Steps Toward Sustainability in Petrochemical Production: Focusing on Renewable Bio-Alcohols

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Petrochemie

- **Petrochemicals is a** branch of the chemical industry concerned with the **processing of crude oil and natural gas** into products such as **plastics**, **fuels, fertilizers, pharmaceuticals, and synthetic rubber.**
- Main products: Ethylene, propylene, butadiene, BTX fraction
- Main technologies: Steam cracker

Deep Catalytic Cracking (DCC)

18th century Ethylene had been known to chemists

1921 First commercialy ethylene production

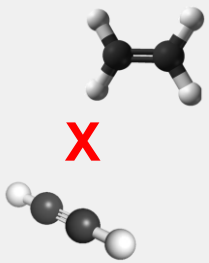
1933 Discovery of polyethylene

1940-1960 Ethylene production from hydrocarbons

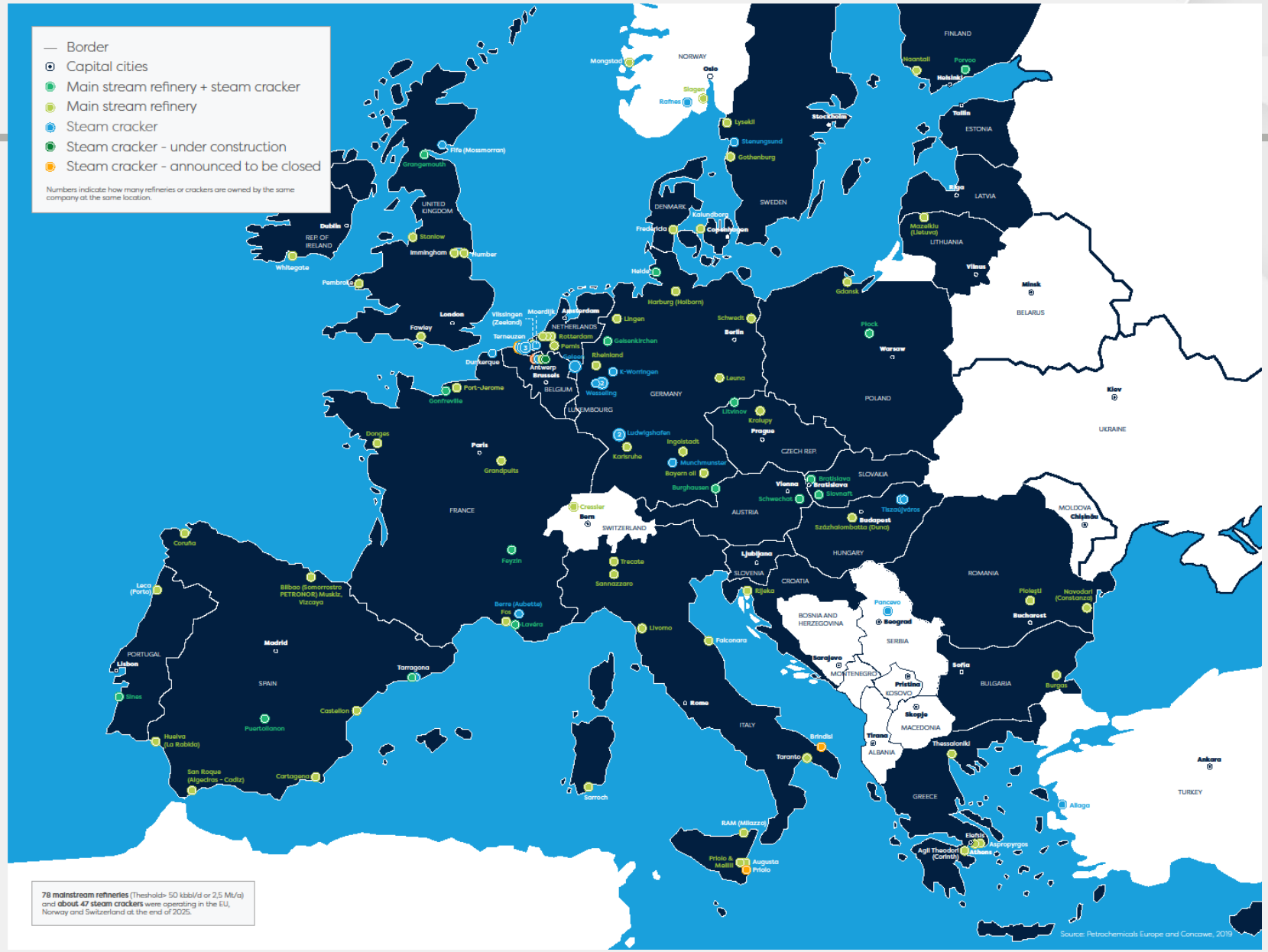
1960-1980 Increassing of the unit capacity

1990-2010 Mega complexes

2020- Green Chemicals?

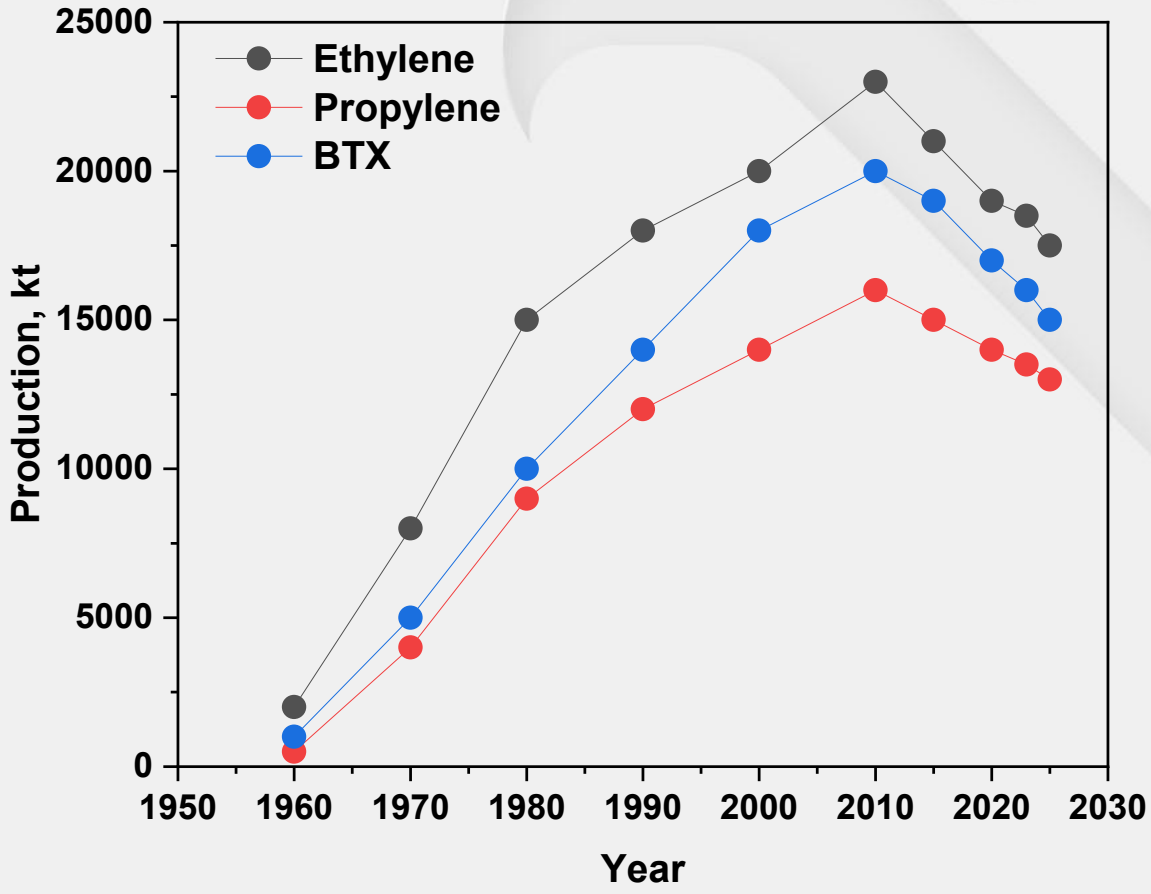


Union Carbide-plant in Clendenin


Border
Capital cities
Main stream refinery + steam cracker
Main stream refinery
Steam cracker
Steam cracker - under construction
Steam cracker - announced to be closed
Numbers indicate how many refineries or crackers are owned by the same company at the same location.
78 mainstream refineries (Theshold> 50 kbbl/d or 2,5 Mt/a) and about 47 steam crackers were operating in the EU, Norway and Switzerland at the end of 2025.
Source: Petrochemicals Europe and Concawe, 2019

European production of base petrochemicals

- Since 2020, 7 ethylene units with ethylene production of **4 000 kT** have closed
- 2 units with a capacity of **1115 kt** of ethylene are planned to be closed in 2027



Reasons

- High energy prices
- Feedstock base (Naphtha vs. Ethane)
- Outdated infrastructure
- Cheap imports from Asia and the USA
- Environmental regulation and decarbonization
- Deindustrialization of European
- Geopolitical changes

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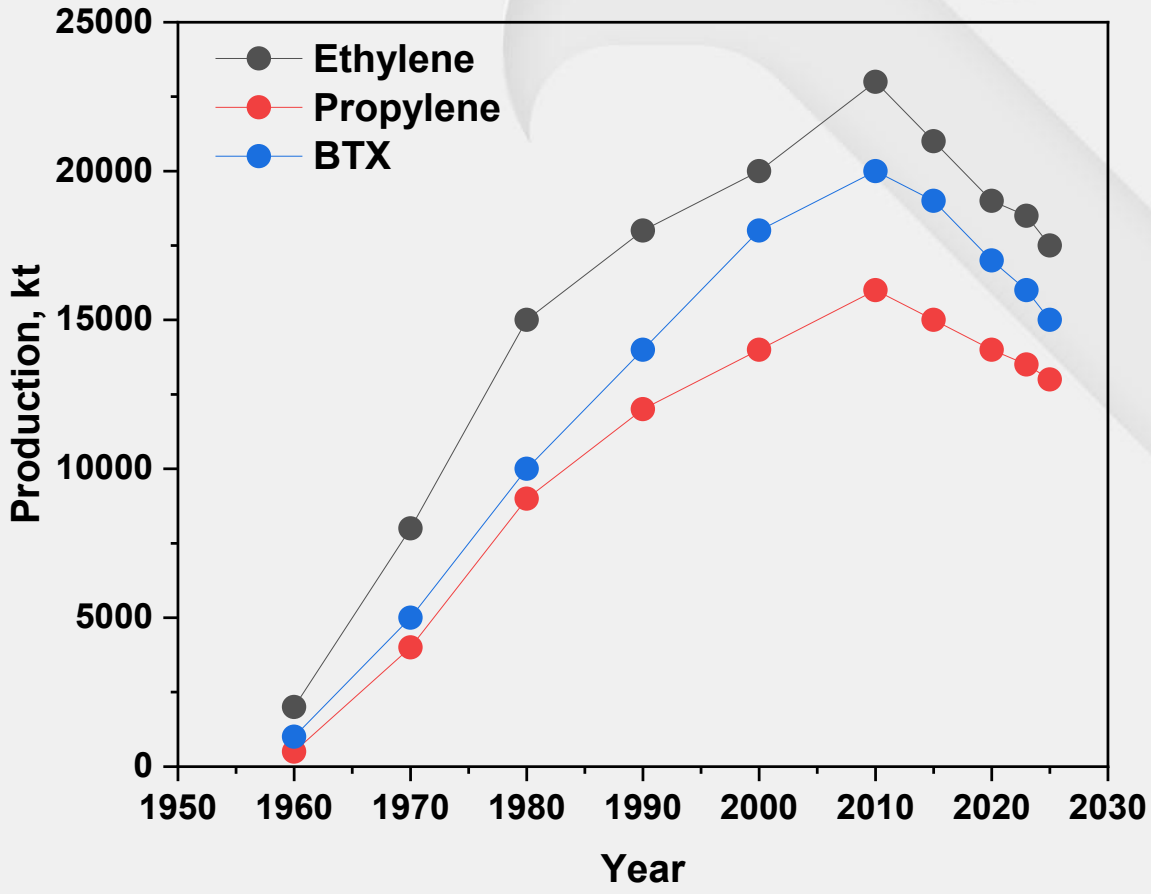

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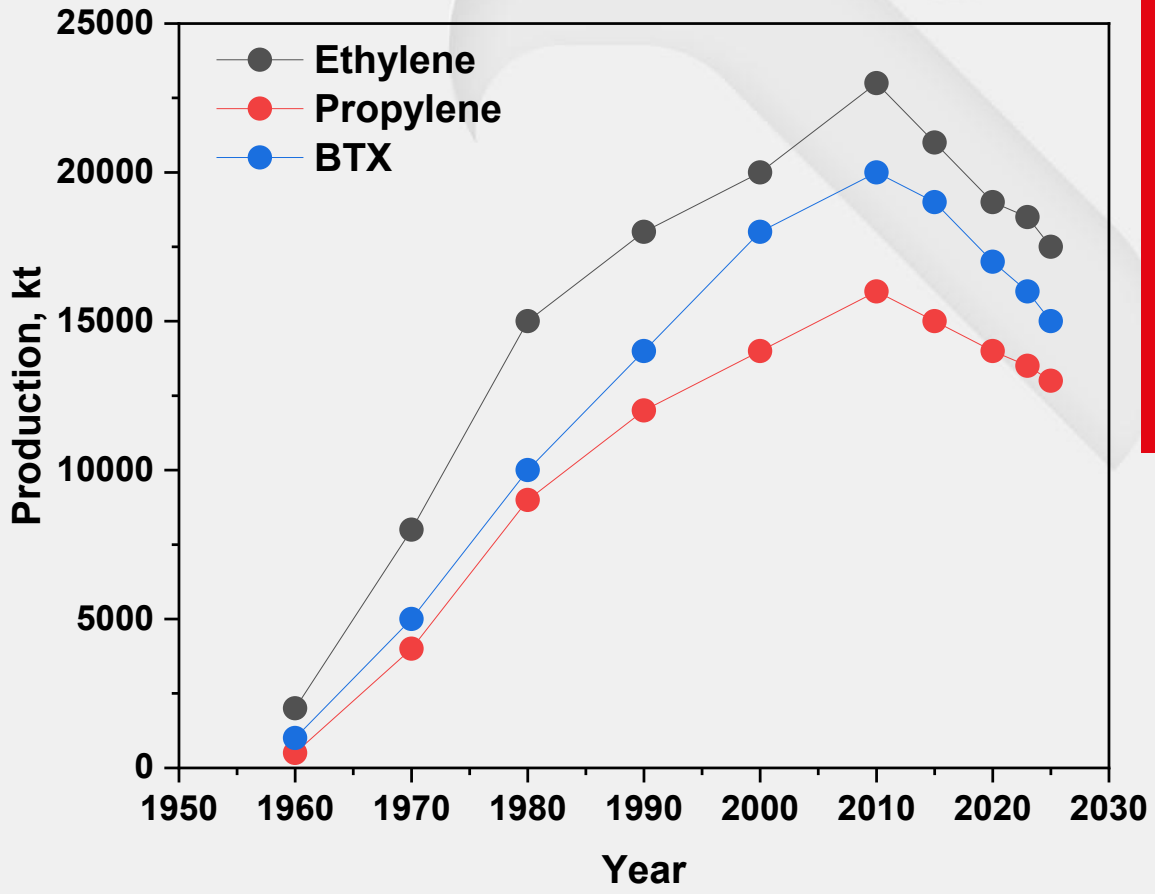
Decarbonization

- Ethylene: 545 kT
- Propylene: 300 kT
- BTX: 250 kT

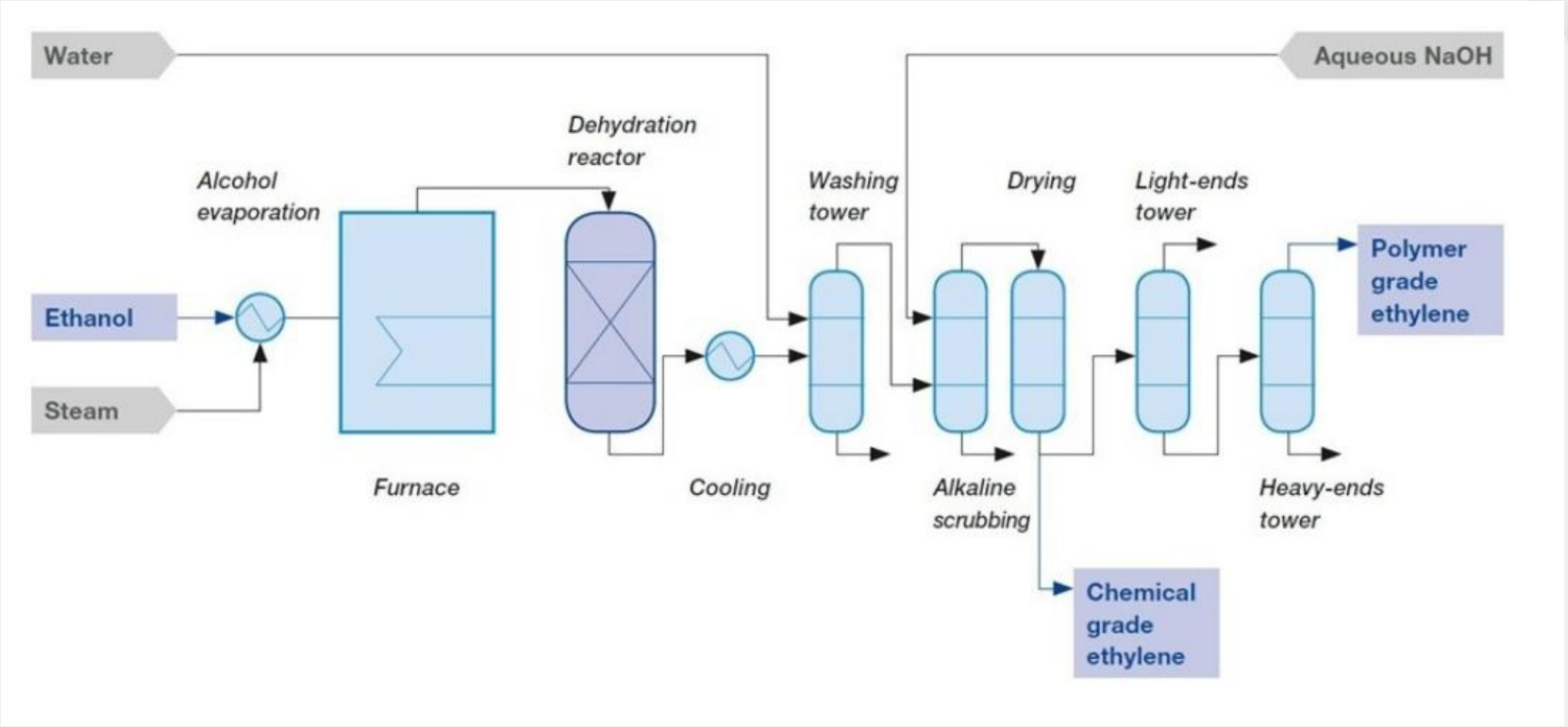


- Chemical recycling – production of pyrolyses oil from polyolefines

- Production etylene ethanol dehydration

Production of etylene from ethanol-BASF EtoE technology

- Reaction temperature: 450-500 °C
- Catalyst: Al_2O_3
- Ethanol conversion: 99.5 %
- Ethylene selectivity: >95 %



Production of ethanol

Global ethanol production : 95 100kt/2024

Sugar-contained biomass

- Corn
- Sugarcane
- Cereals
- Sugar beet
- Cassava
- Sorghum
- Molasses

EU = 4 400 kt/2024
ČR = 100 kt/2024

EU = 2678 kt/ethylene
ČR = 61 kt ethylene

EU = 17 500 kt/ethylene
ČR = 545 kt ethylene

Production of ethanol

Global ethanol production : 95 100kt/2024

Steelanol -Ghent ArcelorMittal

- Enzymatic conversion CO_2 to ethanol
- Technology LanzaTech
- Production capacity: 63kt/year
- Already 4 technology in China and India

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→

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Are we technology for production of green ethylene?

Yes No

Are we enough production capacity/feedstock for replacement of fossil ethylene production?

Yes **No**

Have to we have replace base petrochemical sources?

Yes **No**

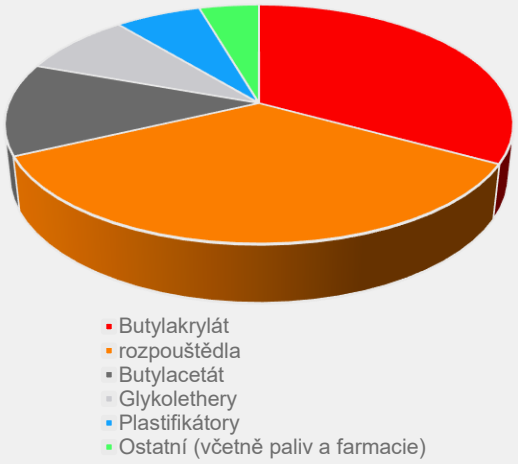
Industry production of Guerbet alcohols

Butanol	1, Hydroformylation of **propylene (90 %)** 2, Hydrogenation of butanal	ABE fermentation
Hexanol	1, Ethylene oligomeration 2, Hydrolysis of hexene	
2-ethyl butanol	1, Hydroformylation of **propylene (90 %)** 1, Wacker proces (oxidation **ethylene**) 2, Aldol condensation of acetaldehyde and butanal 3, Hydrogenation	
2-ethyl hexanol	1, Hydroformylation of **propylene (90 %)** 2, Aldol condensation of butanal 3, Hydrogenation of 2-ethyl hexenal	

Market of Guerbet alcohols

Butanol

Butanol

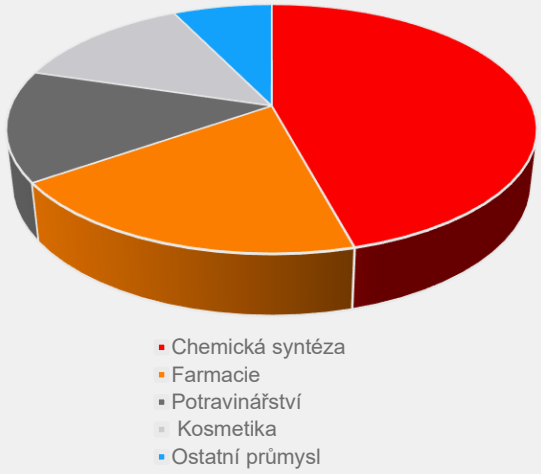


6040kt/2025

6 %

Hexanol

Hexanol

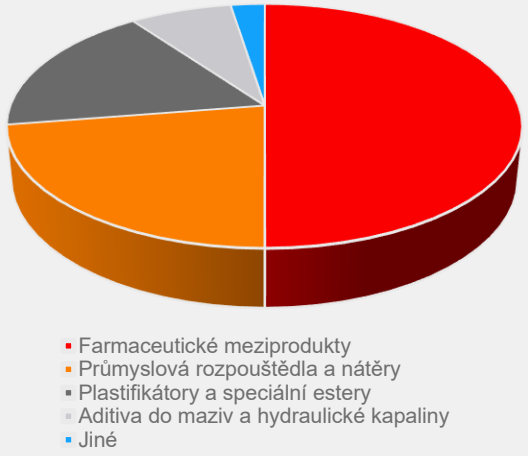


100kt/year

4-4,5 %

2-ethyl butanol

2-ethyl butanol

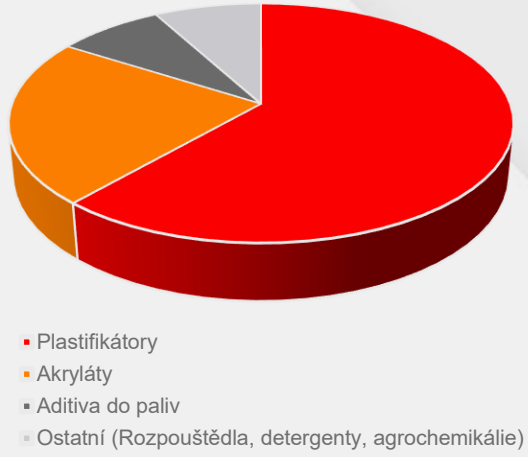


20-25kt/year

7-12 %

2-ethyl hexanol

2-ethylhexanol



5800kt/2025

3 %

Preparation of higher alcohols

Motivation

1, Ethanol is used as energy ethanol (biofuel), today mainly biofuel of first generation – availible biochemical

2, Decreassed of the carbon footprint

Performance

Development of the process ethanol coupling to higher alcohols – Guerbet reaction

Development of the catalytic systeme

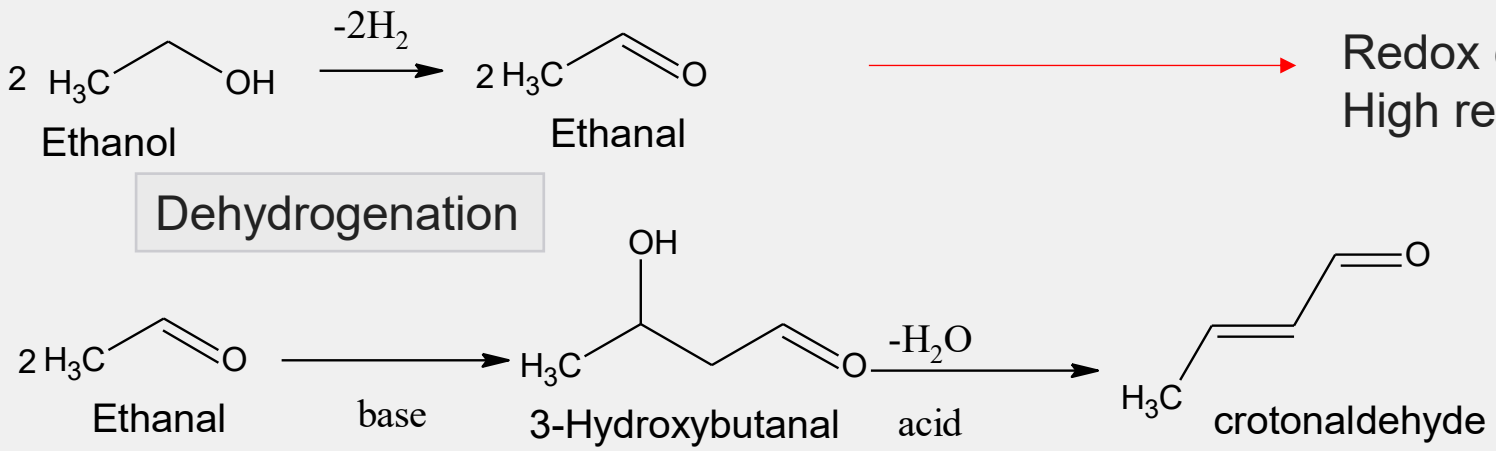
Development of the purification steps

Aim

Heterogeneously catalysed process of production Guerbet alcohols with high selectivity up to 60 %

Guerbet reaction

3 reaction steps



Redox catalysts (Pt, Pd, Cu, Mn, Ni, V, Co…)
High reaction temperature (250 - 450 °C)

Acid-base catalysts
Low reaction temperature (50 -120 °C)

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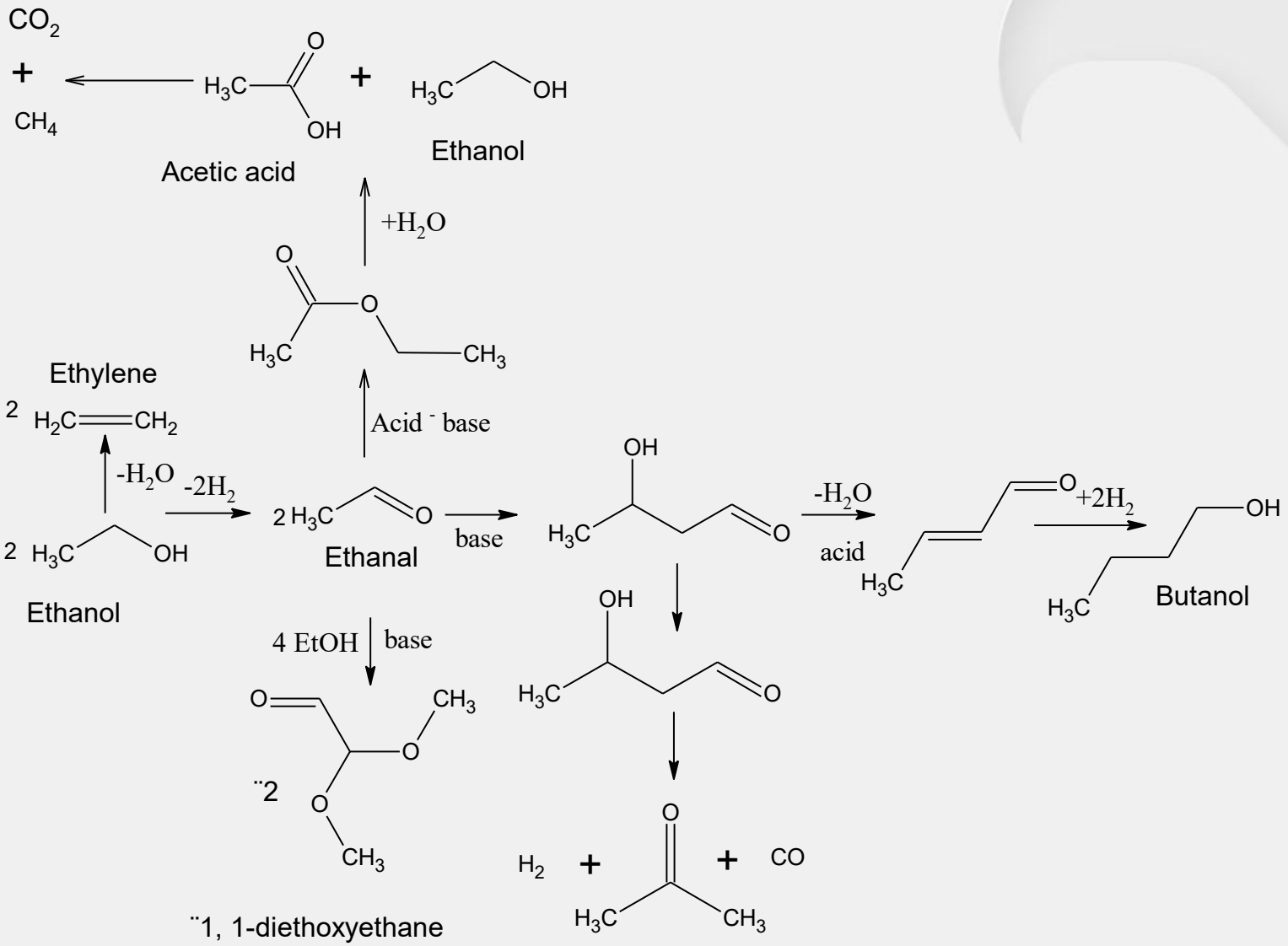
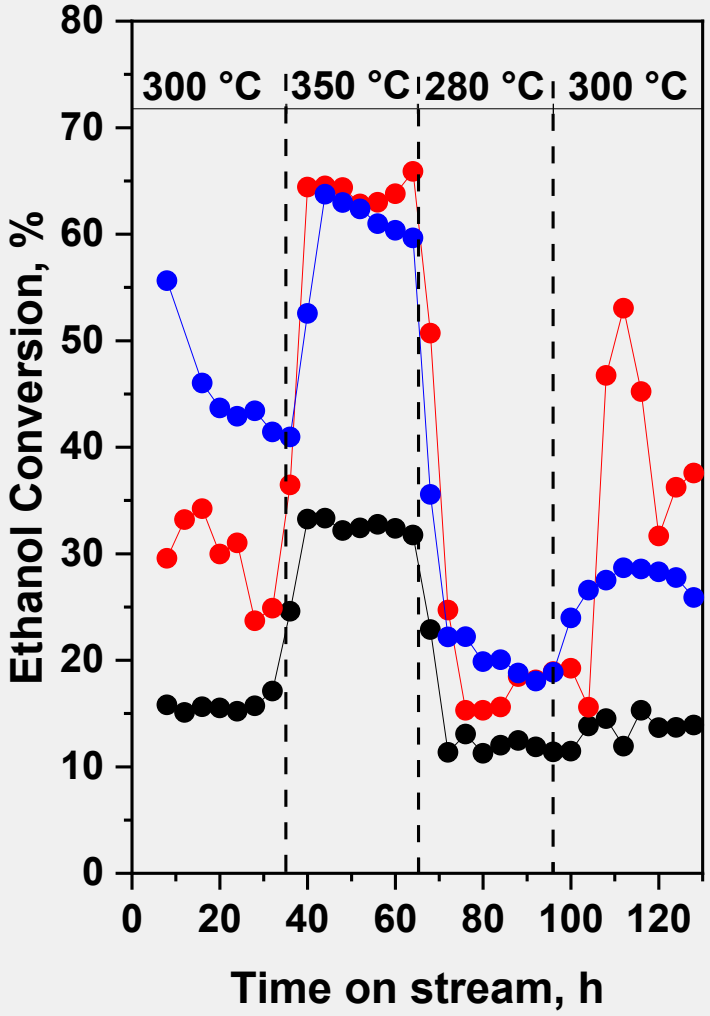
Guerbet reaction-side reaction

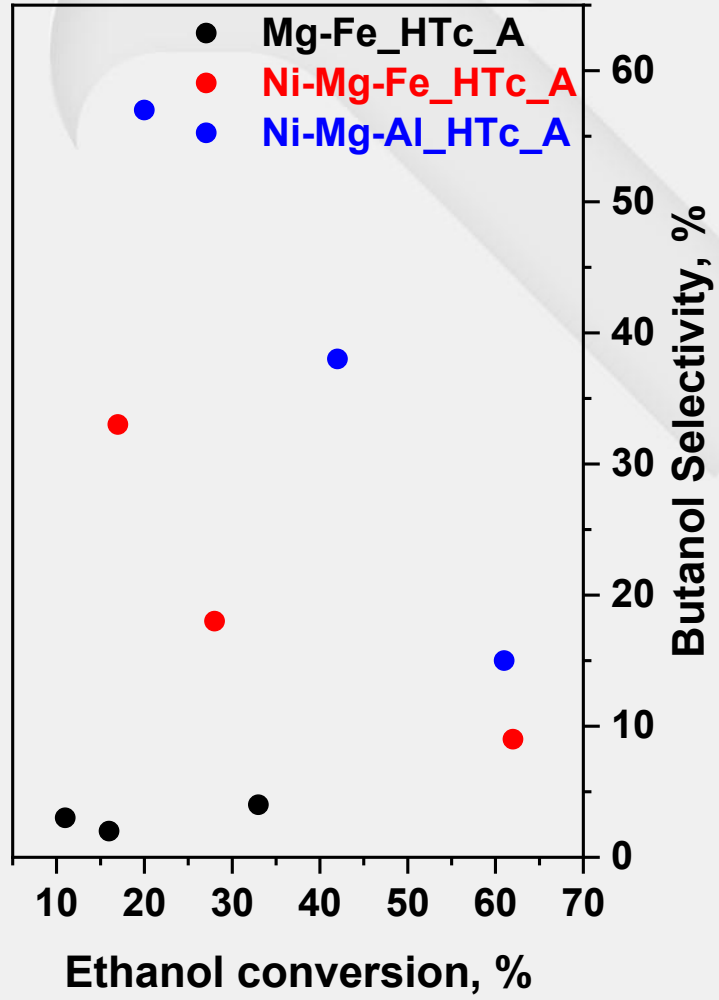


Guerbet reaction

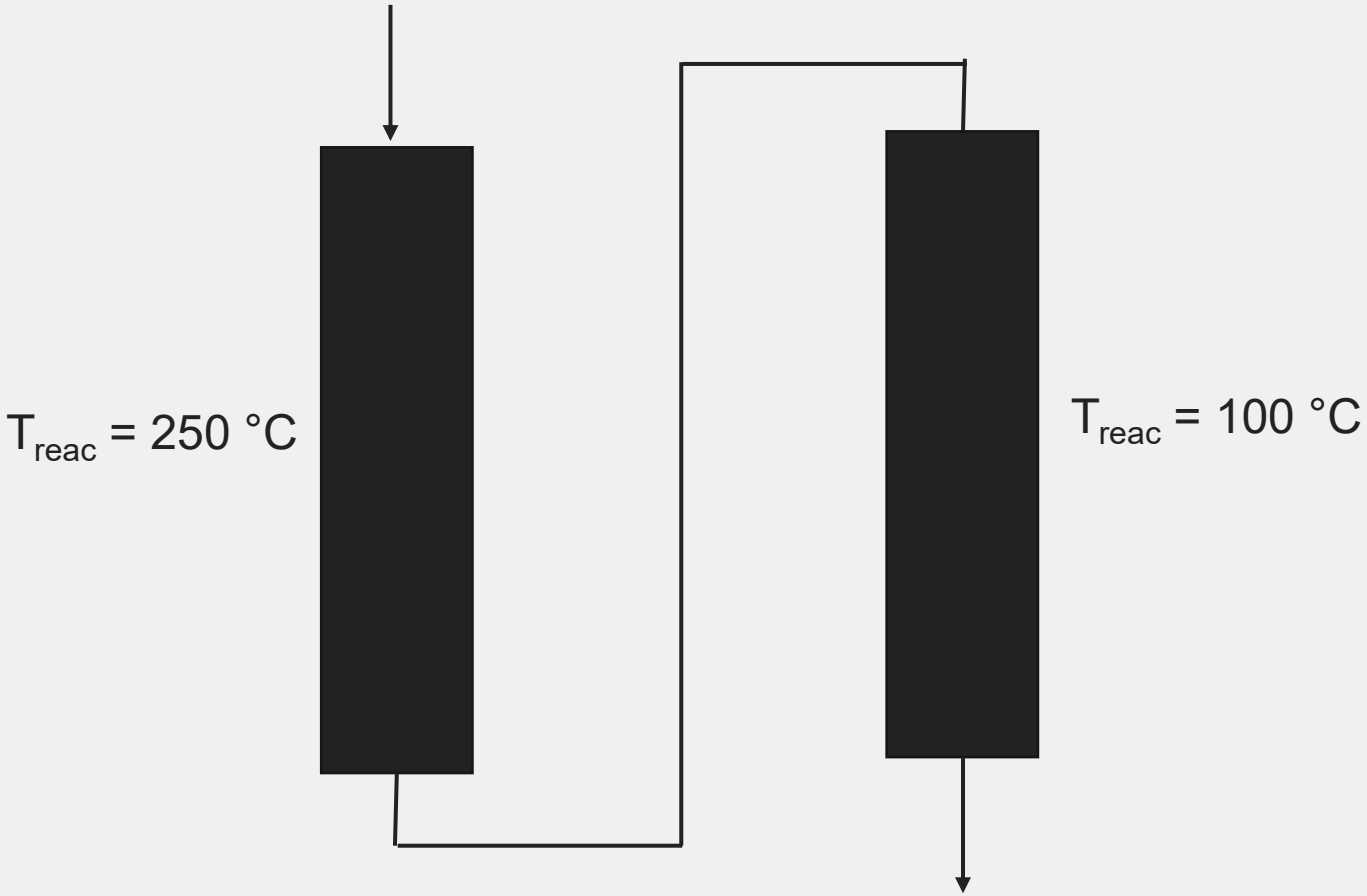
T_{reac} = 250-400 °C

- Cu
- Ni
- Co
- Cr
- Mn
- MgAl
- MgFe
- CaAl
- LiAl





Guerbet reaction two-step



Parameters of aldol condensation

- Time on stream
- WHSV
- Temperature
- Molar ratio of acetaldehyde/butanal

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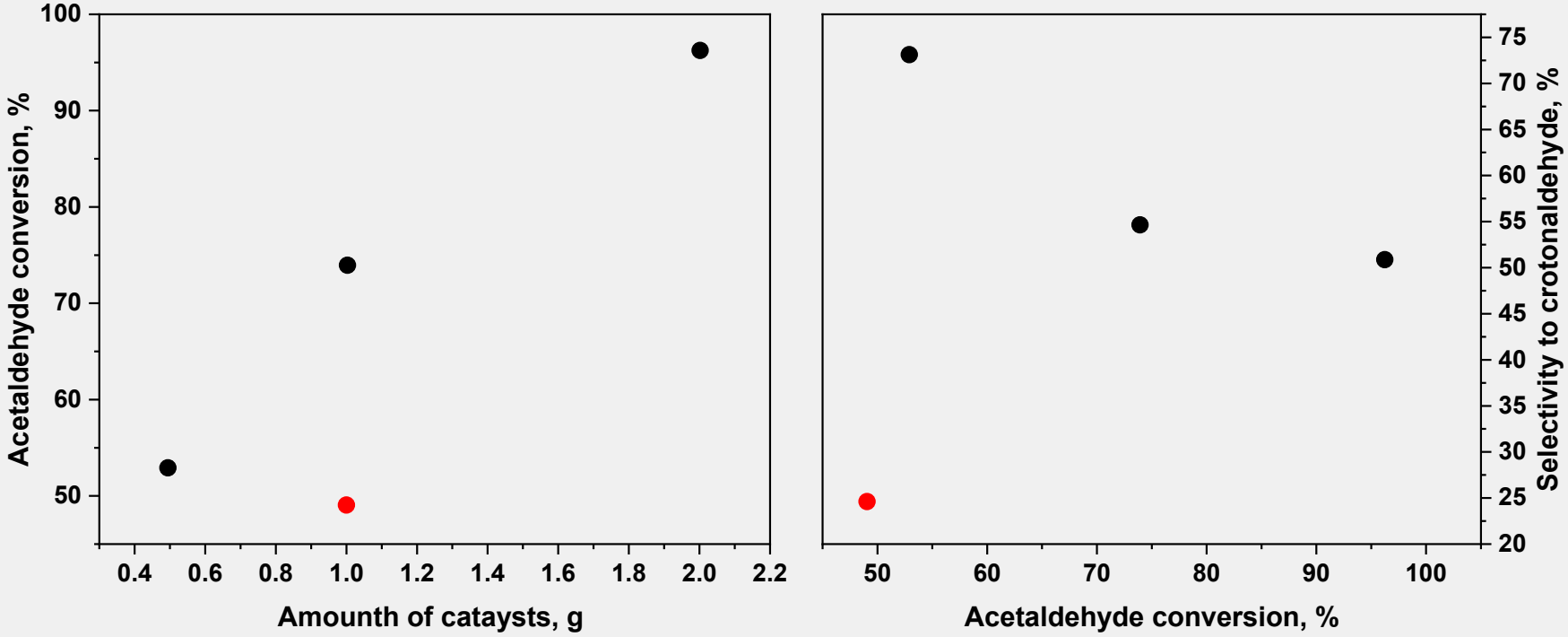

Conclusion

- The petrochemical industry is a key part of the development of human society.
- Legislative pressure for decarbonization could lead to a decrease in the competitiveness of the European petrochemical industry.
- Specialty chemicals can be produced sustainably, but basic petrochemicals cannot.
- The Guerbet reaction is suitable for the production of chemicals for the production of plasticizers, specialty solvents, chemicals for the pharmaceutical, food and cosmetic industries.
- The two-step synthesis will allow for increased selectivity towards targeted alcohols.

Thank you for your attention