

Uhde innovate 2024

Sustainable chemicals technologies Part 3:

Methanol to X – pathways for production of sustainable aviation fuels and selected chemicals

June 6, 2024 | Essen, Germany
thyssenkrupp Uhde | Dr. Thomas Streich

engineering.tomorrow.together.



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Methanol to X

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PetChem: Petrochemicals
BTX: mixtures of benzene, toluene, and the three xylene isomers

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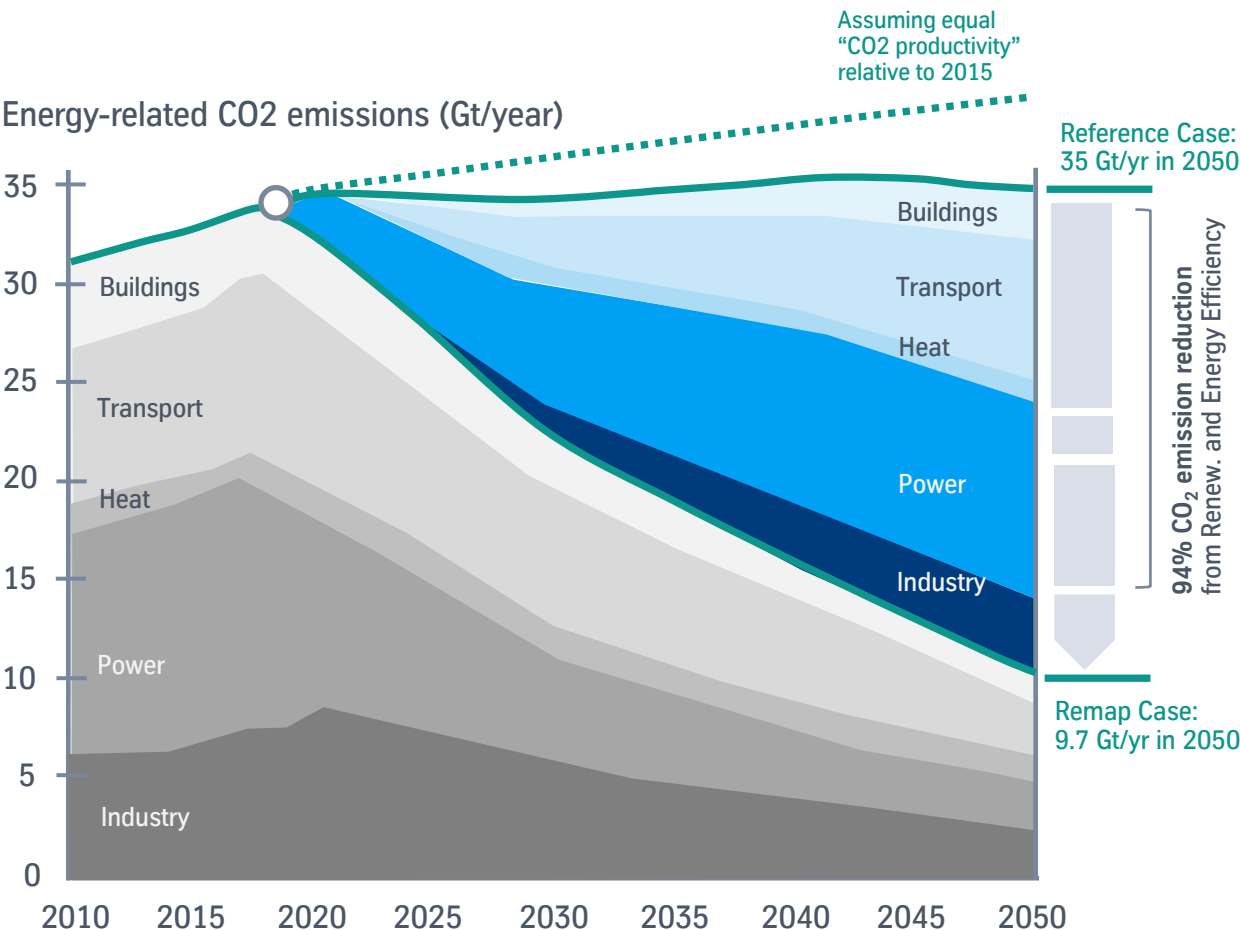
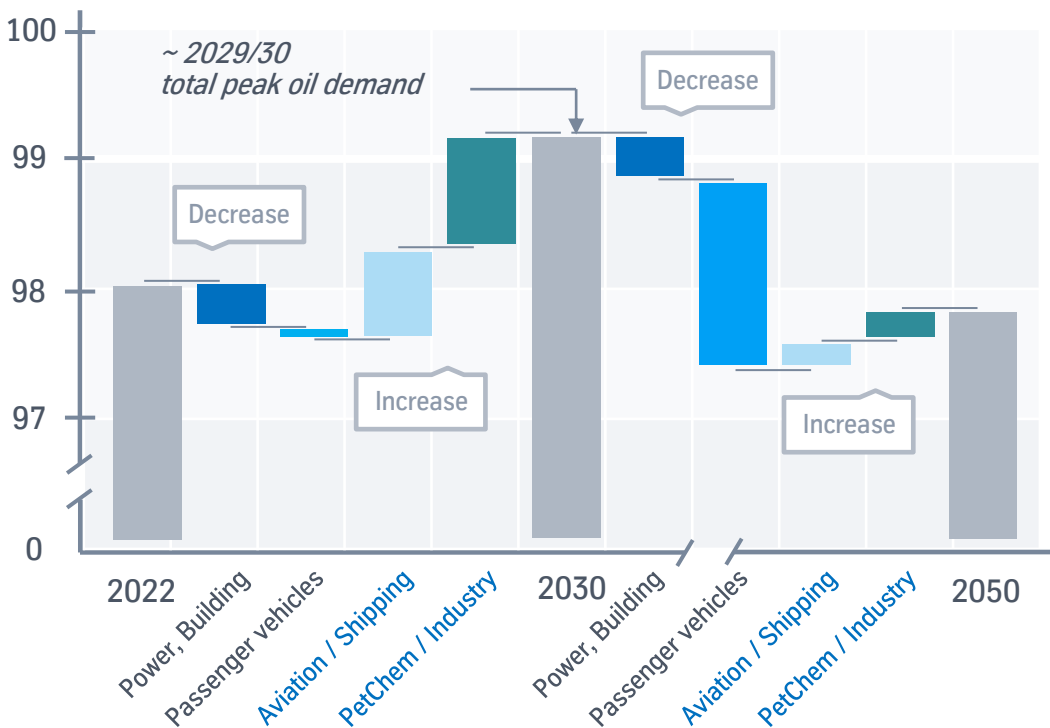


Drivers for Transition in Fuels and Chemical Processing

Challenges between energy demand and regulations

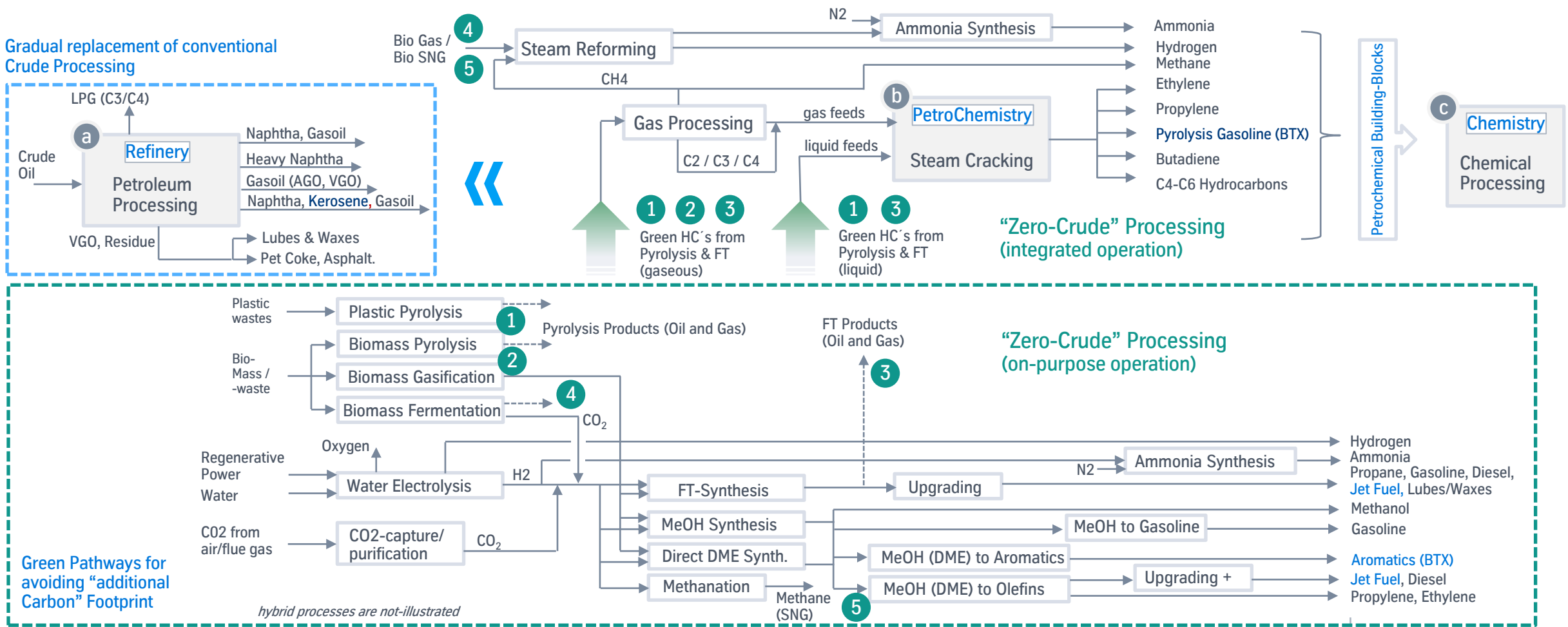
Dilemma: ...the need to meet rising global energy demand
...while at the same time significantly reducing carbon emissions

Global oil-demand outlook by sector (mio. barrels per day)



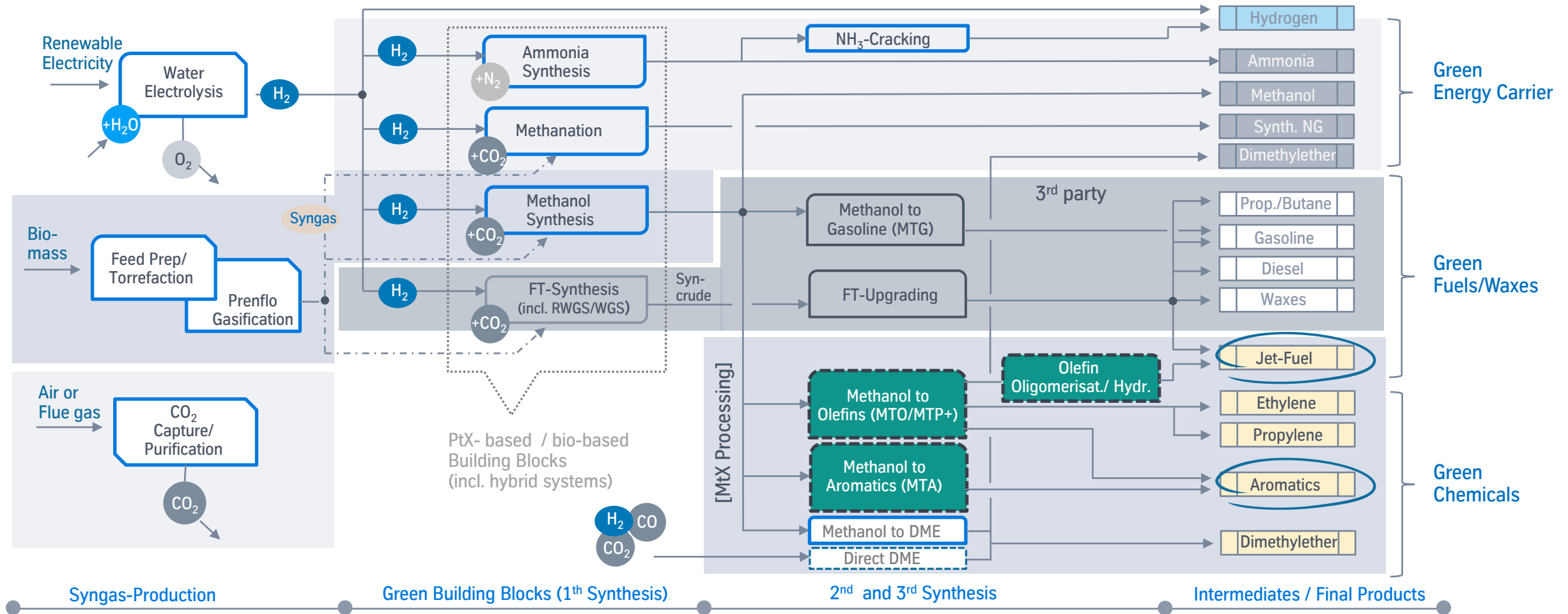
Drivers for Transition in Fuel and Chemical Processing

Multiple approach in case of increasing abandonment of fossil feeds



Syngas-based Pathways for PetChem Production

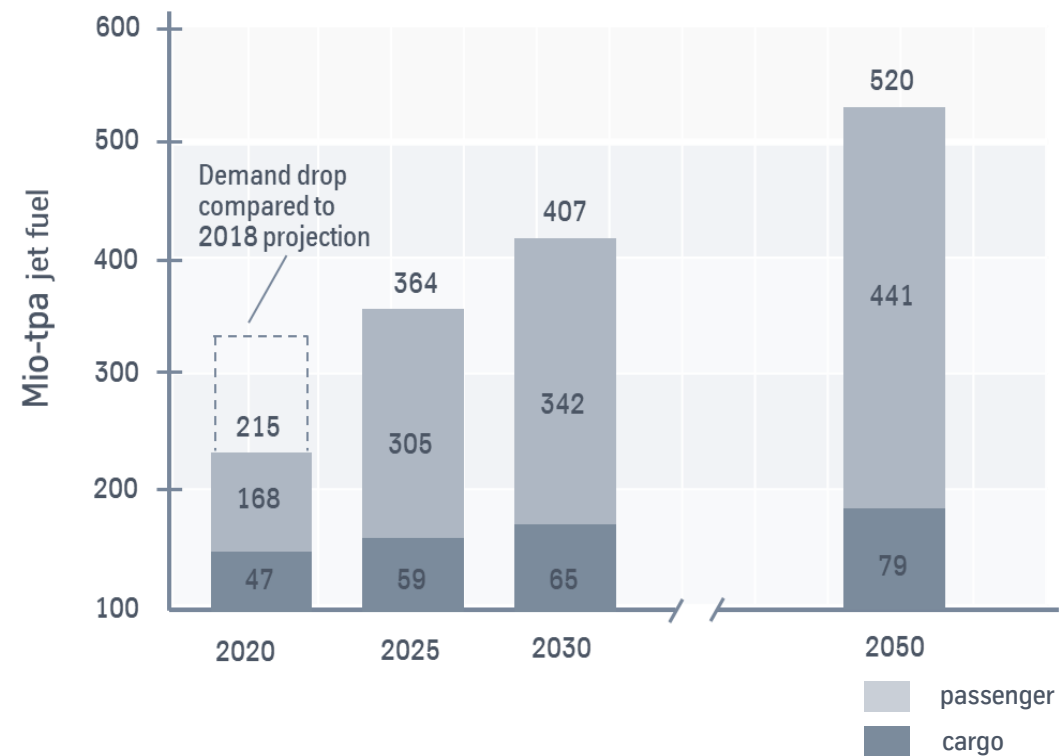
Dedicated routes for renewable chemicals and fuels



Sustainable Aviation Fuel

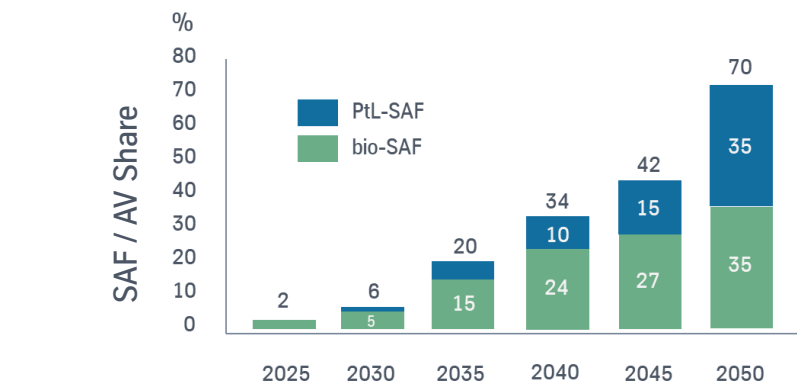
Market Situation and Regulations (SAF Quota Scenario)

Growth in Global Aviation Fuel (AF) Demand



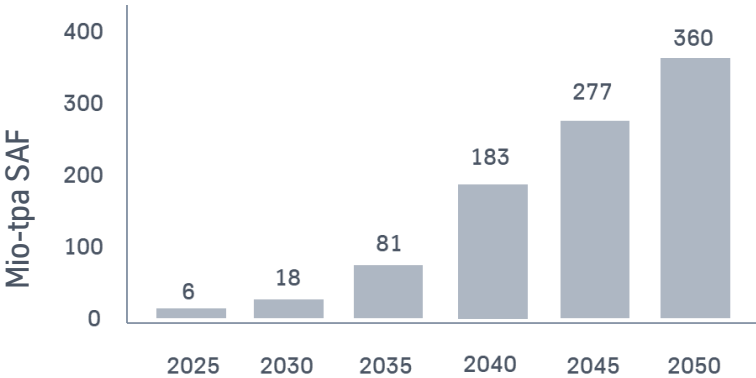
Source: World Economic Forum: Clean Skies for tomorrow, Nov. 2020

EU Quota Scenario



Source: EU Quota according ReFuel EU Directive / Sept. 2023 (own modification)

Expected Global SAF Potential for Net Zero 2050

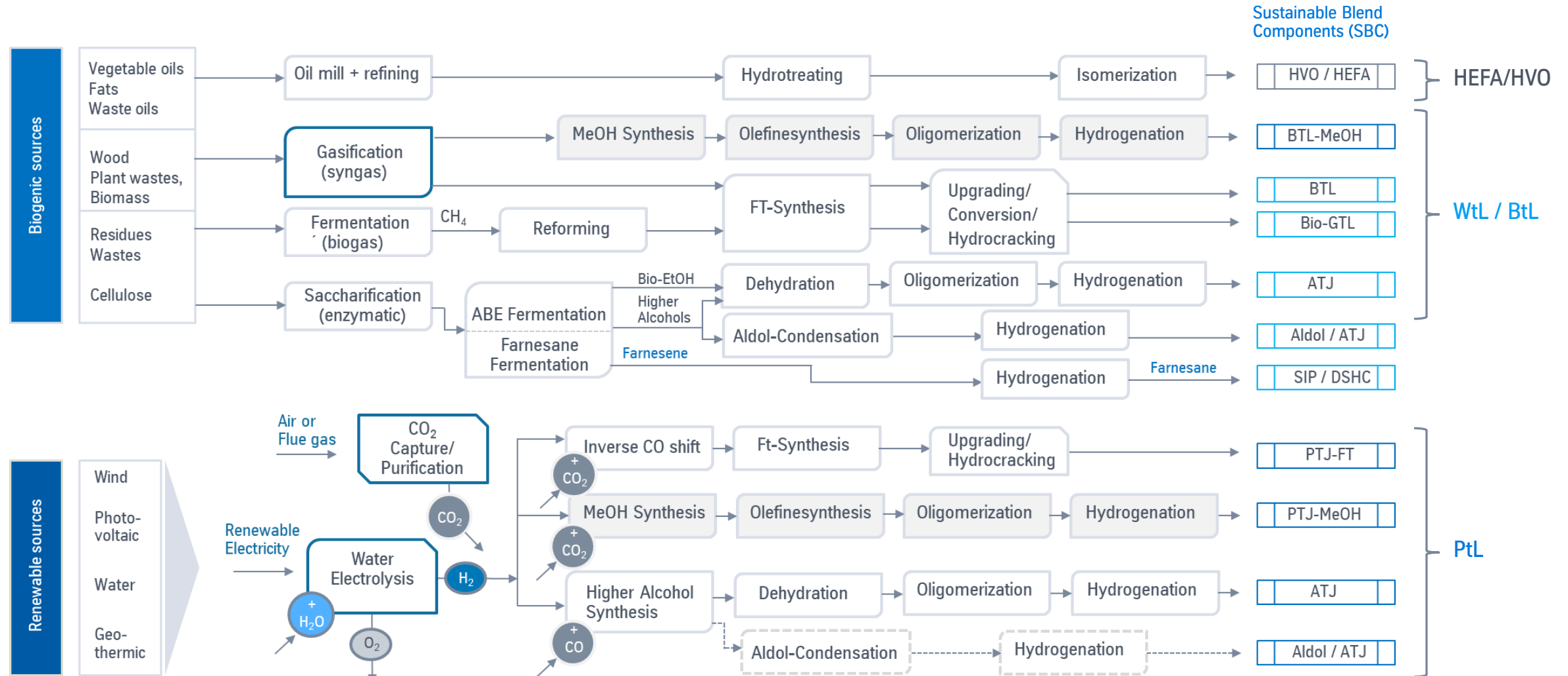


Source: IATA, June 2022 (own modification)



Sustainable Aviation Fuel

Associated SAF/SBC synthesis pathways from different feed sources (simplified)

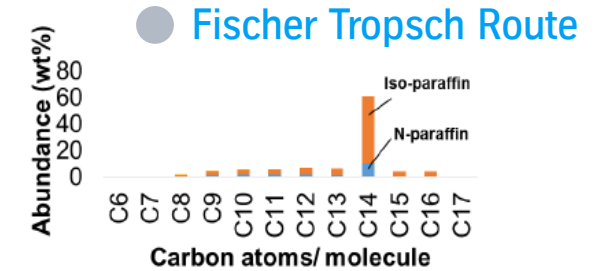
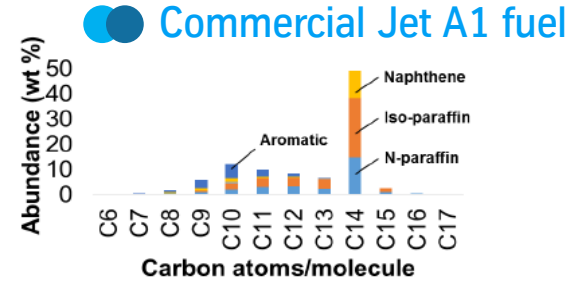
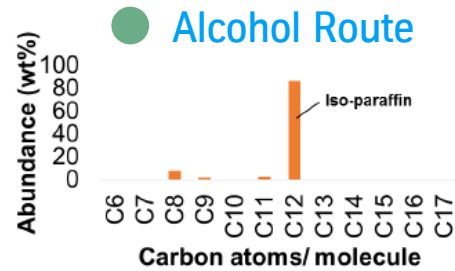


HVO: Hydrotreated Vegetable Oil | HEFA: Hydroprocessed Esters and Fatty Acids



Sustainable Aviation Fuel

Mixtures with sustainable blend components (SBC)

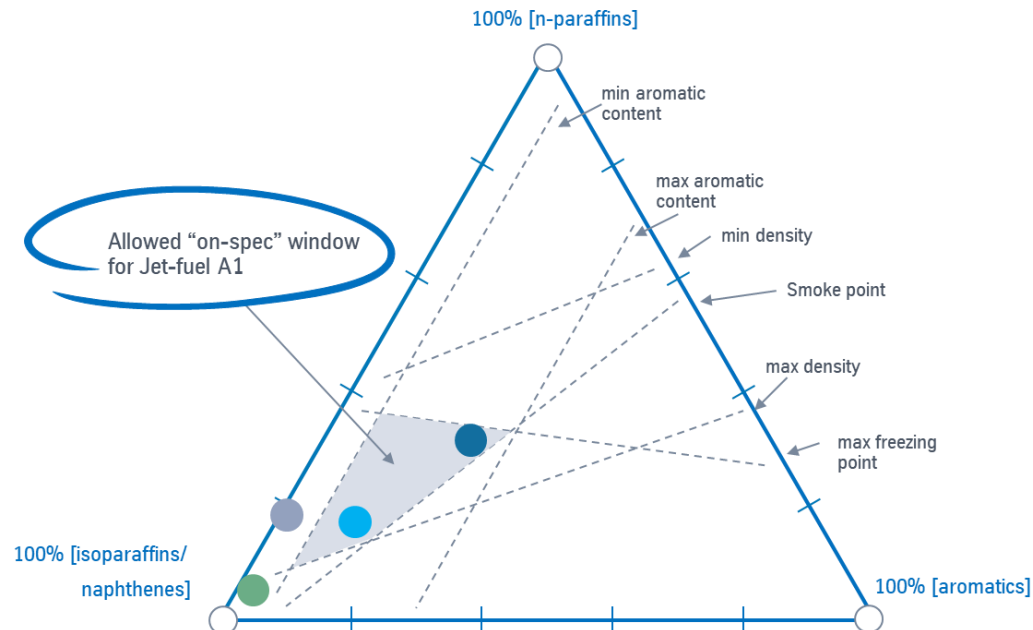


General operating requirements

- Being easy pump-able under all operating conditions
- Efficient combustion under all operating conditions
- Having as high caloric value as possible
- Permitting engine starting under all ground conditions
- Providing adequate lubrication for all moving parts
- Producing minimal corrosive effects on fuel system
- Reducing fire hazards to minimum
- Producing minimal harmful effect on turbine blades

Special fuel characteristics / limits

- Caloric value (gravimetric and volumetric)
- Sulphur Content
- Aromatic Content (min/max)
- Freezing Point
- Combustion characteristics (Smoke Point)
- Volatility / Flash Point / vapour pressure
- Viscosity
- Density



“Conventional (fossil)” aviation fuel is still needed for a full SAF.

Where does the material come from in the future?

» Demand for “100 % drop-in” SAF

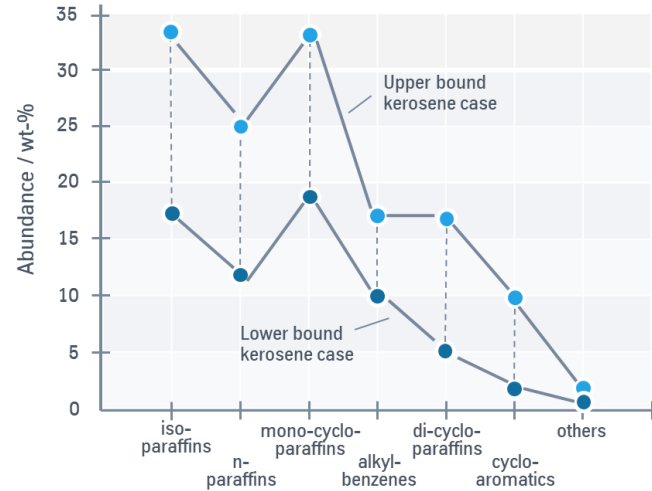


Sustainable Aviation Fuel

MeOH to SAF: Design methodology for 100 % drop-in SAF's – Starting from the end

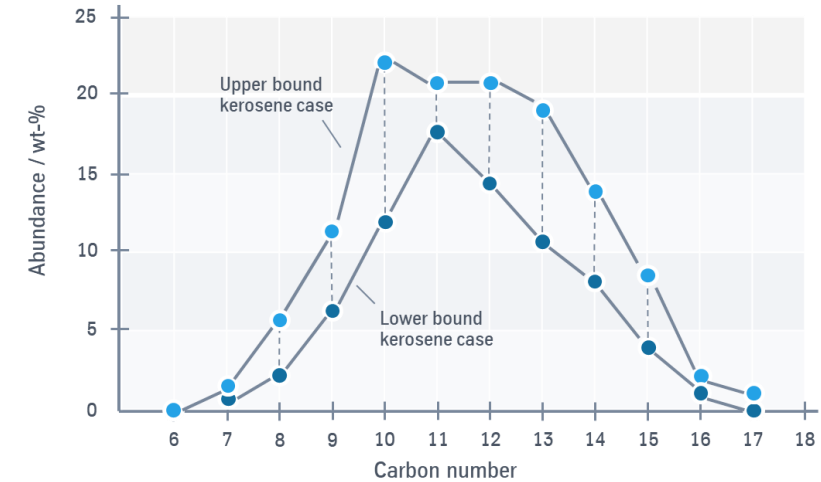
Ideal SAF Specifications

Span of carbon species



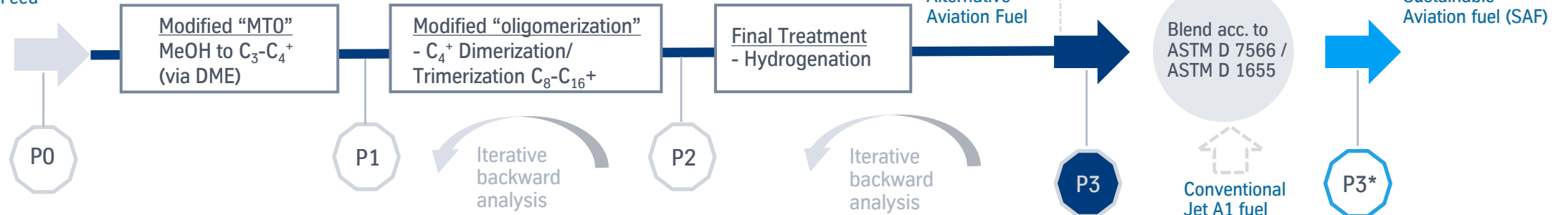
Source: Thermodynamic Properties Jet Fuels . 2015 (own modification)

Span of carbon number distribution



Source: Edwards / AIAA 2017 (own modification)

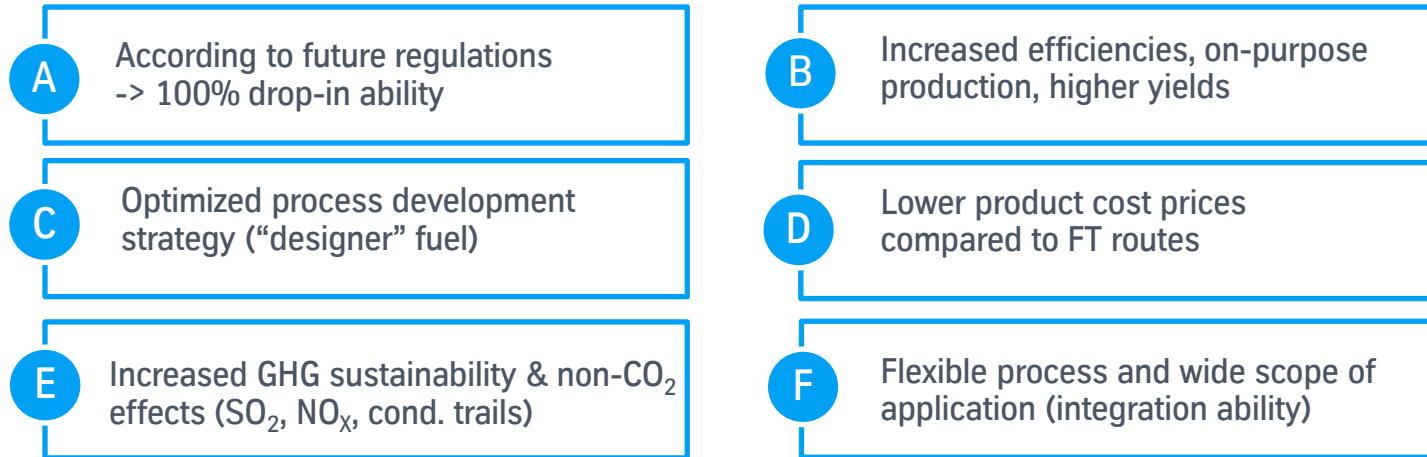
MeOH Feed



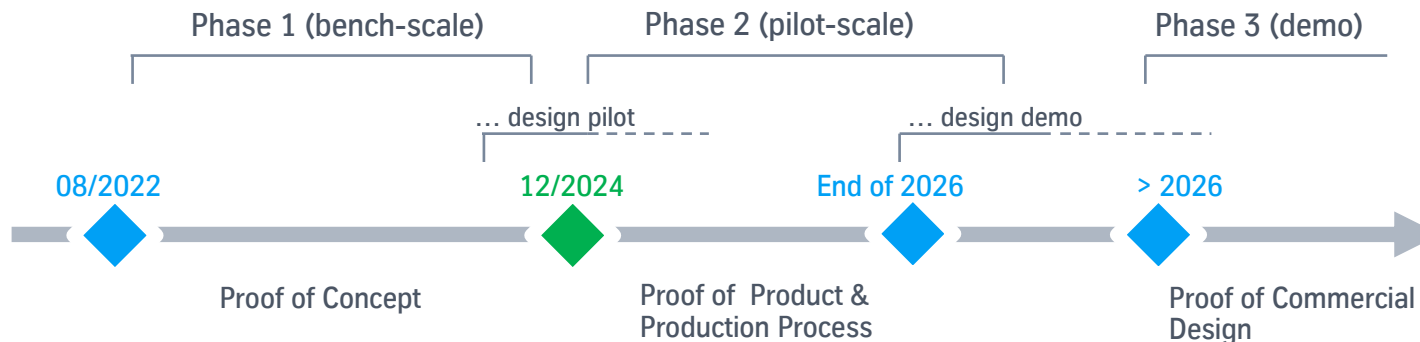
Sustainable Aviation Fuel

MeOH to SAF Project Consortium (Phase 1)

Ambitions and success factors:



Time Line:



Project Consortium & Partners for Phase 1 (funded project)

- **BASF**
Catalyst Developer, Catalyst Producer
- **thyssenkrupp Uhde**
Process Develop. /Licensing & Engineering
- **OMV Refinery**
Refinery Operator / first M2SAF Producer
- **DLR**
Institute for fuel simulation & fuel certification
- **DLR / tk Uhde**
Life Cycle Analysis, Cost estimation
- **ASG**
Certified lab for aviation fuel analysis

as well as dedicated partners in an advisory board

- Airlines
- Aircraft OEMs
- Engine/Turbine OEMs



Sustainable Chemicals (BTX Aromatics)

Current aromatics production

Benzene

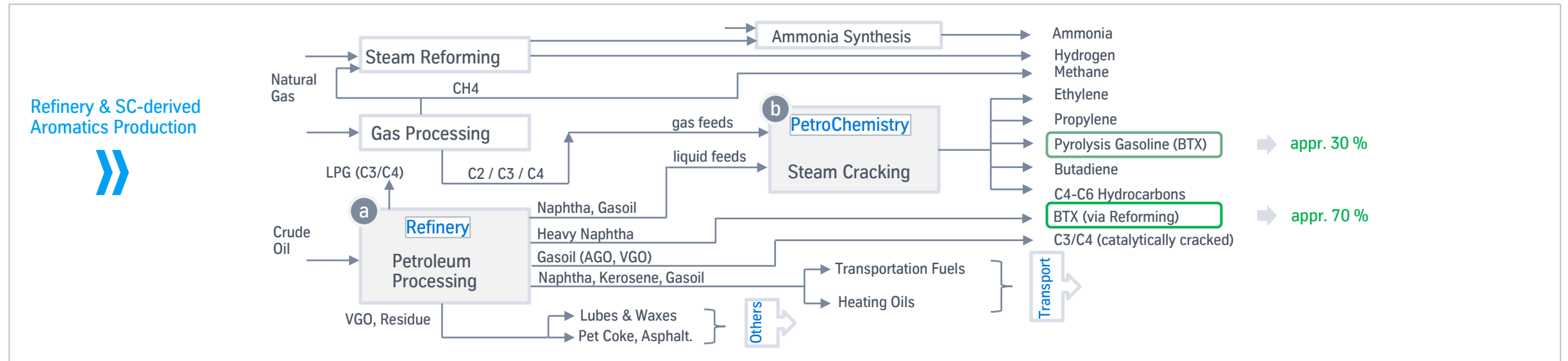
- Refinery derived (via Reforming, FCC, Coking)
- Naphtha Steam Cracking derived / PyGas
- Coal-derived (coke oven light oil)

Toluene

- Refinery derived (via Reforming, FCC, Coking)
- Naphtha Steam Cracking derived / PyGas
- Coal-derived (coke oven light oil)
- By-product of styrene production

Xylenes (m/o/p)

- Refinery derived (via Reforming, FCC, Coking)
- Naphtha Steam Cracking derived / PyGas
- Toluene - Disproportionation / - Methylation
- Transalkylation



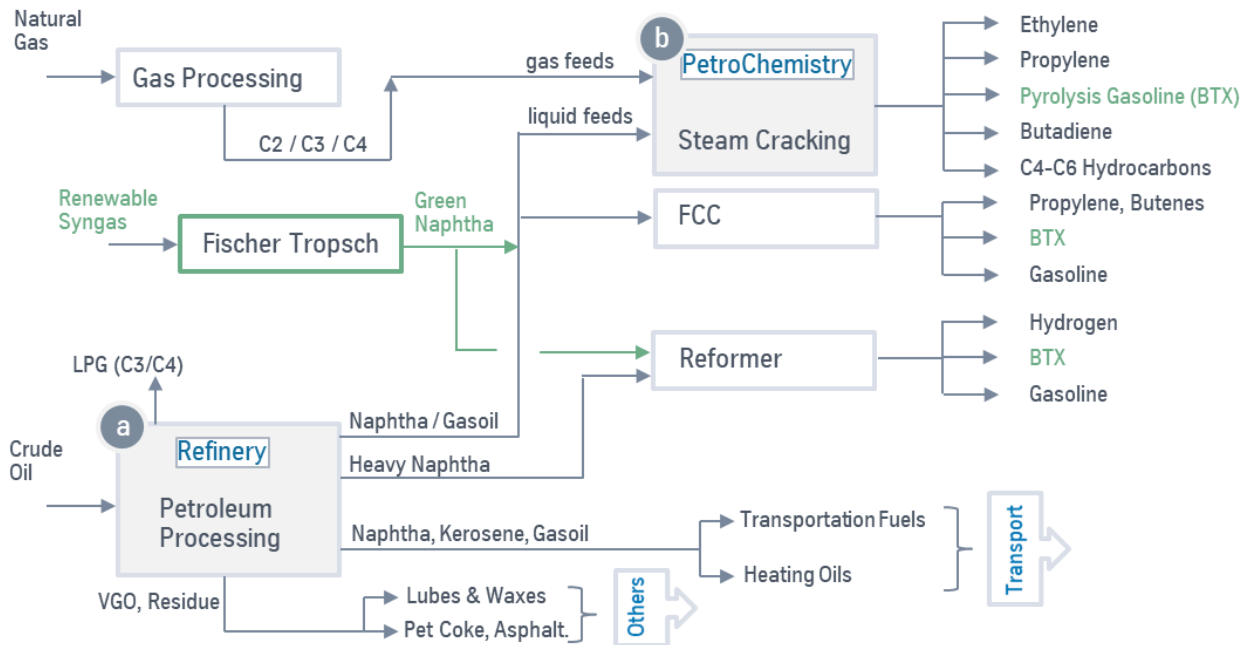
FCC: Fluid Catalytic Cracking | PyGas: Pyrolysis gasoline | VGO: Vacuum gas oil | AGO: Automotive Gas Oil



Sustainable Chemicals (BTX Aromatics)

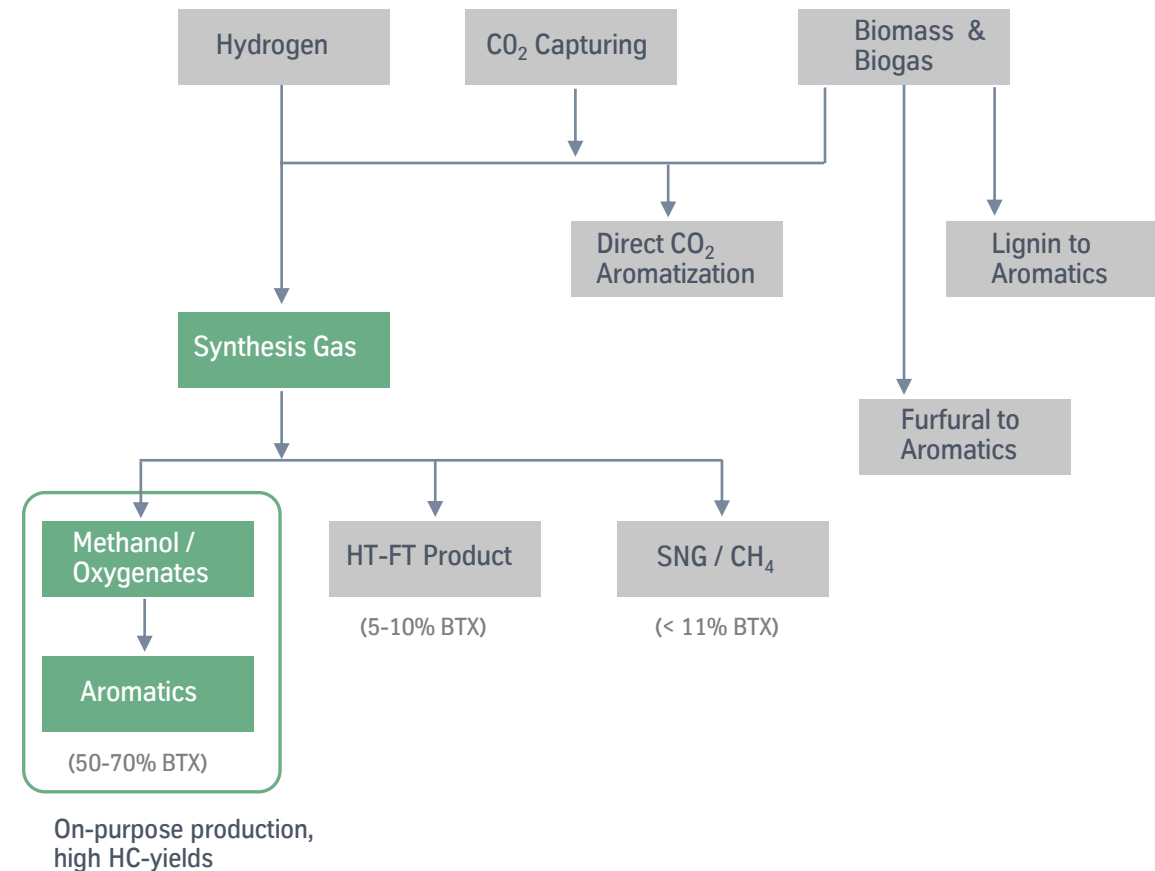
Sustainable aromatic production

BTX-Aromatics: Mainly using existing infrastructure



alternative: direct use of sustainable liquid feeds for SC and Reformer

BTX-Aromatics: New sustainable pathways (only TRL > 3 shown)



BTX: mixtures of benzene, toluene, and the three xylene isomers

TRL: Technology Readiness Level

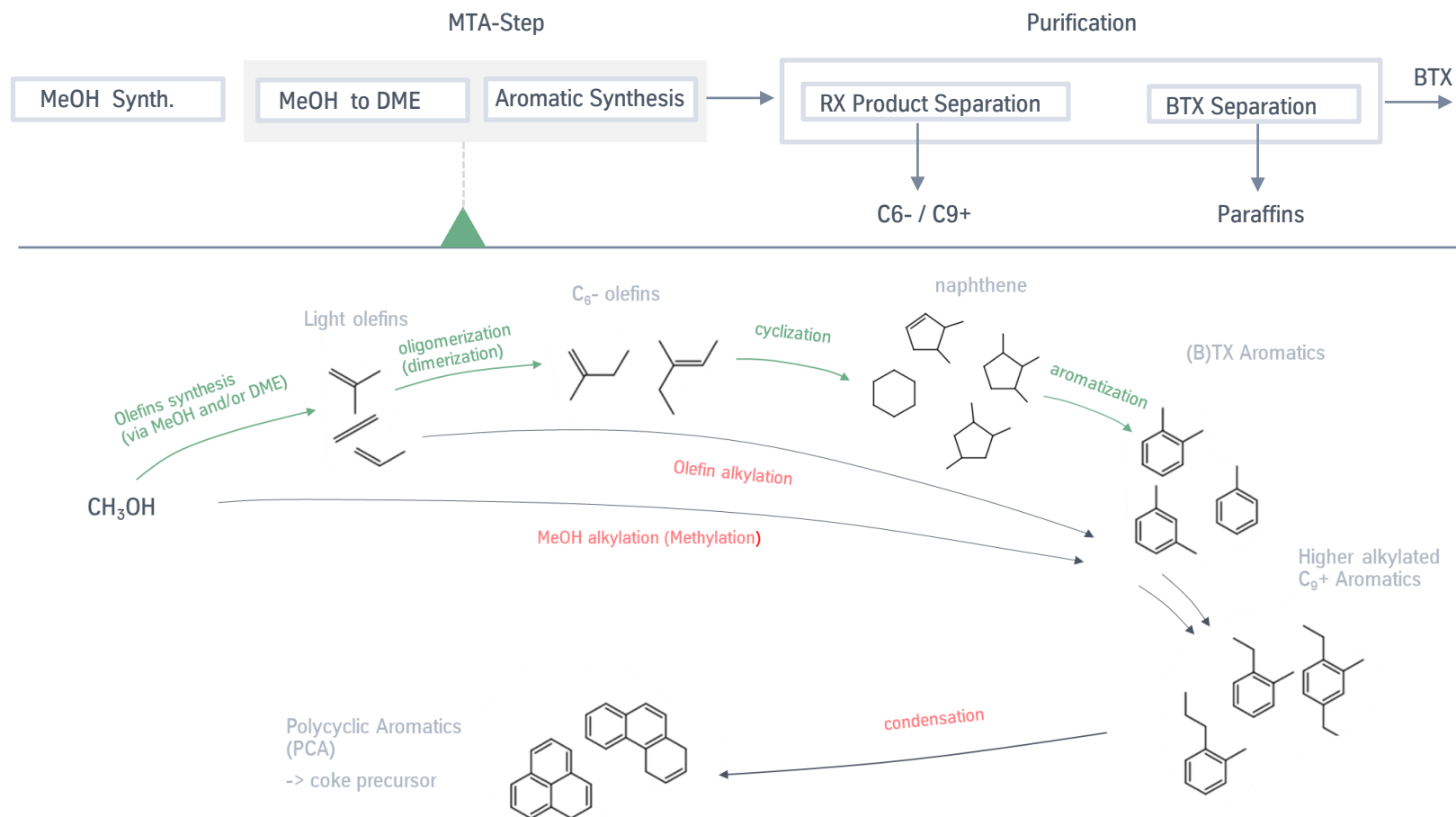
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Sustainable Chemicals (BTX Aromatics)

Chemical reaction mechanism for MtA synthesis – aromatization versus alkylation



Current Development with partners (undisclosed)

Targets / Ambitions:

- Maximum (B)TX yield
- Minimization of paraffin formation
- Minimization of C₉+ formation
- Good regenerability of the catalysts (against coking)
- Catalysts with longer lifetime
- Optimum match of MTA synthesis and BTX purification

Timeline:

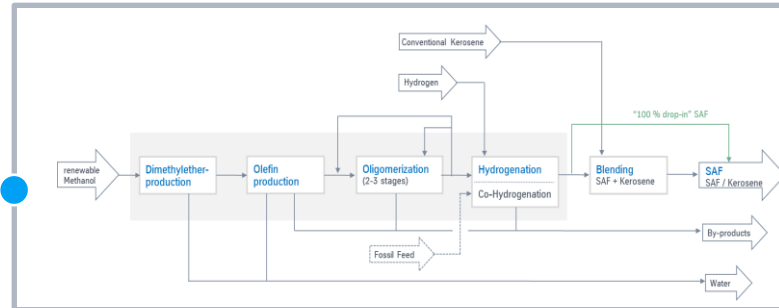
- Currently in incubation phase (prove of concept)
- Next step: Piloting



Conclusion

Uhde as partner for dedicated sustainable “Methanol to X” downstream processes ...

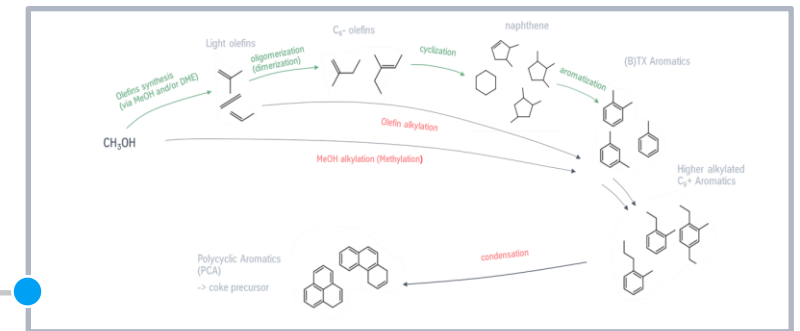
Sustainable Aviation Fuel (M₂SAF) via MeOH Route



Government founded project with several partners for development of efficient produced 100% drop-in aviation fuel

Sustainable Aromatics via MeOH Route (MtA)

Uhde's initiative to develop efficient synthesis steps for sustainable production of aromatics (BTX) from MeOH or MeOH/DME



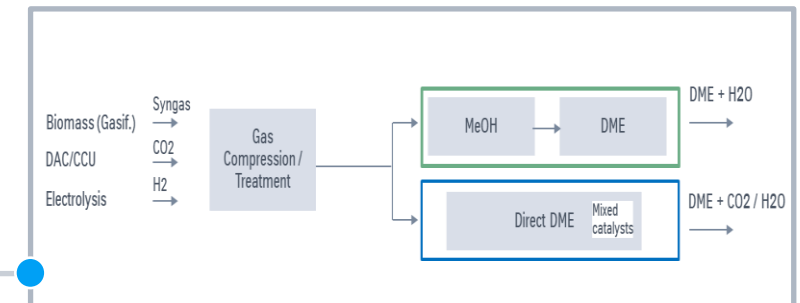
Sustainable/Green DME from bio-based-/e- MeOH



Uhde's proven technology for producing aerosol grade / fuel grade DME as propellant or sustainable LPG blend component / diesel substitute

CO₂-based DME Processes for SAF/aromatics (DTX)

Uhde's initiative on direct conversion of gasified biomass / captured CO₂ to DME as versatile feedstock for sustainable fuels/chemicals



Thank you for your attention



Global Head of Green Technologies /
Decarbonization Portfolio



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