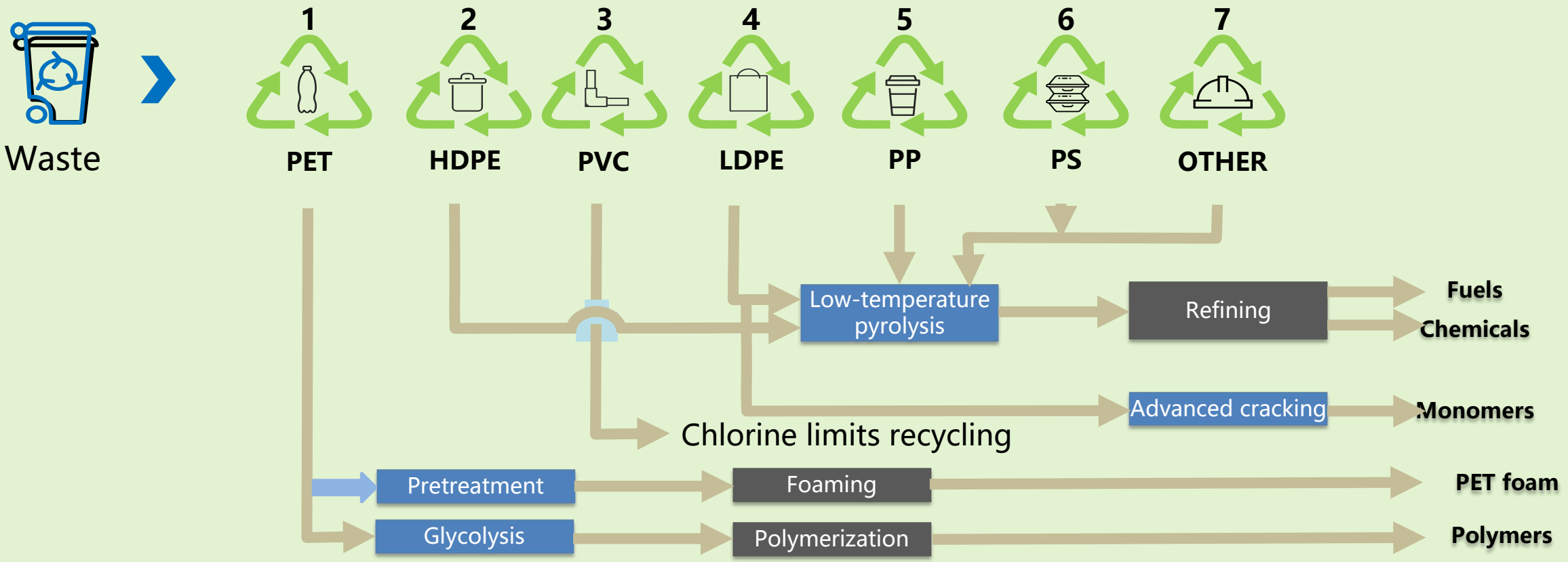


- Honeywell UOP is a recognized renewable fuels licensor
  - Leading experience in sustainable fuels
  - Over 25 years of operating experience
  - Commercially proven units



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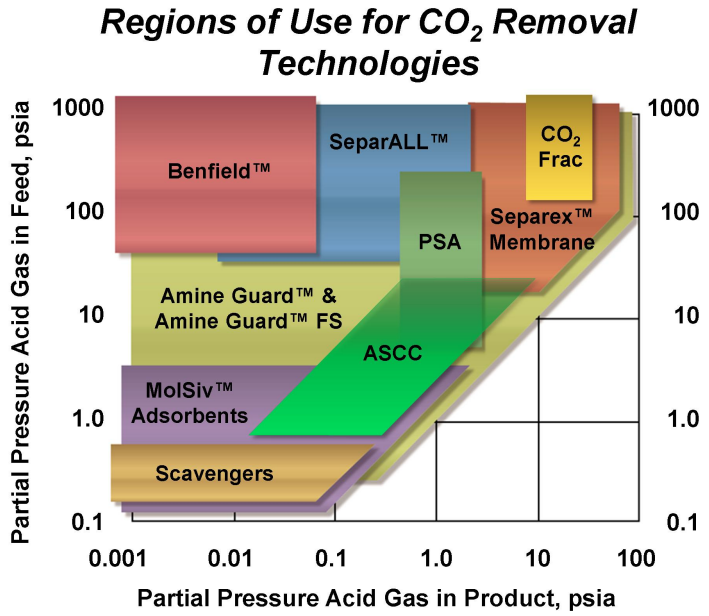
Honeywell UpCycle™ Advanced Plastics Recycling



Honeywell UOP targets potential 90% global plastics recyclability

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Honeywell Carbon Capture



Chemical Solvents

- **AMINE GUARD™ & AMINE GUARD FS Processes**
  UOP is the largest licensor of high-concentration MEA-based systems. Formulated solvents cut operating costs versus conventional MEA (> 600 units)
- **BENFIELD™**
  Fully inorganic solvent for pressurized flue gas and industrial processes (> 650 units)
- **ASCC Advanced Solvents**
  Direct capture from refinery, power, steel, cement and natural gas flue gases. CO_2 capture suits high oxygen and low CO2 levels. High-pressure regeneration cuts downstream power use.

Physical Solvents

- **SEPARALL™ Process**
  Uses Selexol (polyethylene glycol dimethyl ether) for sour-gas H_2S/CO_2 separation. Suitable for Chinese coal gasification. High oxidative stability (>50 units)

Note: Combine solvent absorption with PSA, membranes, or cryogenic separation to optimize CO_2 capture.

Adsorption

- **Polybed™ Pressure Swing Adsorption (PSA) Systems**
  Advanced adsorbents and rapid cycles capture CO_2 (>1100 units, 3 for CO_2 capture)

Cryogenic & Membranes

Capture at higher CO_2 partial pressures

- **SEPAREX™ Membranes**
  Extensive offshore platform CO_2 capture and sequestration experience (>300 units)
- **ORTLOFF CO_2 Fractionation**
  Captures and supplies CO_2 as a high-purity liquid product (2 units)

Honeywell offers extensive CO_2 capture technologies for diverse applications

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CO_2 TO JET

IMAC & LEAP Approach



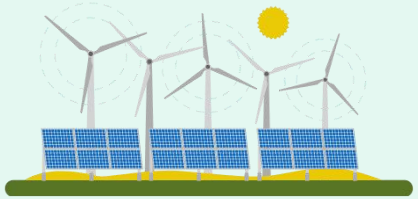
Integrated Operations & Enterprise Data Management

Honeywell FORGE

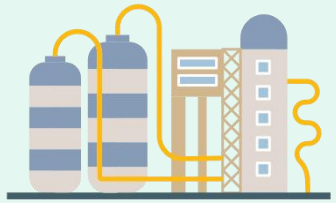
Integrated Industrial Cyber Security



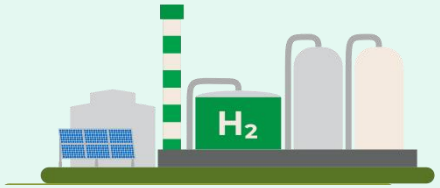
Carbon Capture



Renewable Energy

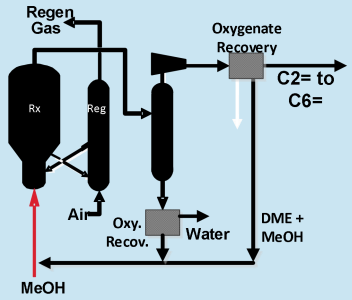


Making Methanol



Green H_2

Making Jet Fuel



Methanol to Olefins (MTO process)

Light olefins



Oligomerization & Hydrogenation

Integrated Safety and Security with Controls



SAF

Equipment Effectiveness

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Advanced Alarm Management

Workforce Competency

Advanced Control

REFORMING ADVANCEMENTS

SCOPE 1&2 DRIVING LOWER EMISSIONS



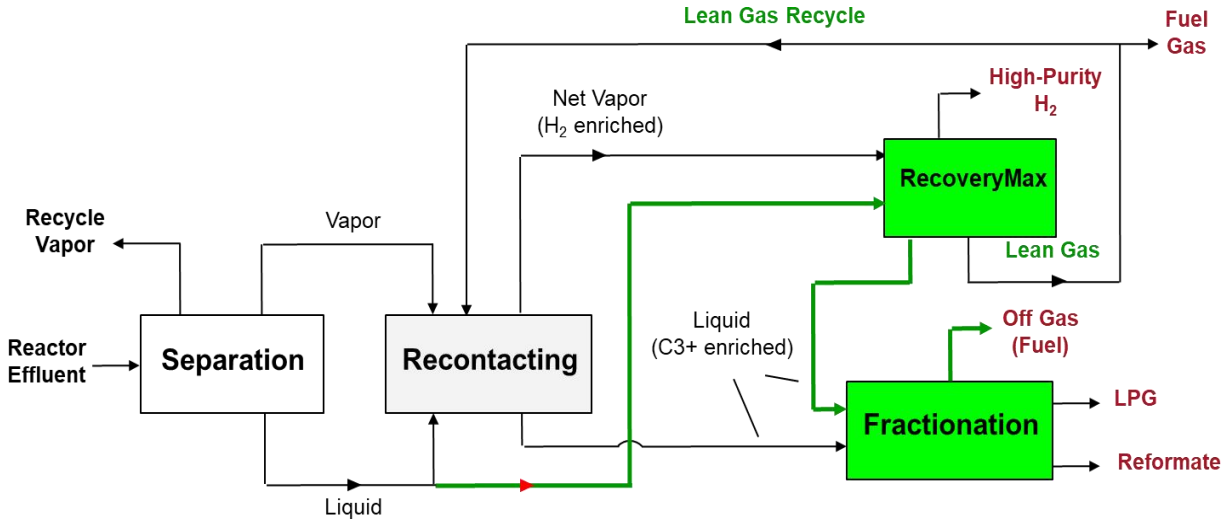
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RecoveryMax™ for Refining and Petrochemicals

What is RecoveryMax?

- An energy-efficient, low-cost system to recover high-value H_2, LPG and reformate from platinum reformer gas
- **Plays a key role in refinery hydrogen balance**
- Modular supply available for revamps
- Commercially proven design



How does it help meet your goals?

Optimized refinery hydrogen and fuel balance offsets CO2 emissions. Maximum reductions:

- Increase hydrogen supply from low-CO_2 process sources and reduce the need for SMR hydrogen production

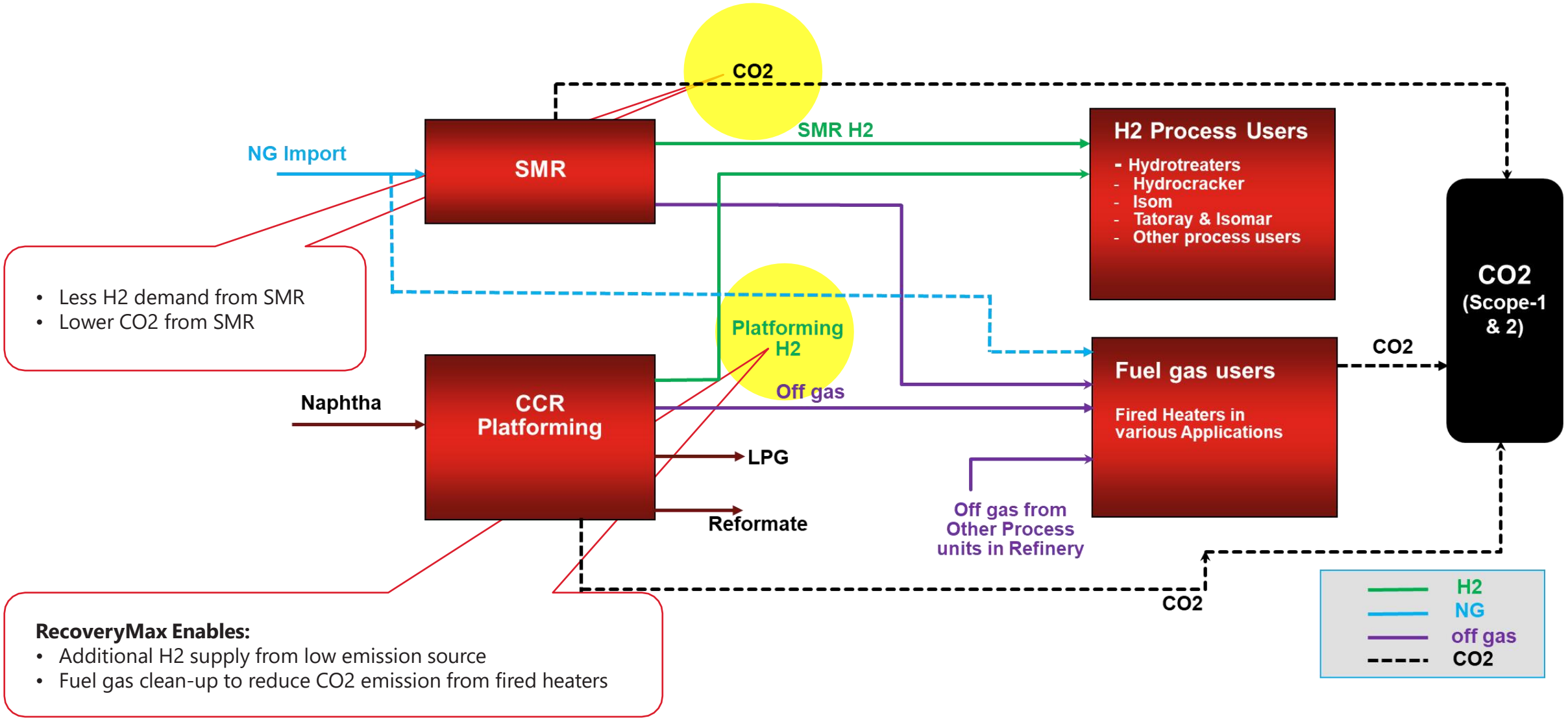
Higher economic returns: **~40 kbpsd typical reformer NPV increases by about $37M**

- Platinum reformer net gas H_2 recovery increases (H_2 recovery rises from 88% to 98+%)
- LPG recovery (LPG recovery rises from ~60% to ~90%). Reformate recovery approaches 100%

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RECOVERYMAX™ REFINERY H2 AND FUEL GAS



- Less H2 demand from SMR
- Lower CO2 from SMR

RecoveryMax Enables:
- Additional H2 supply from low emission source
- Fuel gas clean-up to reduce CO2 emission from fired heaters

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RECOVERYMAX: HIGHER PROFIT, LOWER CO2

Parameters		Conventional Recovery Scheme	RecoveryMax Flowscheme
Hydrogen	kMTA	57	64 ↑ (+12%)
LPG	kMTA	39	65 ↑ (+60%)
Reformate	kMTA	1492	1494 ↑ (+0.13%)
Off-gas	kMTA	76	41 ↓ (-46%)
EEC	$MM	Base	+9
Utility	$MM/yr	Base	+0.7
NPV from Process improvements	**$MM**	**Base**	**+36.7** ↑
CO2 emission (Scope-1 & 2)	kMTA	Base	(85) ↑
CO2 credit	**$MM/yr**	**Base**	**+4.2**
NPV including CO2 credit	**$MM**	**Base**	**+68.6**

Notes / Assumptions:
1: 40,000 bpsd Platforming unit with 104RON
2: CO2 reduction credit $50/MT.
3: 8400 hours operation per year.
4. Conventional Recovery case includes once-through PSA

Utility Price basis:
1: Fuel gas: $4/MMBtu. 2: H2 price: $1100/mt. 3: Electricity: $0.08/KWh.

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WE
BELIEVE
The technologies needed for the decarbonization and transforming are not new – they're built on the foundation of proven technologies applied in new ways.
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THANK YOU

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