# “Double” disruptive technologies

## Positioning to impact the petrochemical industry

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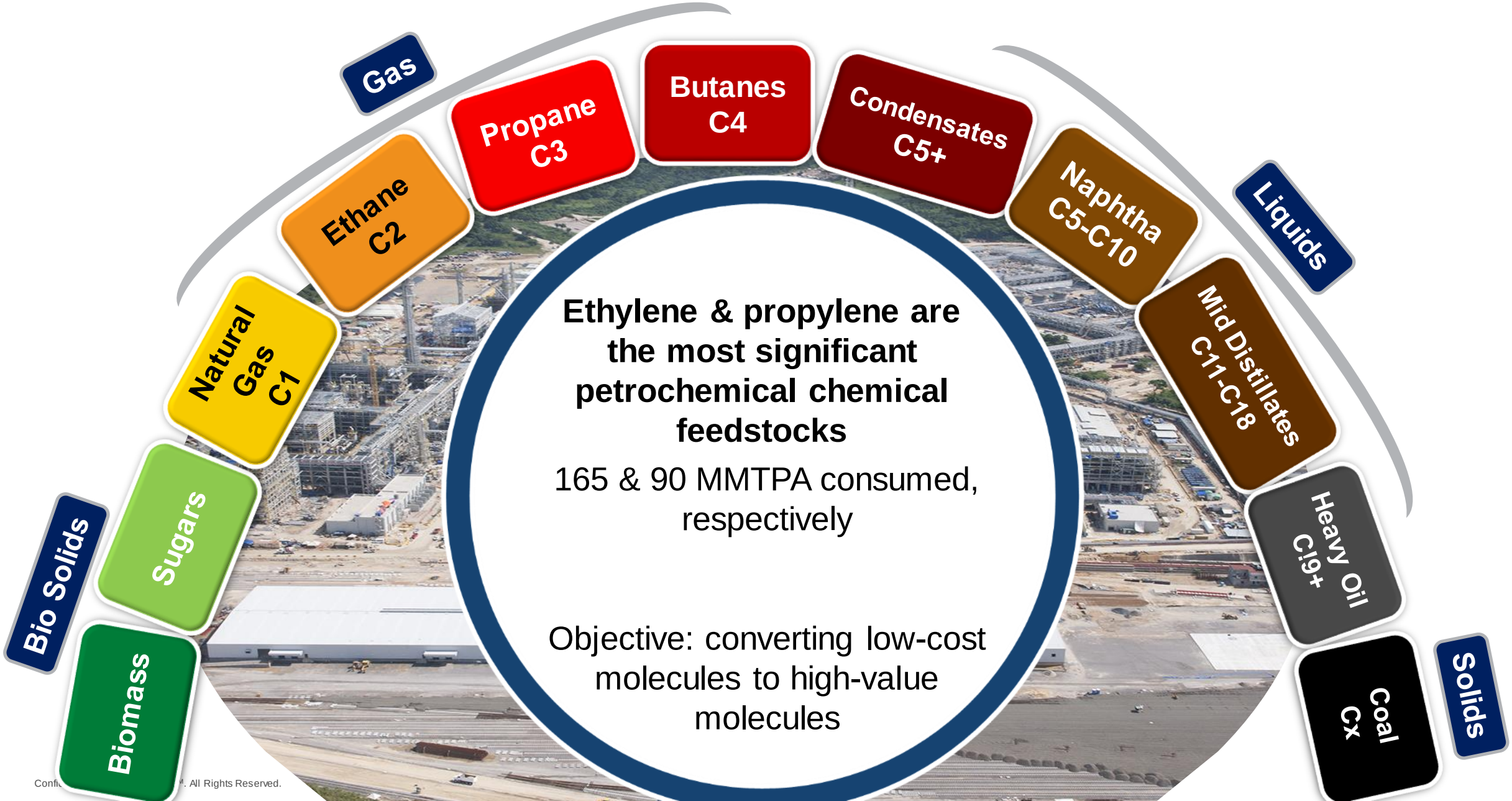
# Agenda

- What are disruptive technologies?
- What are they and what makes them interesting?
- Implication for the industry

**In business, “disruptive” relates to a new product, service or idea that radically changes an industry…one that successfully challenges the established incumbent(s)**

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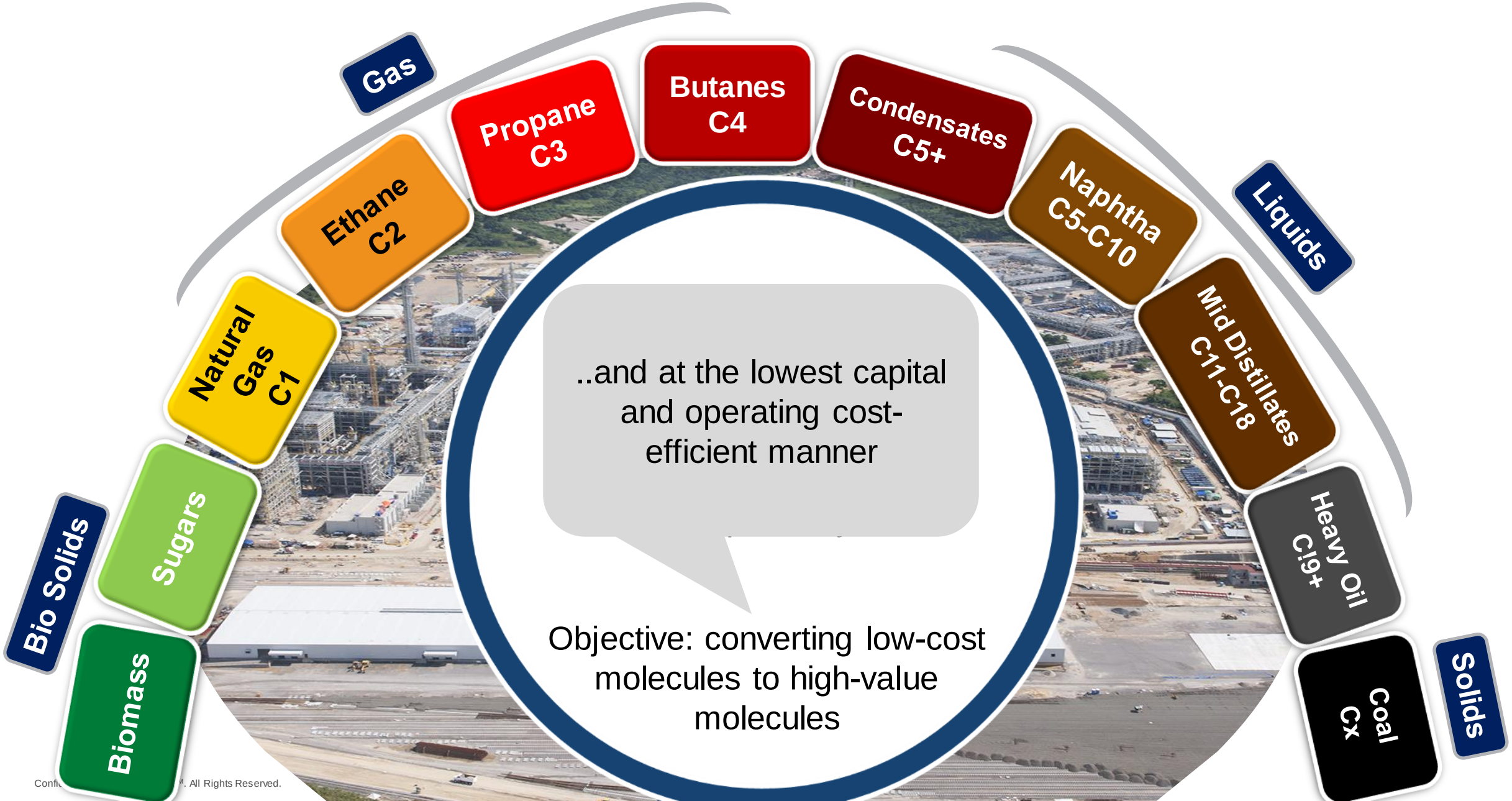


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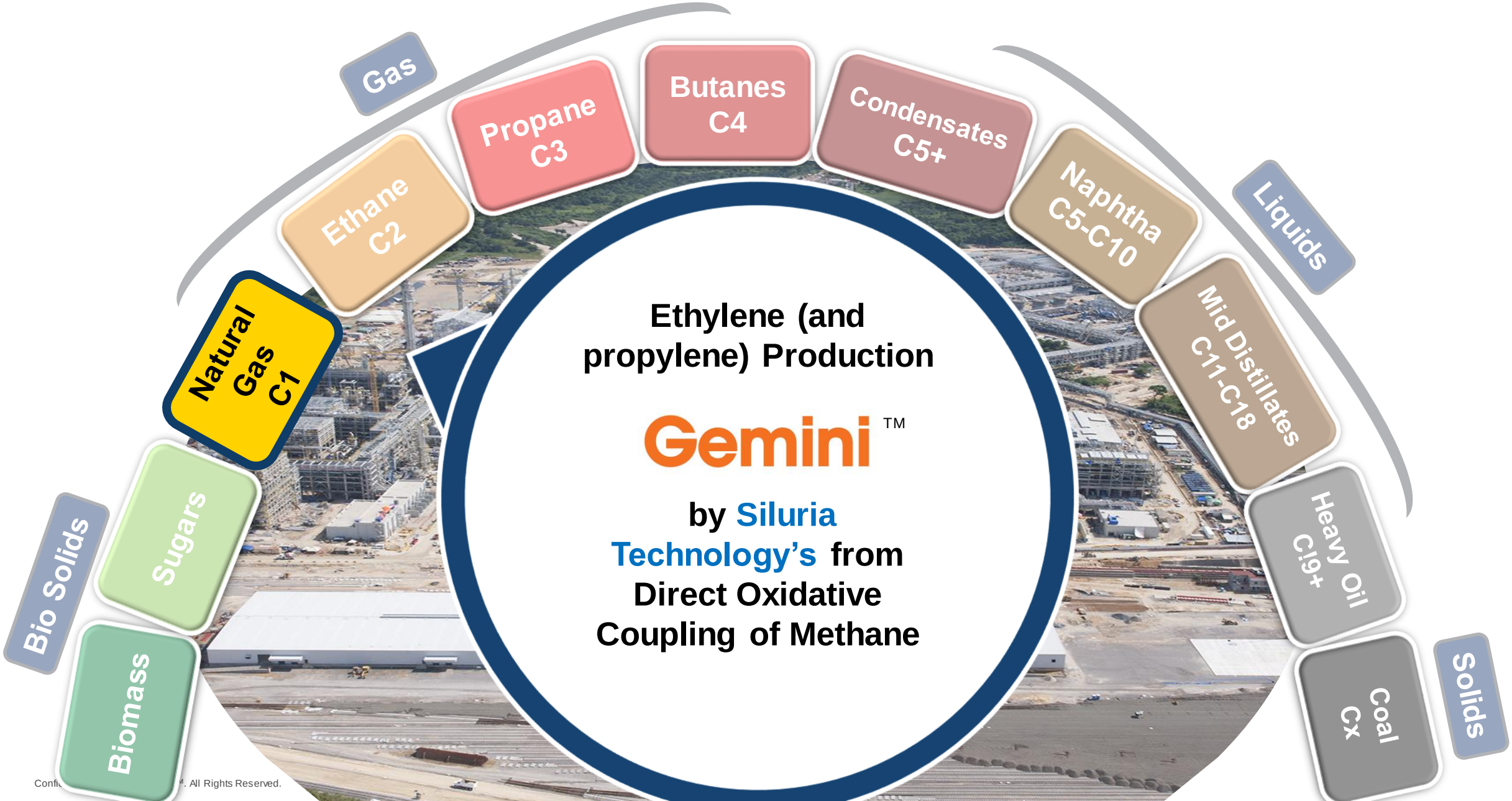


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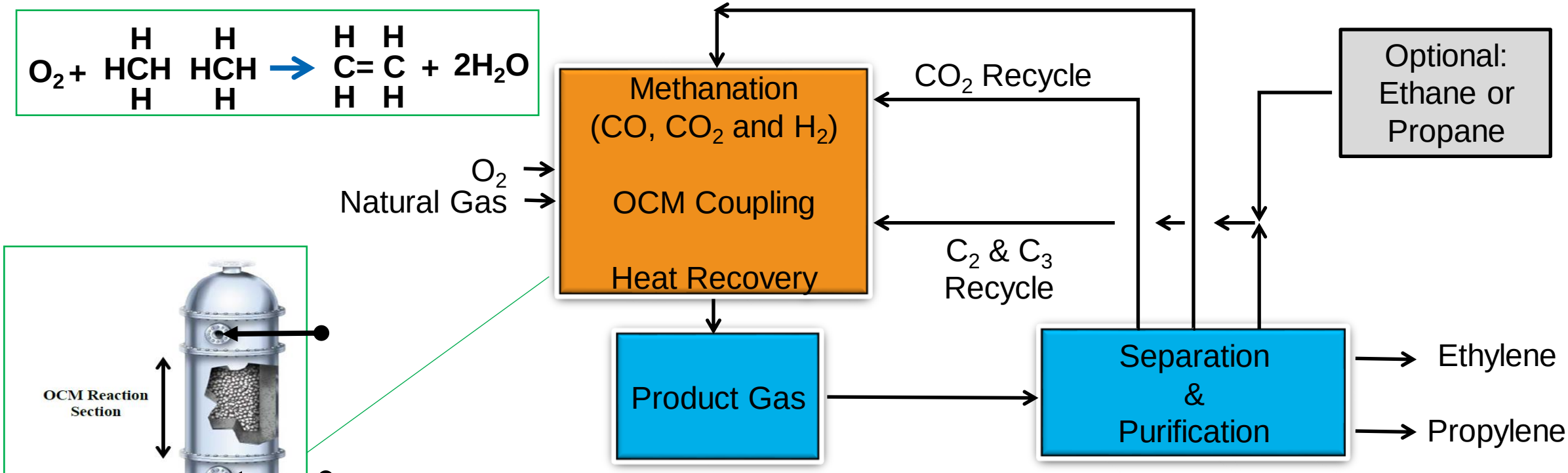
# Siluria's OCM technology produces ethylene and propylene from methane and other NGLs




Souces:
Siluria Technologies
PEP: 2018-06 Siluria OCM Process Evaluation

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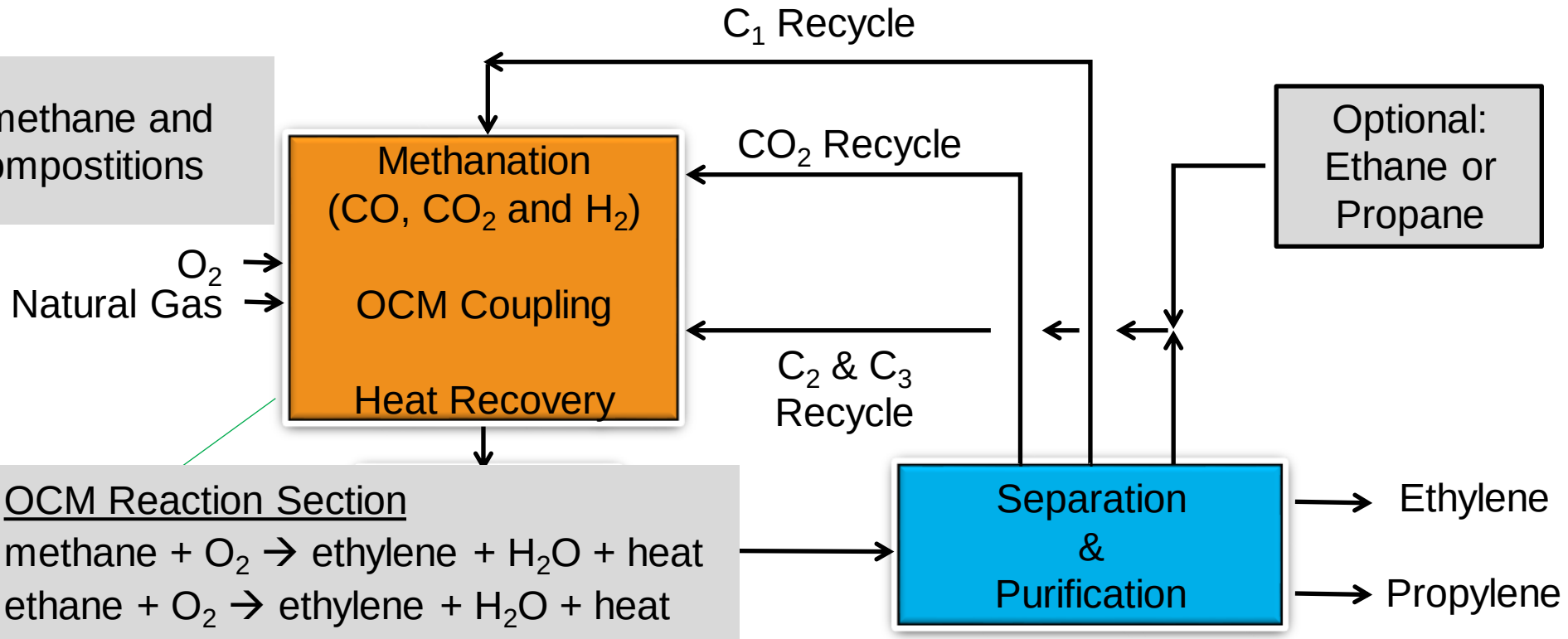
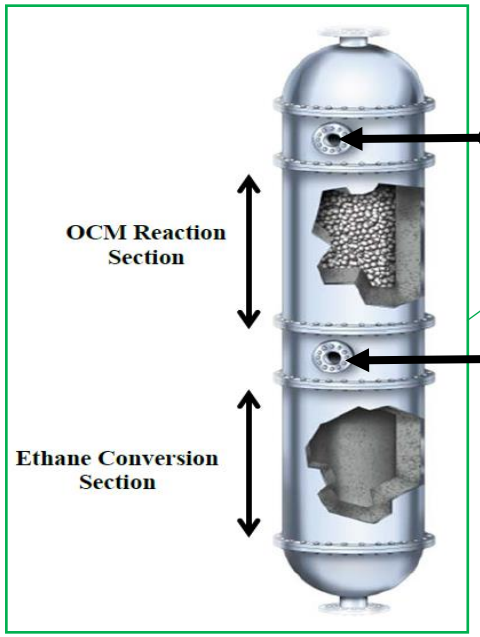
# Siluria's OCM technology produces ethylene and propylene from methane and other NGLs

Can feed a mix of methane and NGLs feedstock compostitions




**OCM Reaction Section**

methane + $O_2$ → ethylene + $H_2O$ + heat

ethane + $O_2$ → ethylene + $H_2O$ + heat

**PB Conversion Section**

ethane + heat → ethylene + $H_2$

propane + heat → ethylene + $H_2$

propane + heat → propylene + $H_2$

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# Siluria's OCM process (in the Demonstration Stage) is expected to be competitive in "advantaged" configurations…

**Siluria's Technology can be vehicle for upgrading light olefin assets, for example….**

| Asset | Feedstock | Integration Dimension | Advantages |
|---|---|---|---|
| Steam Cracker Integration | • Natural gas<br>• Cracking furnace methane containing off-gasses | • Feedstock:<br>❖ Natural gas<br>❖ Methane containing off-gases<br>• Cold-end integration | • Additional ethylene production<br>• Lower feedstock costs e.g., off gases<br>• Adds $C_1$ as feedstock<br>• Reduced GHG intensity<br>• Debottlenecking opportunities |
| PDH Integration | • PDH off-gases containing methane/ ethane | • Feedstock:<br>❖ Methane/ethane-containing off-gases<br>• Cold-end integration | • Additional propylene production<br>• Ethylene for PP plant<br>• Lower overall feedstock costs<br>• PDH increased efficiency (fuel-gas production climbs as PDH catalyst ages) |

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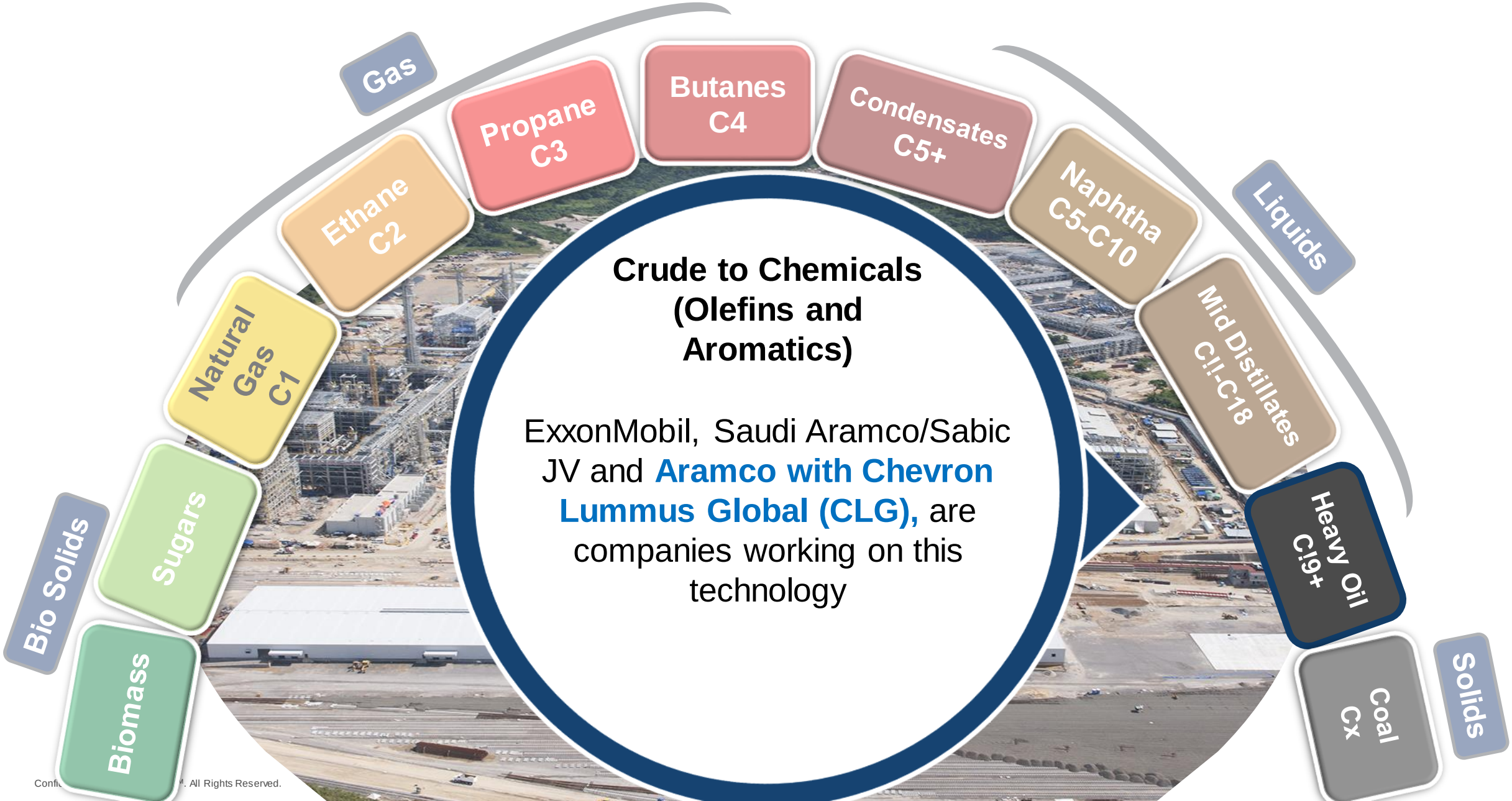


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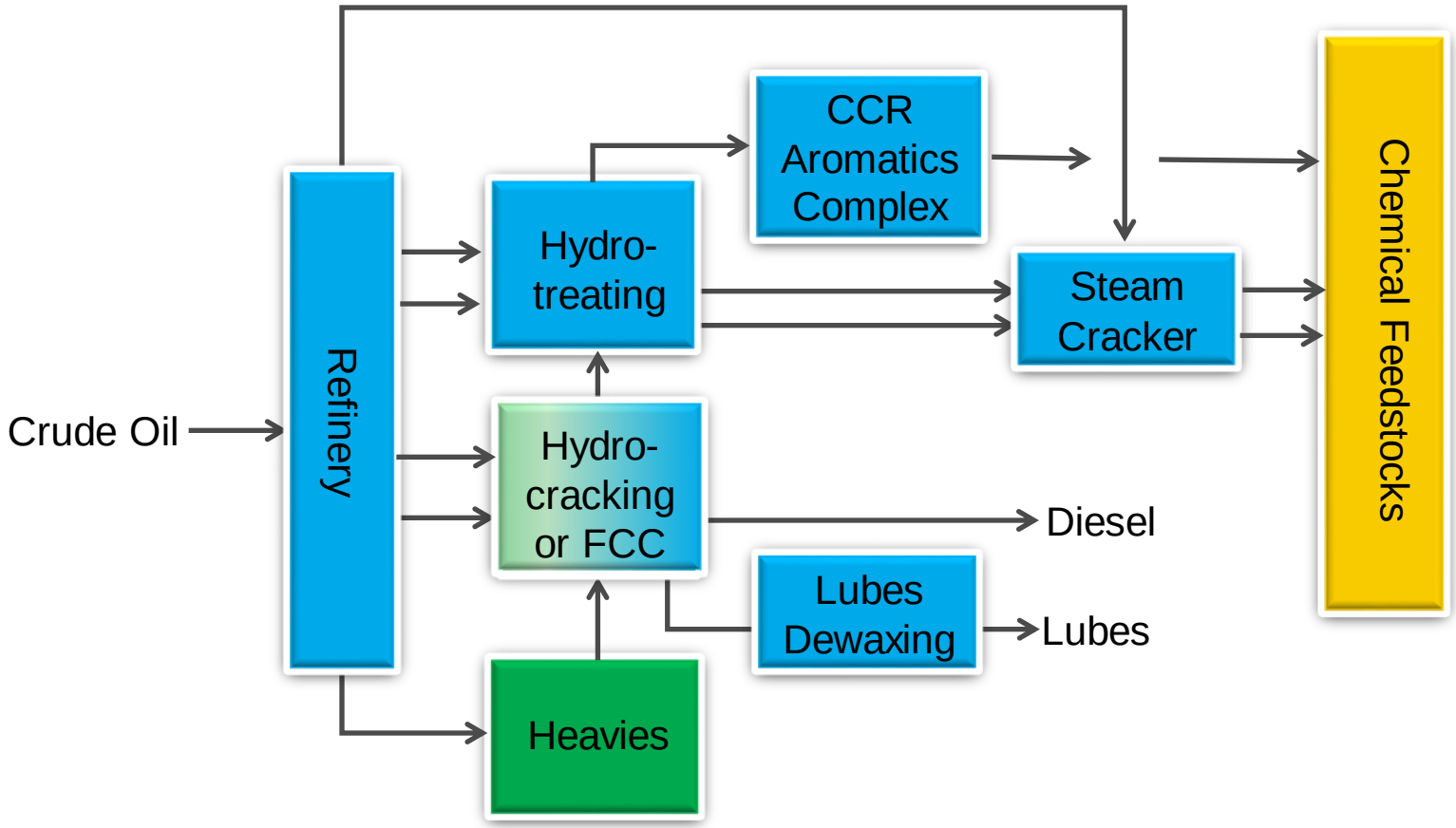
# Crude to “more” chemicals could be very significant industry “disruptor”

- Reconfiguration in refinery to convert heavy-ends of crude to lighter molecules, “right” for producing petrochemicals
- In order to produce 40-50% of the bbl to chemical feedstocks
- Versus traditional 20-25% for an integrated refinery
- Half of this to light olefins




Source: PEP 29J: Steam Cracking of Crude Oil

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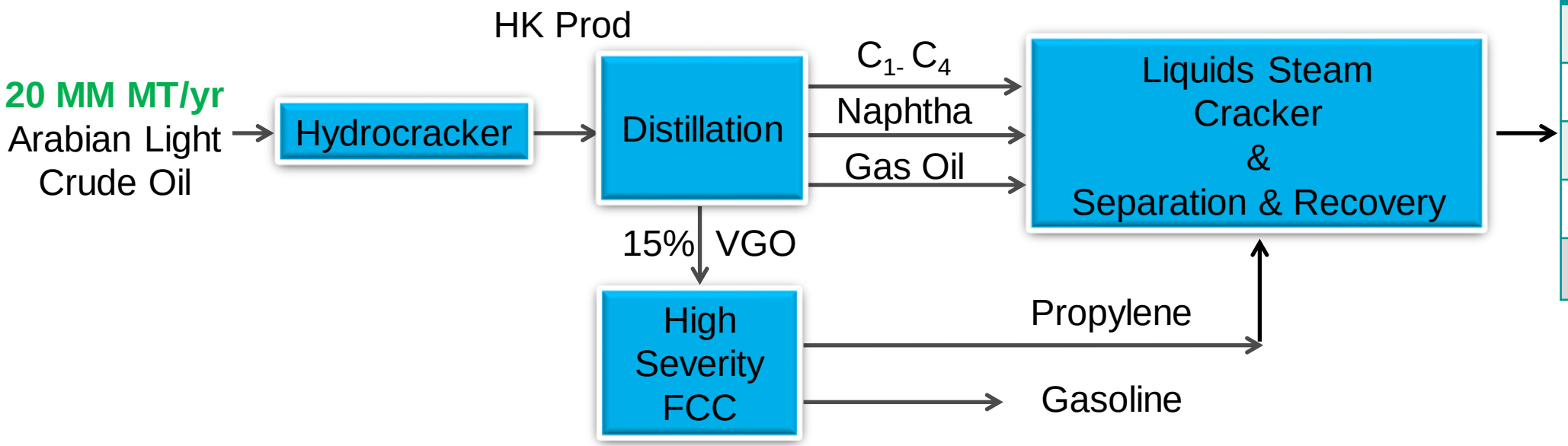
# Crude-to-olefins is expected to have very significant impact on chemical industry — e.g., for Saudi Aramco/CLG

- Feeds whole (light) barrel to hydrocracker (HK)
- Making distillation more simple than conventional CDU
- HS FCC technology by JV with JX Nippon




| Product | MM MT/yr |
|---|---|
| Ethylene | 4.7 |
| Propylene | 3.0 |
| Mixed $C_4$ | 2.6 |
| Pygas | 4.0 |
| Total | 14.3 |

Light olefins production is ~40% of crude feed…but 72% for chemical feedstocks

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Source: PEP 29J: Steam Cracking of Crude Oil

# Crude-to-olefins is expected to have very significant impact on chemical industry — e.g., for Saudi Aramco/CLG

(*Reuters* 1/8/18)

**Saudi Aramco signs crude-to-chemicals technology agreement**

"… 70 to 80 percent of crude intake will be converted into chemicals, with an eye to beginning commercialization in two years..."

"… thermal crude-to-chemicals technology - would cut capital costs by 30 percent compared to conventional refining…"

→

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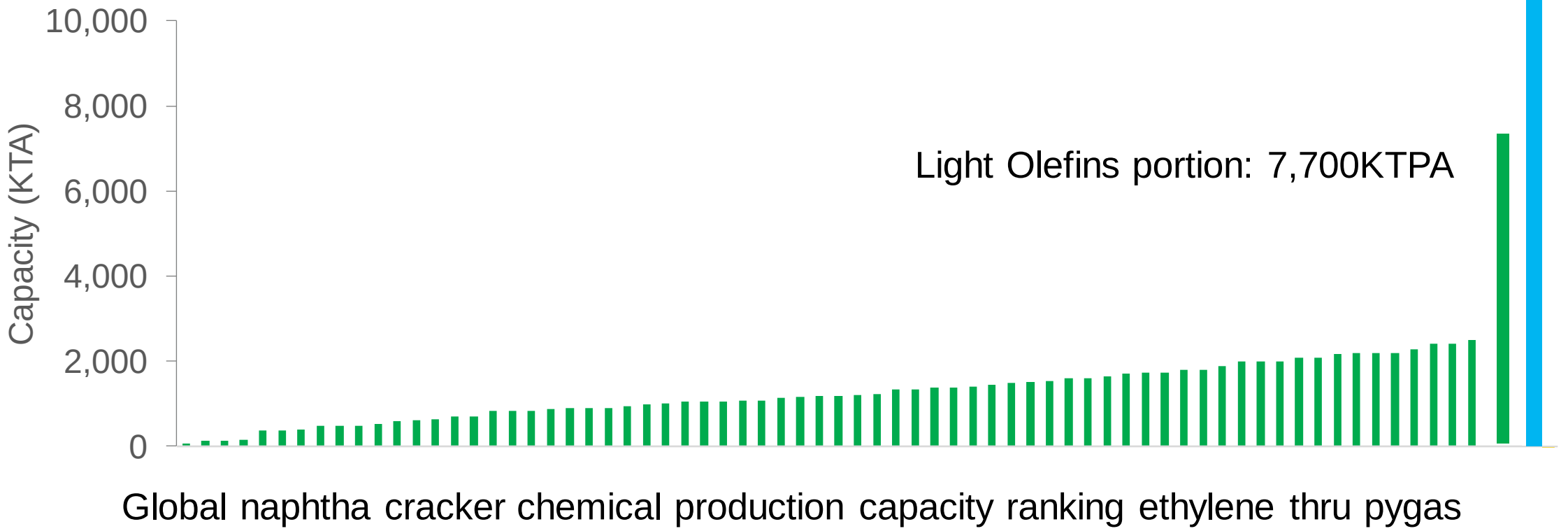
Aramco/CLG is expected to produce 14,300 KTPA
(we are going to need a "bigger" ~~boat~~ slide)

## Naphtha steam cracker capacity ranking

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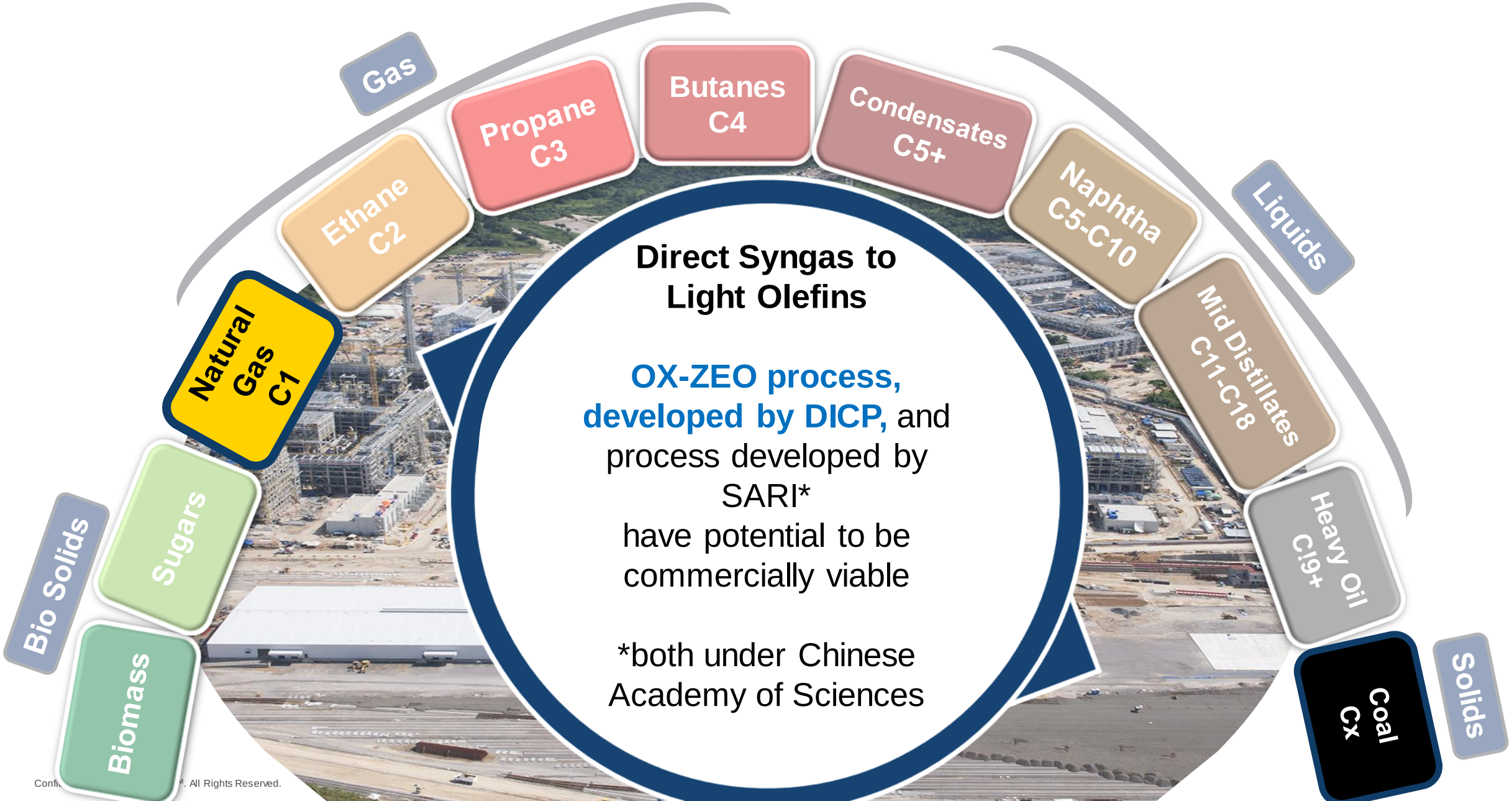


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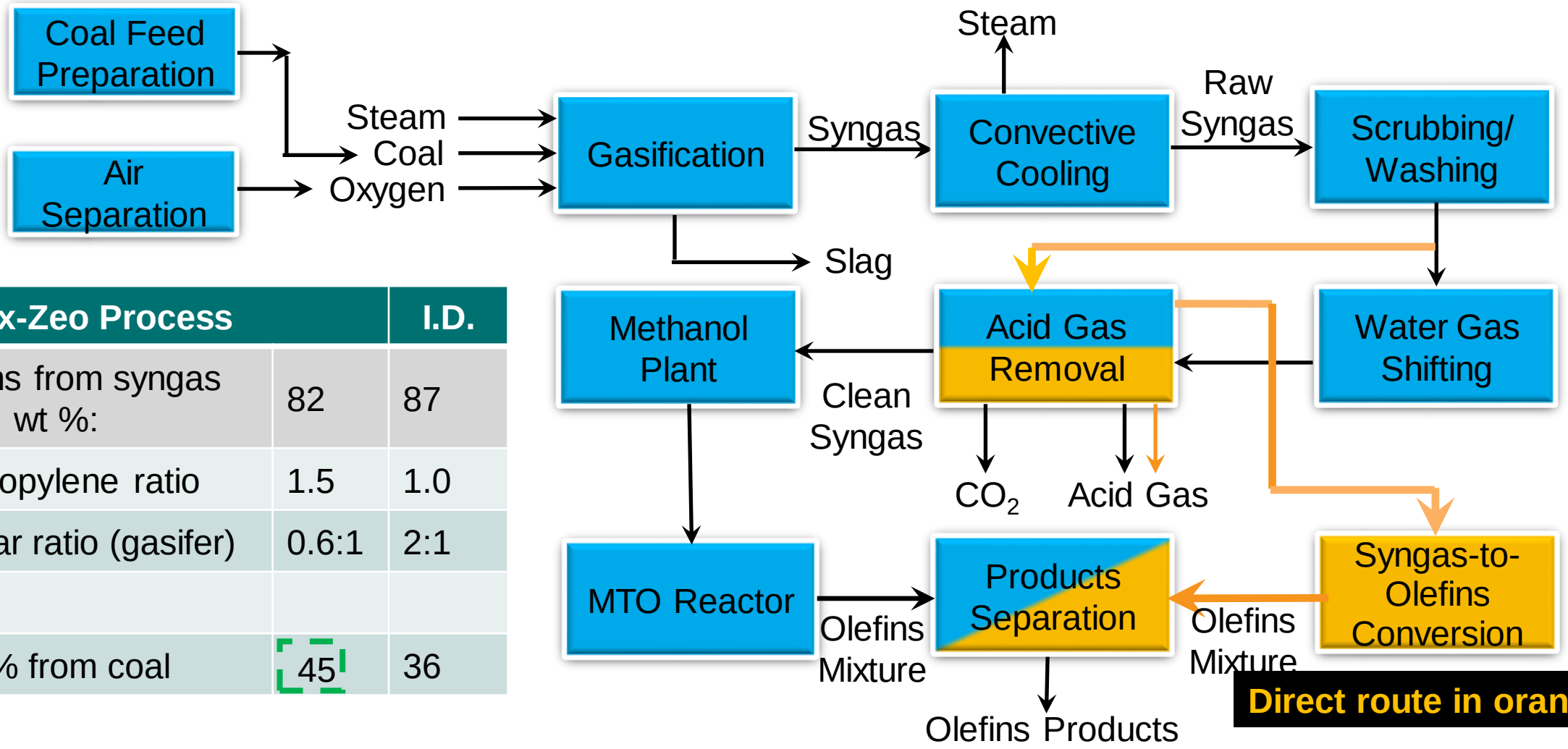
# Based on an oxide of Zn/Cr metals with modified zeolite catalyst, "direct" syngas process yields high light olefins without need for a methanol intermediate

| Ox-Zeo Process | | I.D. |
|---|---|---|
| $C_2$-$C_4$ olefins from syngas conversion, wt %: | 82 | 87 |
| Ethylene/propylene ratio | 1.5 | 1.0 |
| $H_2$/CO molar ratio (gasifer) | 0.6:1 | 2:1 |
| | | |
| Carbon eff% from coal | 45 | 36 |

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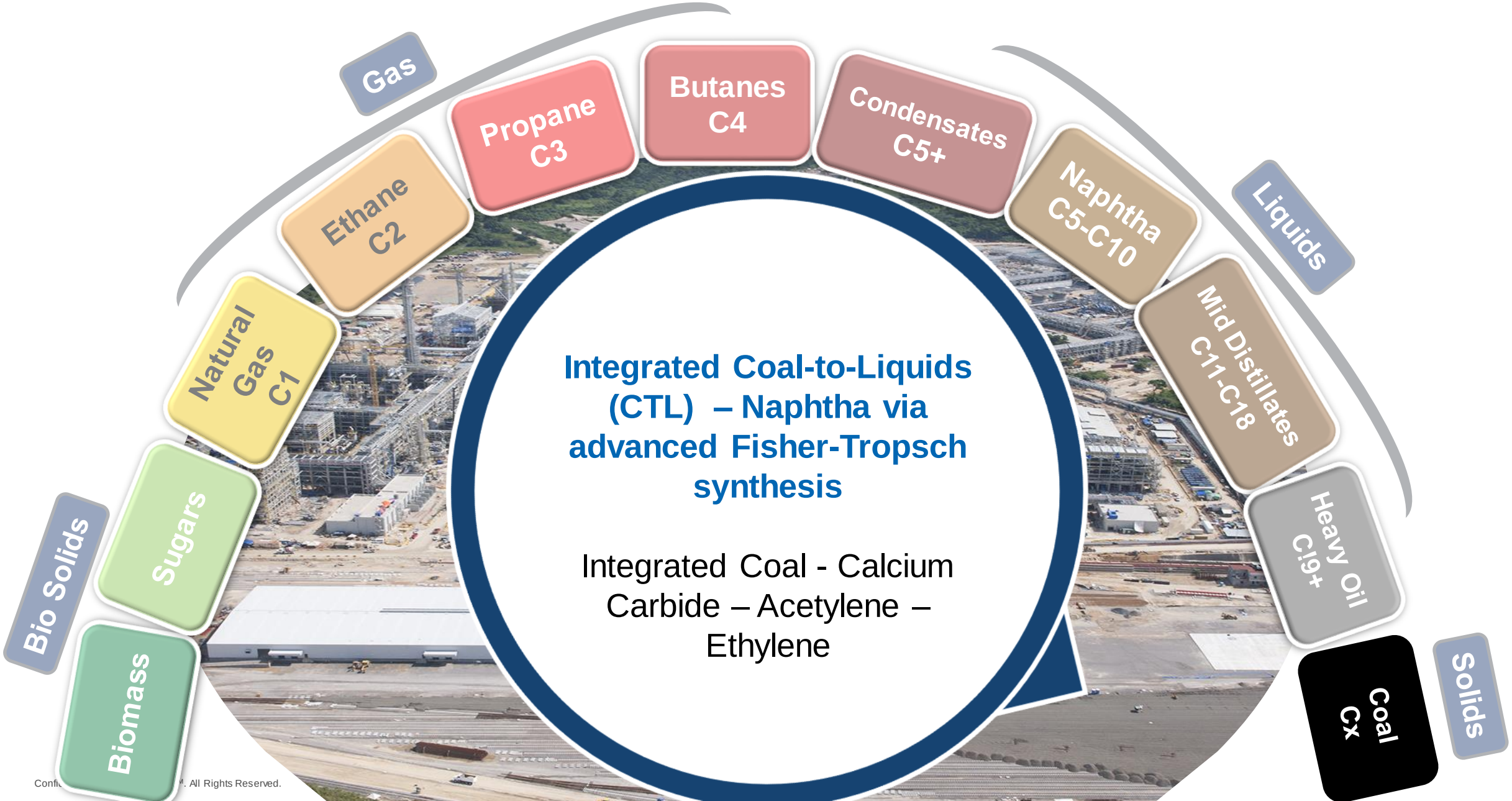
Source: PEP 299: Direct Syngas to Light Olefins

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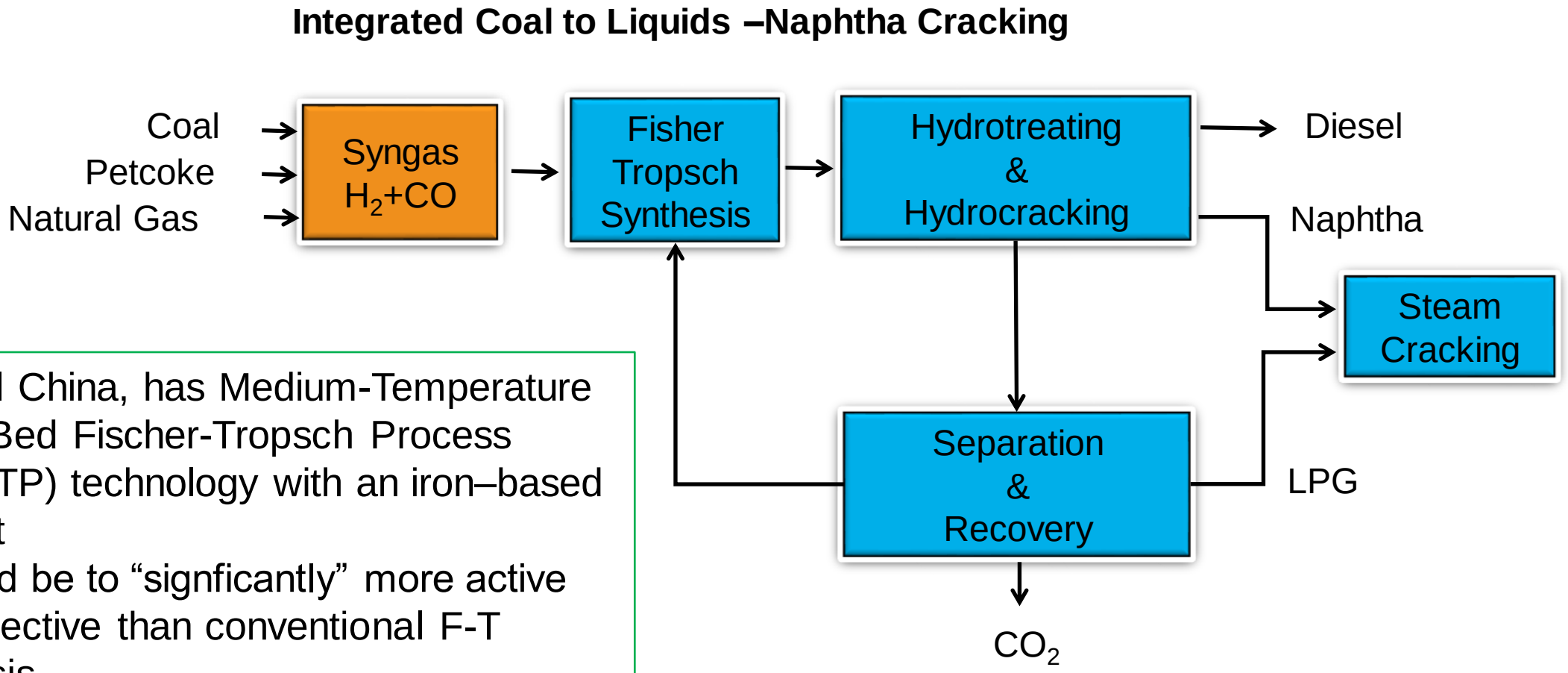
# Several CTL developers in China claim to have superior slurry Fischer-Tropsch (F-T) catalyst & reactor technology




- Synfuel China, has Medium-Temperature Slurry-Bed Fischer-Tropsch Process (MTSFTP) technology with an iron–based catalyst
- Claimed be to “signficantly” more active and selective than conventional F-T synthesis

Source: PEP 305: CTL Enhanced Production of Naphtha and Light Olefins

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# There are CTL plants totalling 4 MM TPA of naphtha from coal being commercialized and planned in China

| Company | Shenhua Ningmei's | Lu'an | Shaanxi Energy | Yitai |
|---|---|---|---|---|
| Liquid Fuels, MM TPA | 4 (55 Bn RMB/ $7.9 Bn) | 1 | 4 | 1 at Yili & 2 at Ordos |
| Stage of Development | Commecial Dec 2018 | Commercial Dec 2017 | Feasibility | Approved, Op Pilot (160KTPA) |
| Coal Feed, MM TPA | 20.4 | 5? | 20 ? | |
| Naphtha, MMTPA | 1.08 | 0.25 | 1.0 | 0.25 & 0.75 |
| LPG, MMTPA | 0.34 | 0.09 | | |
| Diesel. KTPA | 2.73 | 0.71 | | |

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Source: PEP 305: CTL Enhanced Production of Naphtha and Light Olefins

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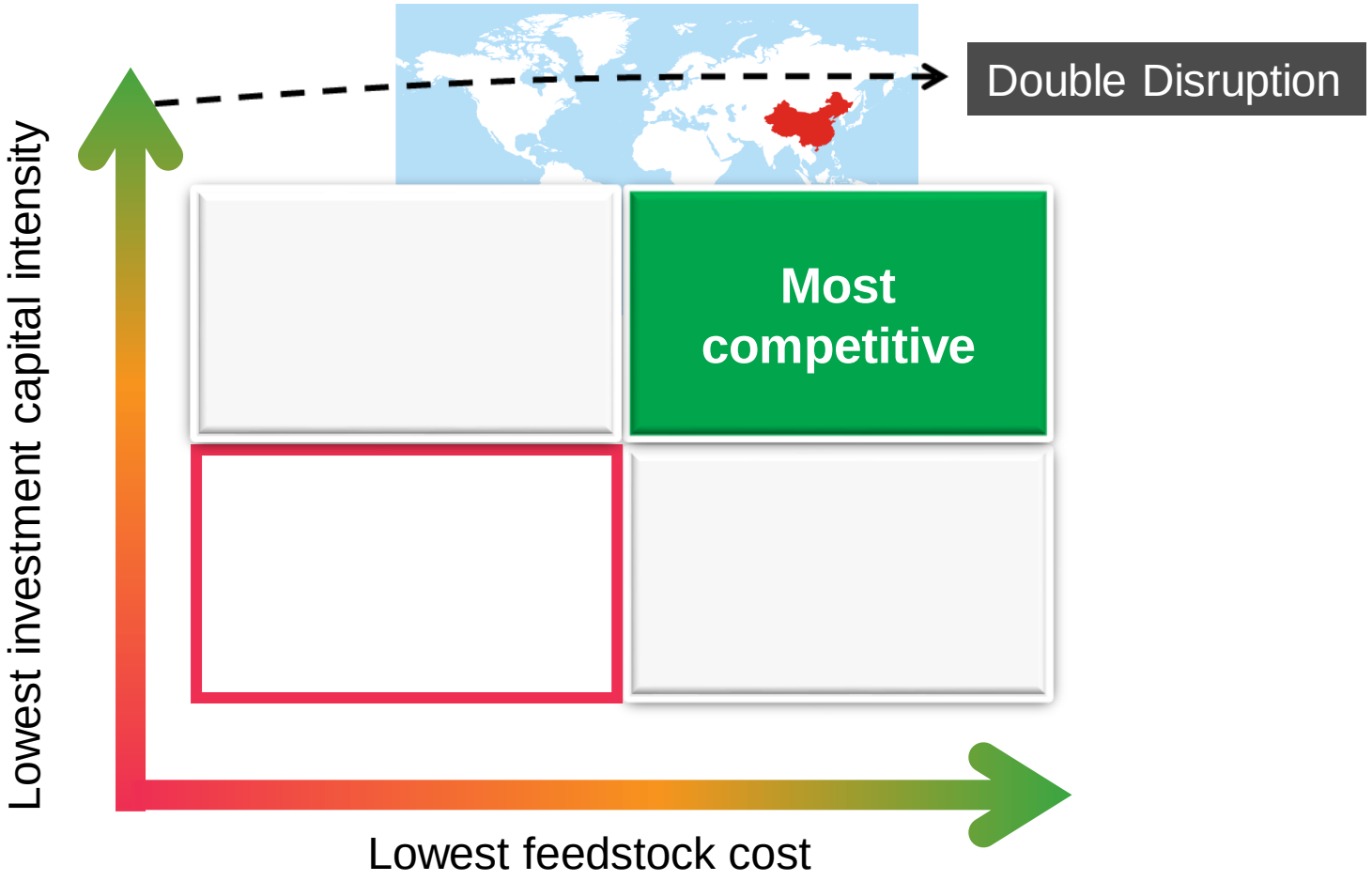
# And finally...




China investment location factor ~0.53 USGC, due to:

- Efficient construction methods
- High construction productivity
- Low skilled labor cost
- Extensive domestic equipment manufacturing capabilities

?? **Market drivers are expected to close this advantage over time**

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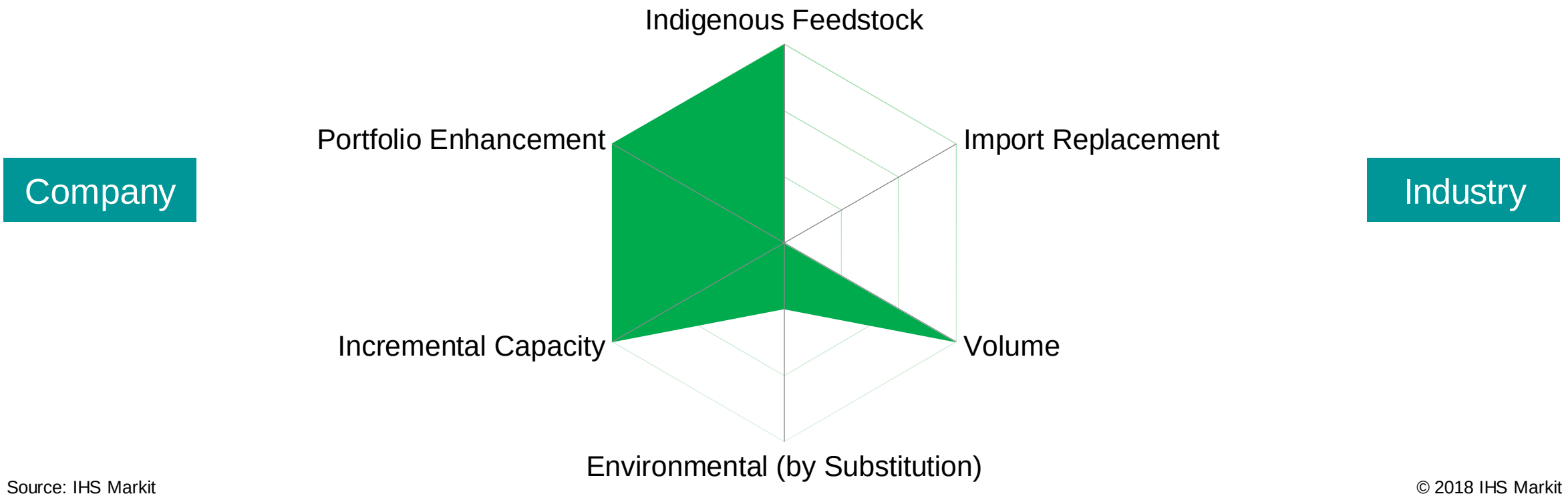
Source: PEP 204C: Location Factors

# Crude oil to chemicals …target to drive chemical feedstock capacity and value add to crude oil, especially in Middle East

## Impact footprint: Crude oil cracking

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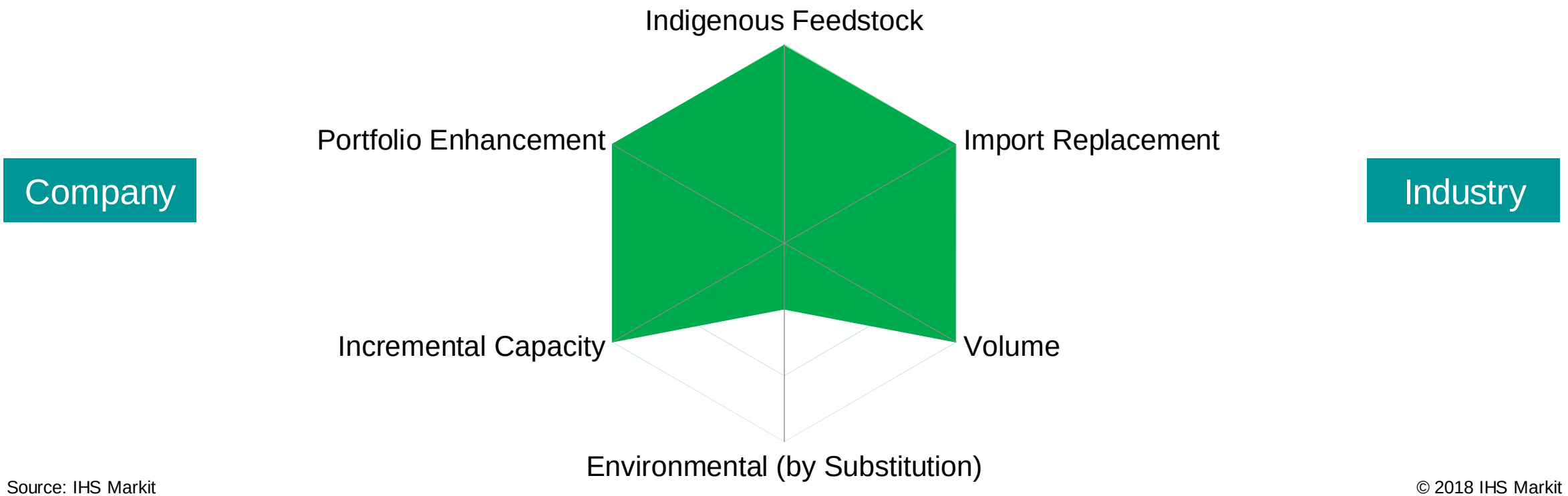
# Crude oil cracking …but also could have a significant import impact, if built in petrochemical -deficit regions

## Impact footprint: Crude oil cracking

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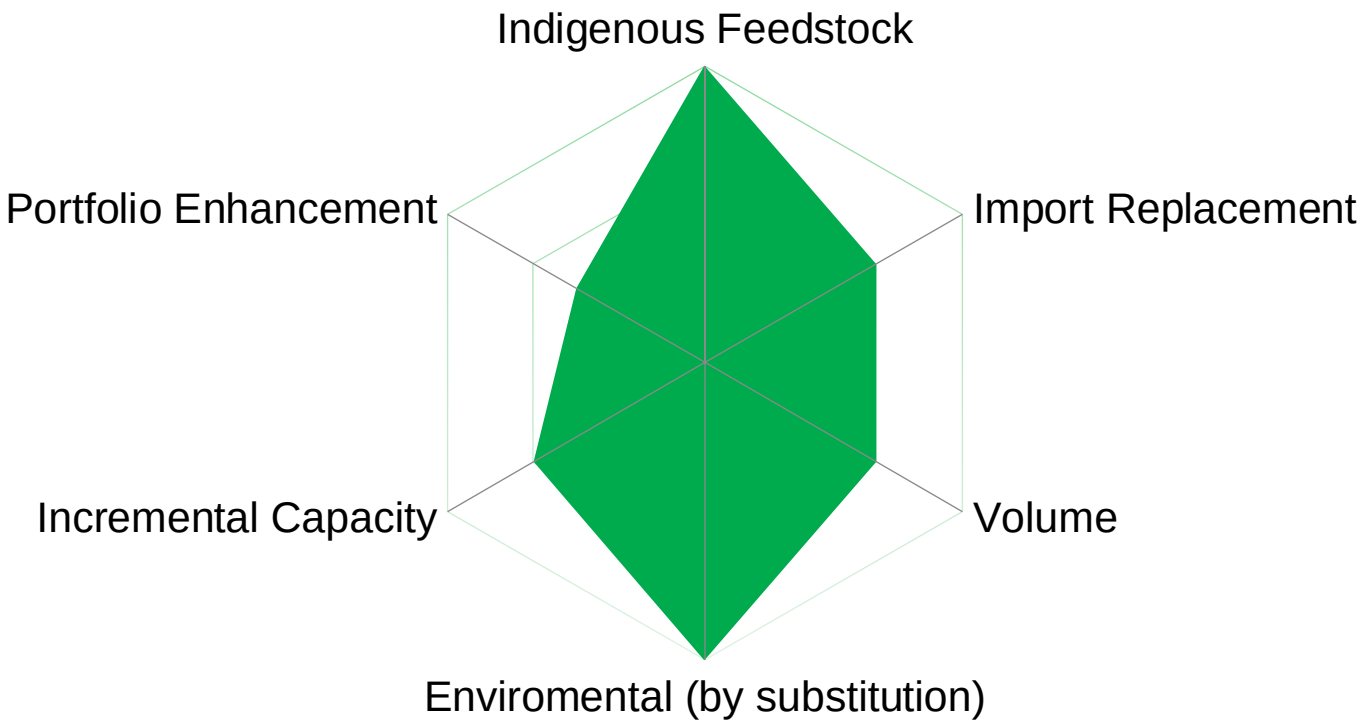
# Ox-Zeo Direct conversion of to olefins….could have industry impact in China by making coal-based technology more sustainable

## Impact Footprint: Ox Zeo DCIP (Direct conversion) of coal-based synthesis gas to olefins

Company




Industry

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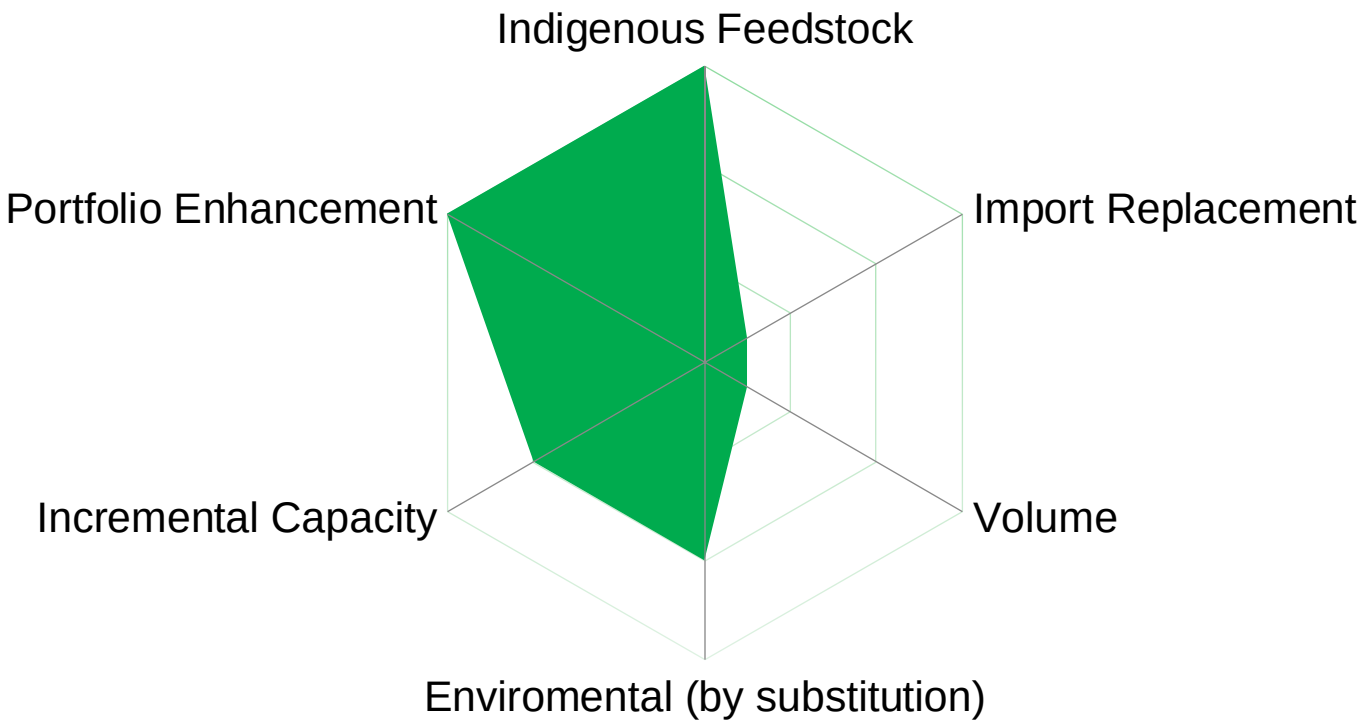
# Siluria's OCM to ethylene….positioned to impact at company level

## Impact footprint: Siluria's OCM to ethylene

Company




Industry

Source: IHS Markit

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# Really finally…the bar is moving up for capital and operating resources to achieve a competitive & sustainable advantage by:

- **Securing feedstock advantage**
- **Converting lowest cost molecules to high value products**
- **Leveraging technology developments – especially revolutionary ones**
- **Integrating physically, upstream and downstream**
- **Decreasing Capital Intensity: through scale, simplicity and location**

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