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Plastic Pyrolysis Oils as Feedstock for Steam Crackers: Opportunities and Challenges

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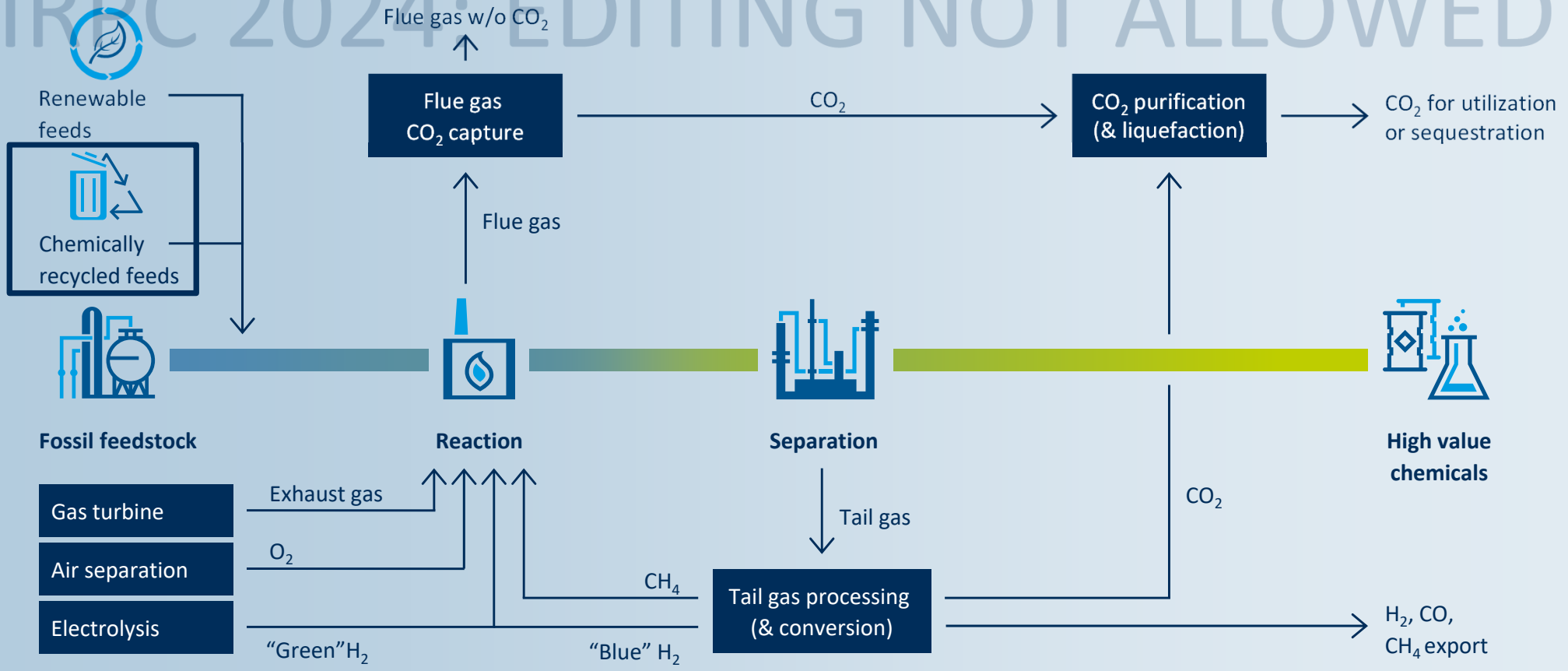
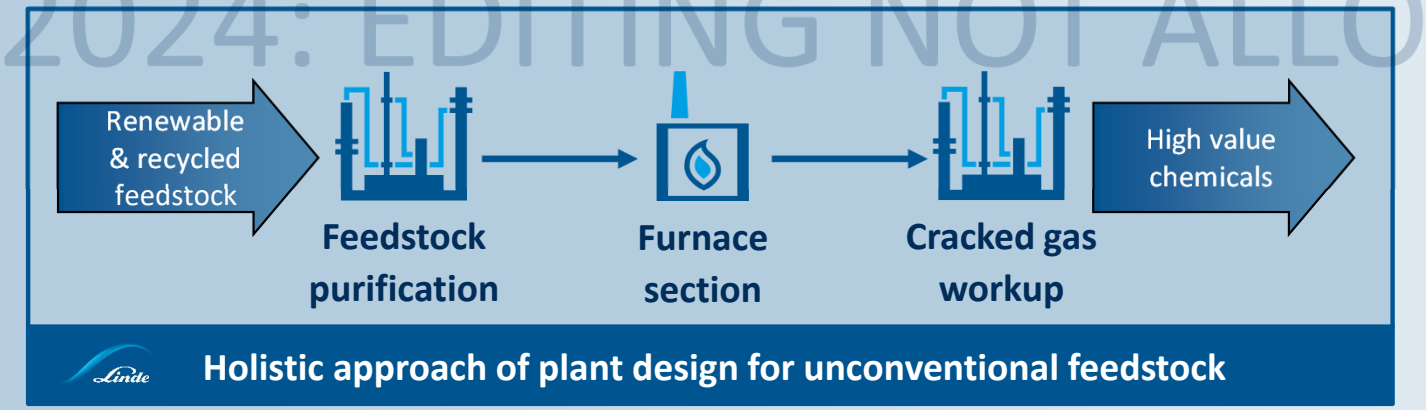
The Carbon Management Toolbox

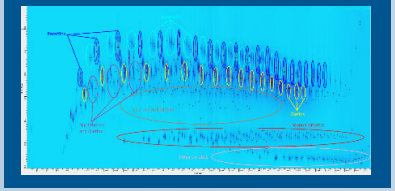


Processing of Unconventional Feedstock

Linde approach



Detailed analytics



Pilot testing

Design

furnace
separation
contaminants
purification

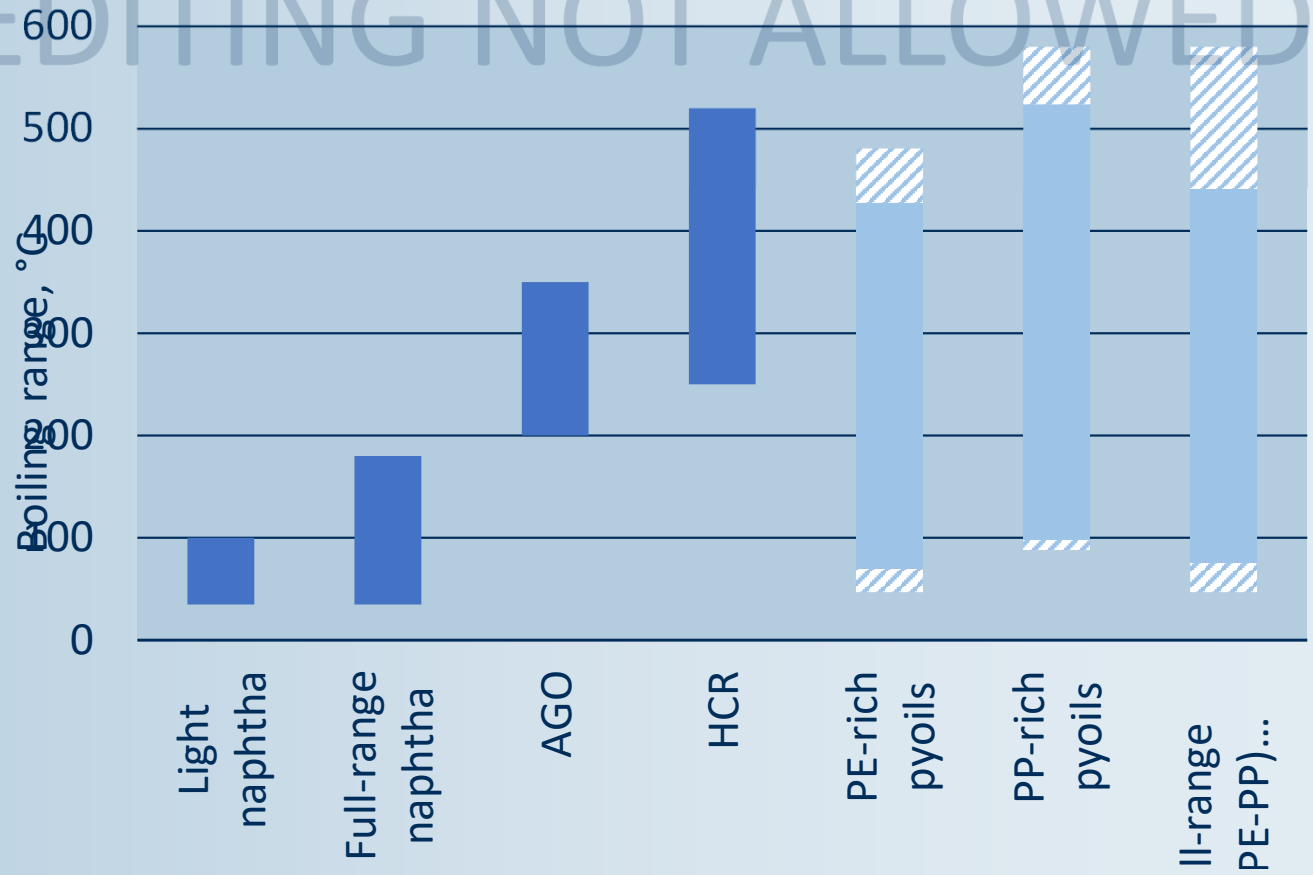
Boiling Range

Broad curve with high final boiling point

→ **Broader boiling range** compared to conventional feedstock

→ From light naphtha to heavy feed

→ Very **high final boiling point**



Hydrocarbon Composition

Details by two-dimensional gas chromatography (2D-GC)

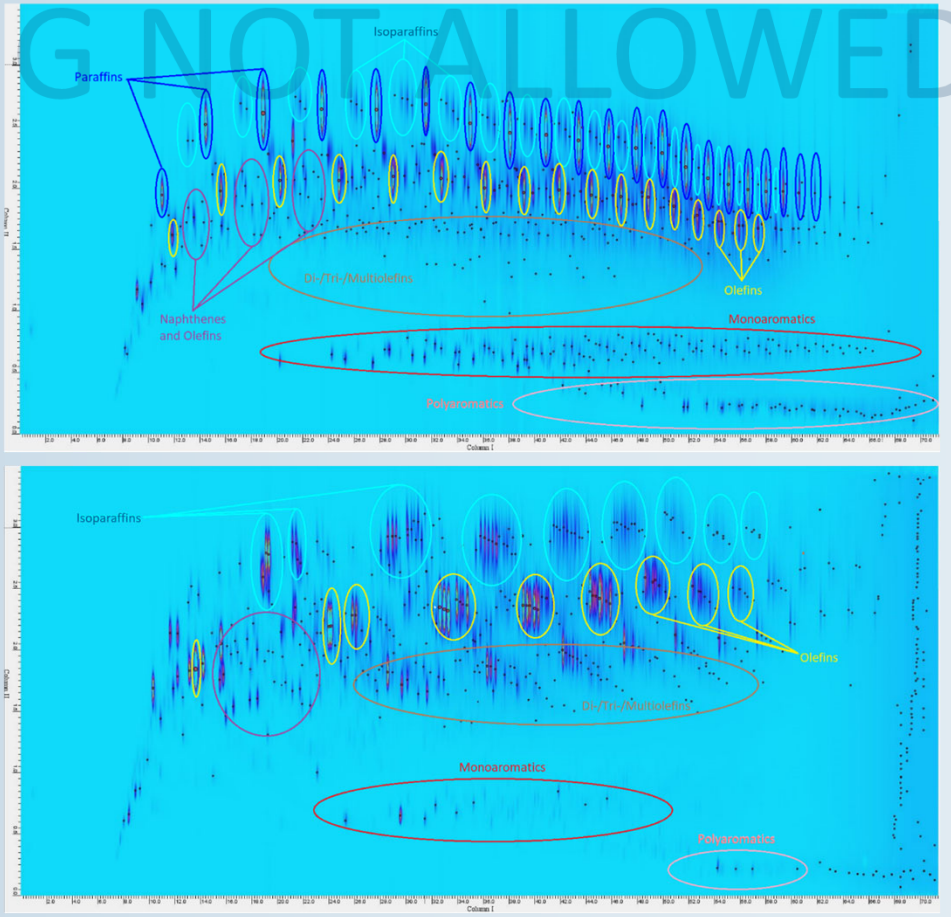
→ **Specific test** procedure developed

→ **Numerous different pyoils** characterized

→ **Key components** and **relevant characterization** in place

→ **Broad quality range** together with **uncommon features**

Plastic pyrolysis oils significantly differ from one to another and also to conventional feedstock
(even though they might show some similar properties)



Contaminants & Impurities

Identifying a major challenge in plastic pyoils

→ High **contaminants** and **impurities** concentration

→ Wide **variation** in different pyoils (depending on plastic waste and pyrolysis)

→ Major concern: **nitrogen** compounds and **oxygenates**, **halides**, **metals**

→ Analysis of **relevant contaminants**

Important: **How do contaminants react** in steam cracking?

Pilot Steam Cracking

Providing insight to cracking performance

Pilot cracking unit operated at commercial conditions

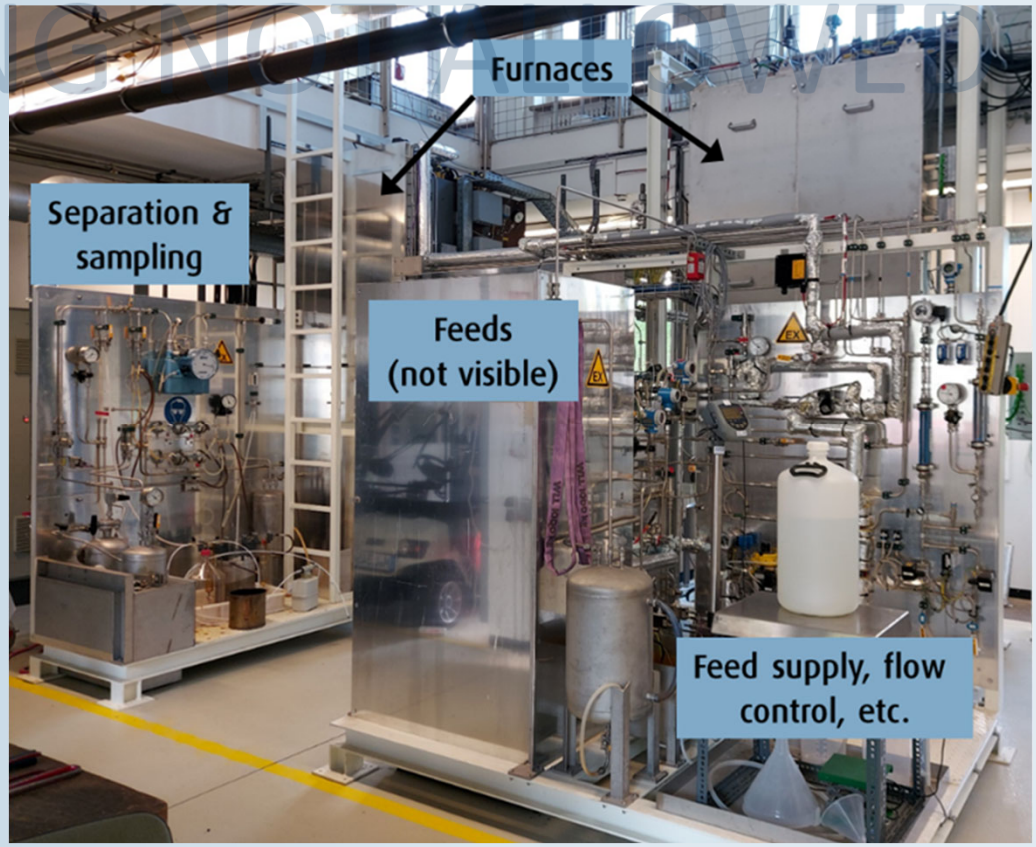
→ Basis for furnace design

→ Comparison of cracking performance

In-detail analysis for cracked products

→ Cracked gas and liquid fraction

→ Trace analysis (as a result of contaminants)

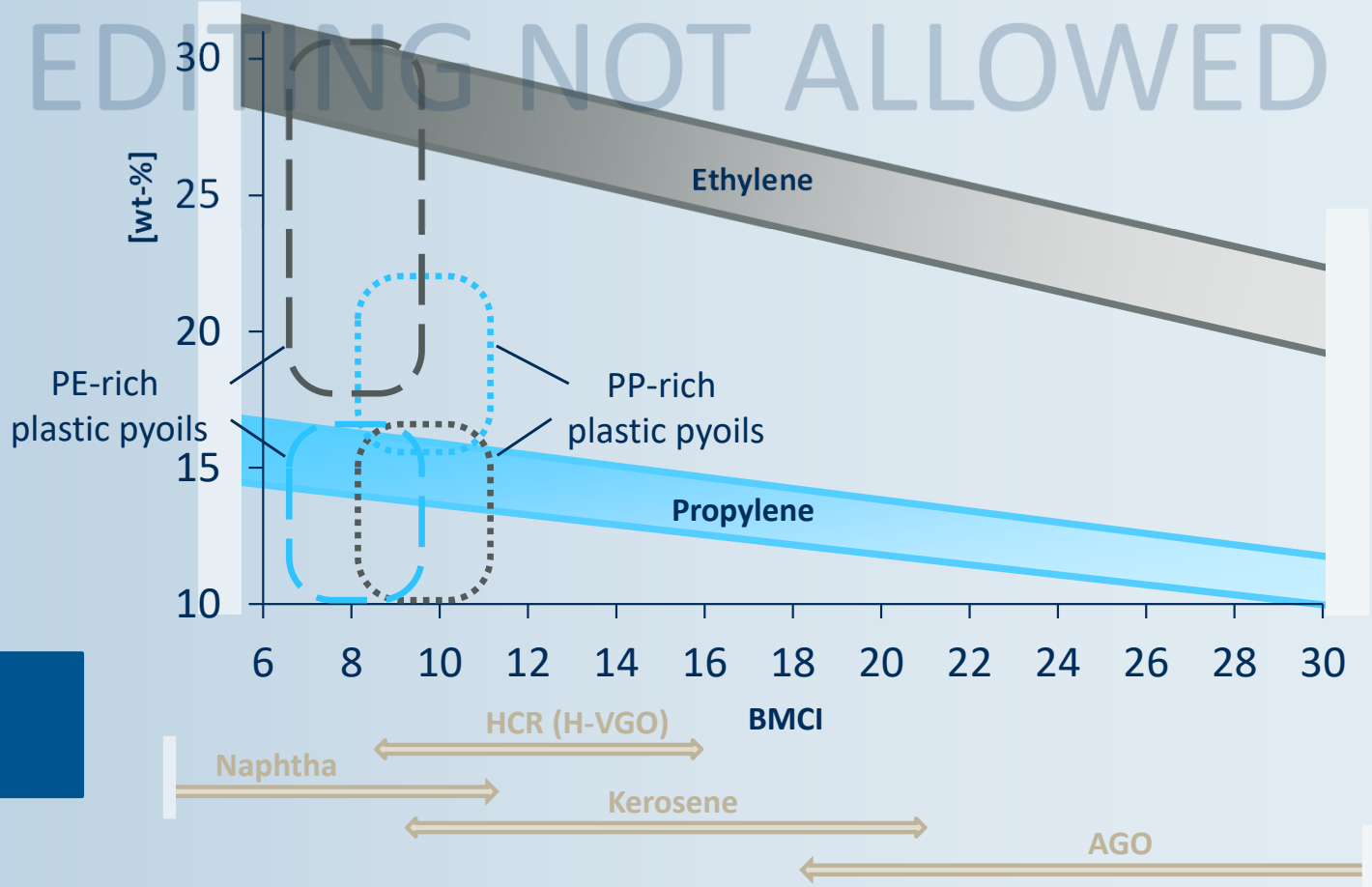


Pilot Steam Cracking

Expectation vs. reality

→ **BMCI not suitable** to predict yields

→ **Different behavior** of PE- vs. PP-based pyoils



Detailed insight into **plastic pyoil characteristics** is required

Pilot Steam Cracking

Comparison of cracked gas (once through)

Feedstock	Naphtha	AGO	HCR	PE-rich pyoil	PP-rich pyoil	Mixed pyoils
Ethylene+propylene [wt-%]	45	37	44	34 – 45	32 – 35	34 – 40
Propylene/ethylene [wt/wt]	0.51	0.50	0.48	0.4 – 0.7	0.9 – 2.0	0.6 – 0.9
Σ C_4 olefins [wt-%]	9	8	8	2 – 8	8 – 14	5 – 10
C_{5+} [wt-%]	23	36	28	27 – 40	32 – 40	31 – 39

→ Untreated (not purified), full-range **plastic pyoils show similar olefin yields** compared to conventional feedstock

→ **Propylene to ethylene ratio is correlated to amount PE vs. PP** amount in plastic waste for pyrolysis

→ **P/E ratio >>1** for PP-based plastic pyoil

Purification & Pre-Treatment

Know-how and capabilities

Vacuum Distillation (20 L)

Adsorbent/catalyst testing (@p/T)

Hydroprocessing (up to 550 °C / 200 bar)

Full set of **pre-treatment facilities** in place to prepare feedstock for **steam cracking** test and **overall optimization**

Pyoil Upgrade by Hydroprocessing

High pressure pilot hydrogenation

→ Possibility for **hydrotreatment** and **hydrocracking**

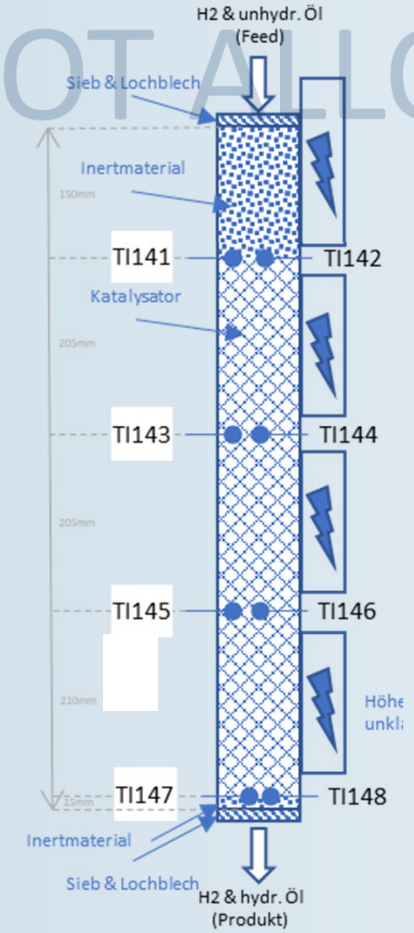
→ **Trickle-bed** reactor

→ **Gas recycle** and intermediate purification

→ **Continuous operation** (24/7)

→ **Flexible conditions** depending on requirements

→ Flowrate as required for subsequent pilot cracking



Pyoil Upgrade by Hydroprocessing

Successful purification

→ **Quality improvement** by hydroprocessing of PE-/PP-based plastic pyoils

→ Complete **removal of impurities**

→ **Saturation** of olefins and di-olefins

→ **Partial saturation** of aromatics

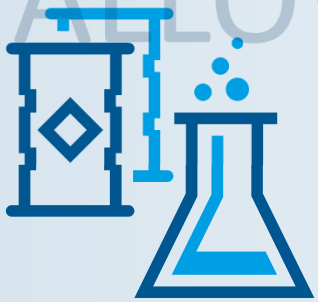
→ Manipulation of **carbon structure** (together with influence on **boiling curve**) depending on **type** of plastic pyoil and **conditions**

Example of plastic pyrolysis oil

Pure/untreated – Diluted – Hydrotreated

Pilot Steam Cracking

Influence of hydroprocessing on cracked gas yields



Ethylene ↗ ca. 5 wt-%

Propylene ↗ ca. 2 wt-%

Hydrogen ↗

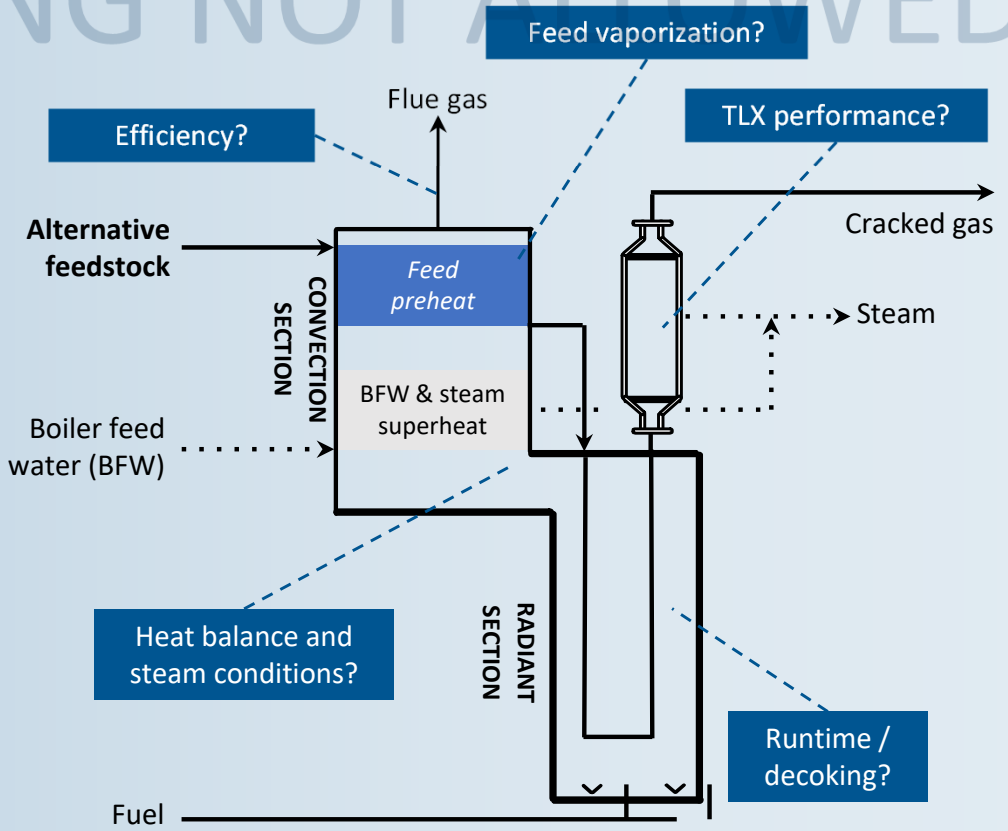
C5+ / pygas and CO_2 ↘

Hydroprocessing of plastic pyrolysis oils significantly **improves yields of high value chemicals** in steam cracking

Plant Design Considerations

Impact on furnace design

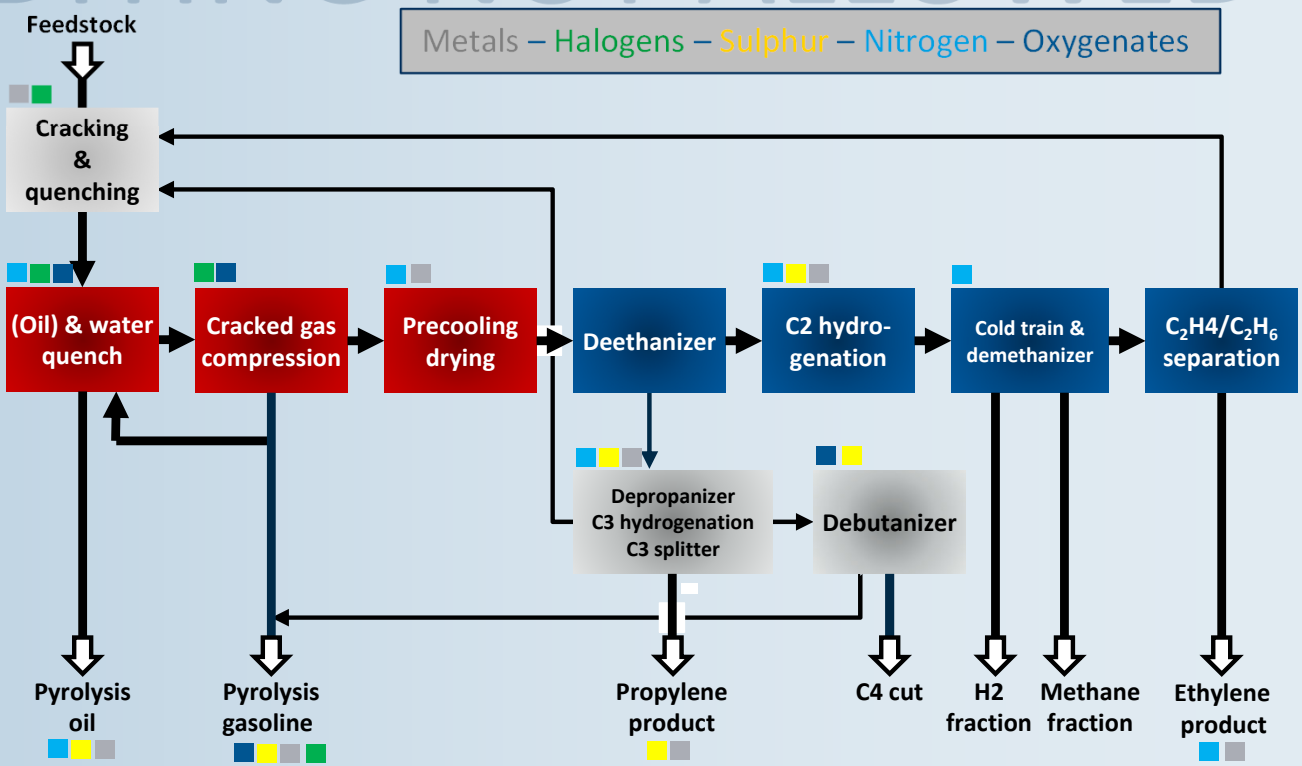
- → **Existing furnace design suitable** for preheat and evaporation of the new feed?
- → Performance of **convection section heat transfer**?
- → Furnace **run length?**
- → Transfer line exchanger **fouling behavior?**



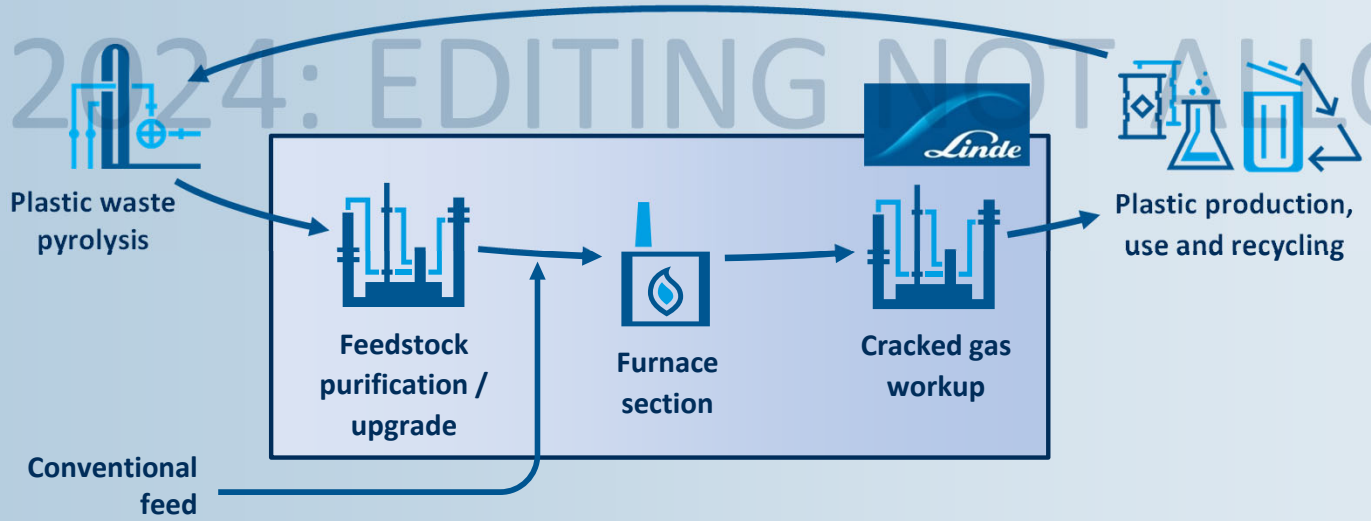
Plant Design Considerations

Impact on separation section

- → Identification of **key impurities**
- → Estimation of **distribution factors**
- → **Evaluation of the effects** on performance and products
- → **Identification of risks** (e.g. fouling, safety)
- → **Techno-economical analysis, selection and engineering** of most suitable removal concepts



Summary



→ **Characterize** project-specific feed in Linde's in-house pilot scale cracking furnace by detailed cracked gas analysis

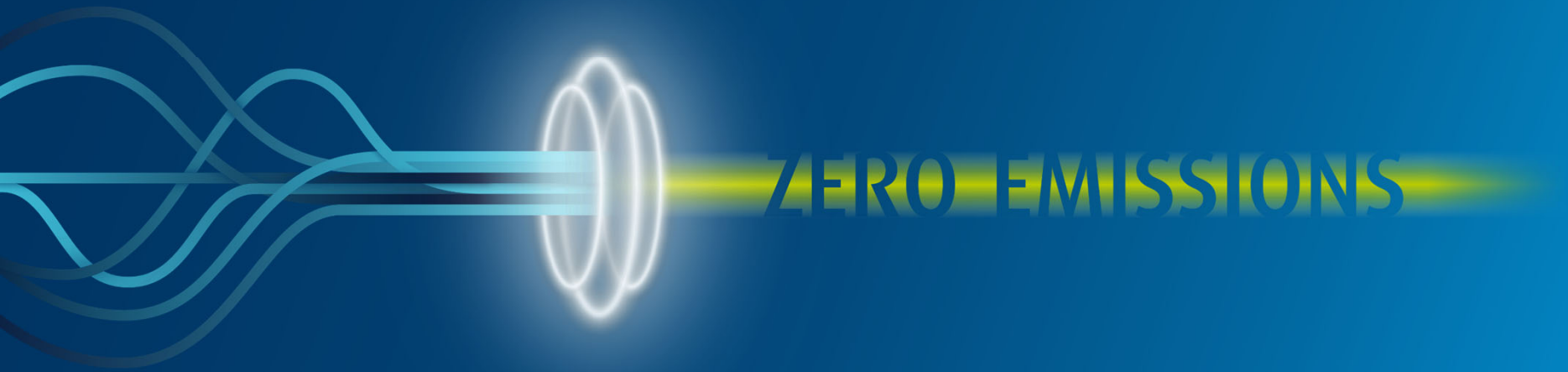
→ **Evaluate** impact of cracking on furnace convection section (design and operation)

→ **Assess** impact of impurities on steam cracker separation section (e.g. corrosion, fouling, product contamination)

→ **Define** acceptable addition to steam cracker

→ **Identify** recommended purification / upgrading steps and evaluate techno-economic scenario

Thank you for your attention



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