Summer School June 13-14th, 2023

at KIT

BL2F

Transforming Black Liquor to Biofuel

This project has received funding from the European Union Grant Number 884111

Welcome at KIT

This project has received funding from the European Union Grant Number 884111

BL2F Summer School, Tuesday 13.6.2023

	Welcome
10.00	Intermediates to renewable fuels – Motivation and goals of the summer school (Nicolaus Dahmen, KIT)
10.30	High Temperature Liquefaction: Status and an example of pilot demonstration (Jukka Konttinen, TAU)
11.00	On the fundamentals of supercritical water salt separation and concomitant HTL using black liquor (David Baudouin, PSI)
11.30	Networking break
11.50	Laboratory visit

This project has received funding from the European Union Grant Number 884111

BL2F Summer School, Tuesday 13.6.2023

	Chair: Ursel Hornung
14.00	Hydrodeoxygenation (HDO) of bio-oils (Juha Lehtonen, VTT)
14.30	Oxymethylene ethers (OME) as clean and sustainable diesel substitutes (Marius Drexler, KIT-IKFT)
15.00	Hydrogen economy and use for transport fuels (Jukka Konttinen, TAU)
15.30	Reactor concepts for synthetic natural gas production from CO_2 (Mathias Held, KIT-EBI)
16.15	Transfer to the social event by bus

This project has received funding from the European Union Grant Number 884111

BL2F Summer School Wednesday 14.6.2023

	Chair: Mya Belden and Nicolaus Dahmen
9.30	Hybrid Key note: Towards liquefaction of sustainable feedstock to upgraded intermediate products (Tooran Khazraie, Valmet)
10.00	Pyrolysis oils and their applications (Frederico Fonseca, KIT-IKFT)
10.30	Group work on case studies for different fuel intermediates
12.00	Lunch in the Casino
13.00	Presentation of group working results

This project has received funding from the European Union Grant Number 884111

Case study

Groups work on value chains of different renewable intermediates:

HTL biocrude	Maximilian Wörner
Fast pyrolysis bio-oil	Naiara Telis
Methanol +	Moritz Herfet
LC alcohol to jet	Henri Steinweg
Hydrogen	Frederico Fonseca
Biogas	Philip Konnerth

Henri ist blau, Max ist grün, Moritz weiß mit Kreuz, Najara weiß, Frederico gelb und Philip rot.

This project has received funding from the European Union Grant Number 884111

Case study

Task: Find a process example for one possible process chain utilizing the specific intermediate to examine the following questions

- What does the process look like (schematic)?
- Which feedstocks can or are be used?
- Which products are obtained?
- Which fuel applications are possible?
- What is the fuel (energy) efficiency?
- What dou you think are main advanges/disadvantages of the process?

Present the results in bullet point form together with a simple process scheme after the lunch break.

This project has received funding from the European Union Grant Number 884111

BL2F Summer School Wednesday 14.6.2023

	Chair: Nicolaus Dahmen
16.00	Distinctive aspects of techno-economic analyses of the generation of renewable energy carriers (Paul Heinzmann, Andreas Rudi, KIT-IIP)
16.30	Online: Sustainability and feasibility of the production of bio-oil integrated to Pulp Mill (Tero Joronen, BL2F coordinator, TAU)
17.00	Closing (Ursel Hornung)

This project has received funding from the European Union Grant Number 884111

Intermediates to renewable fuels – Motivation and goals of the summer school

Nicolaus Dahmen

BL2F

Transforming Black Liquor to Biofuel

This project has received funding from the European Union Grant Number 884111

Scope and outline

- What are renewable fuels (refuels)?
- What is the role they may play in future?
- Which types of refuels exist and what are possible pathways for their production?
- What is the role of intermediates and what are the most relevant ones?

This project has received funding from the European Union Grant Number 884111

Traffic sectors

	Alternatives
Passenger cars	Full electric battery
Light trucks	Full and hybrid electrical
Heavy trucks	Fuel cell, H_2 ICE, reFuels
Railway	
Maritime	LNG, methanol, reFuels, NH_3,
Aviation	reFuels w/o aromats
Machines for construction, agriculture, forestry	Electrical, fuel cell, H_2 ICE, reFuels
Military	reFuels

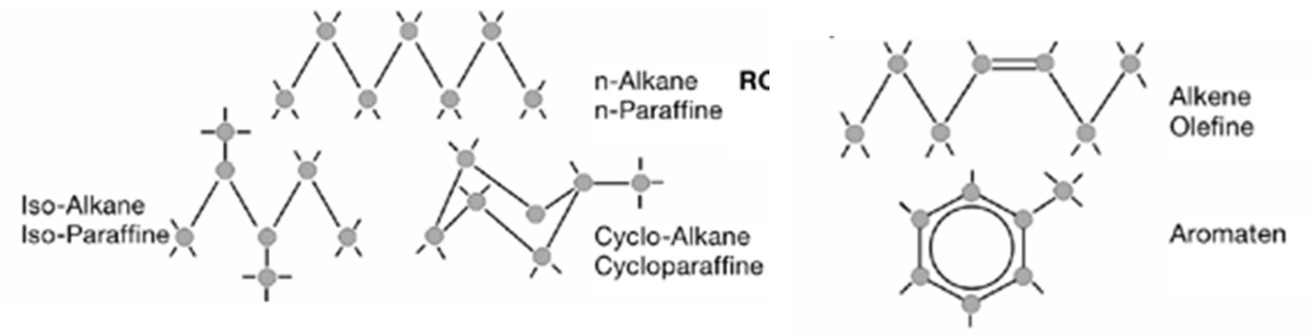
In future, there is a still significant demand for liquid and gaseous hydrocarbon fuels!

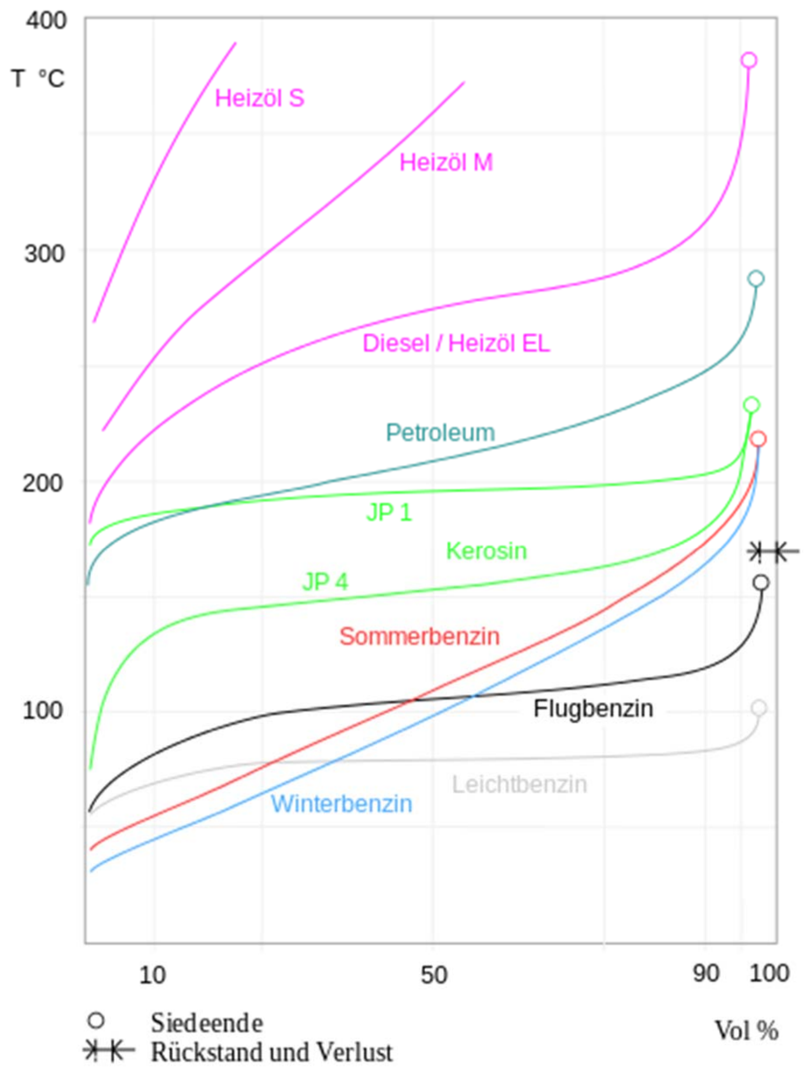
This project has received funding from the European Union Grant Number 884111

Conventional liquid fuels

- Multi component mixtures of linear, branched and cyclic hydrocarbon fractions from crude oil and additives.

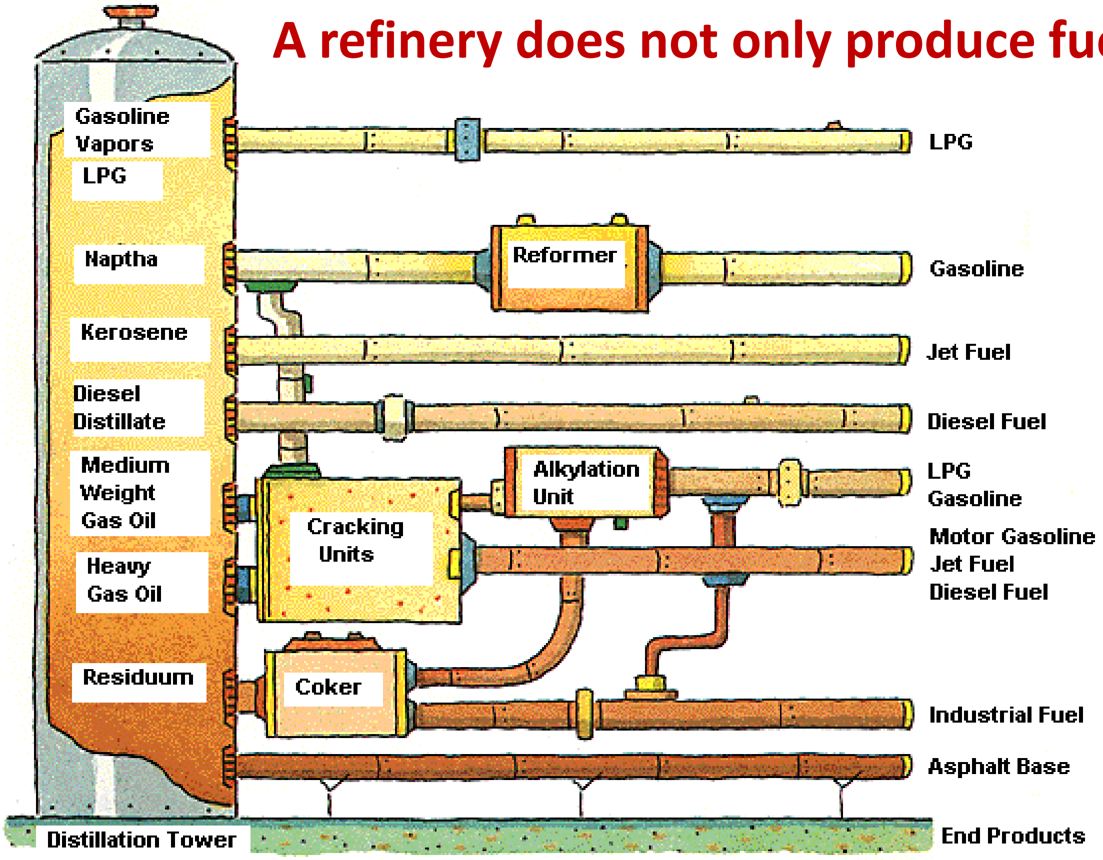
	Gasoline	Kerosene	Diesel
C-Atoms	5-11	8-13	9-22
Norm	EN 228	Jet A, A-1	EN 590





This project has received funding from the European Union Grant Number 884111

Fuel production today



A refinery does not only produce fuels!

Naphta	7,01
Otto fuel	18,82
Gasoline comp.	2,50
Diesel fuel	31,36
Fuel oil (light)	12,52
Middle distillate	2,02
Fuel oil (heavy)	4,15
Heavy components	2,25
Liquid gas	2,97
Refinery gas	3,64
Special gasoline	0,49
Text gasoline	0,06
Jet fuel	2,59
Bitumen	3,86
Petrocoke	1,73
Waxes	0,32
Lubricants	2,47
Residues	1,26
	100

Output of Germany´s refineries in 2020

Total amount ca. 100 kt

En2x Gründungs-bericht 2021

https://www.e-education.psu.edu/eme801/node/470

This project has received funding from the European Union Grant Number 884111

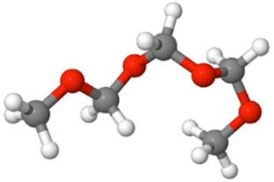
What are renewable fuels?

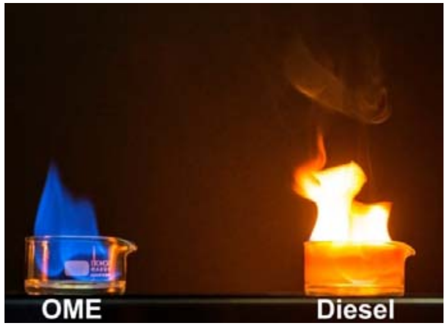
– reFuels comprise all fuels that are produced on the basis of non-fossil carbon and hydrogen sources, including advanced biofuels and electro-fuels (eFuels).
– In blends and, in perspective, also as full fuel they meet the existing standards.

This project has received funding from the European Union Grant Number 884111

Attempt to classify reFuels

- **Pressurized and liquid gases:**
  - Compressed or liquefied hydrogen
  - Compressed renewable Gas (CReG) (analog CNG)
  - Liquefied Natural Gas (LReG) (analog LNG)
  - Liquefied Propane (analog LPG)
  - Dimethyl ether (DME)
- **Hydrocarbons (Drop-in-Fuels)**
  - Fischer-Tropsch gasoline, diesel, jet fuel
  - Methanol-to-gasolie
  - Gasoline and jet fuel from olefin oligomerization
  - Synthetic aromats (blend component for jet fuel)
  - Upgraded bio-oils/-crudes
- **Oxygenates (Near-Drop-in-Fuels, blend components):**
  - Methanol
  - Ethanol, Butanol
  - Octanol
  - Dimethyl ether, oxymethylen dimethyl ether (OME)
  - Methyl-tert.-Butylether (MTBE)





This project has received funding from the European Union Grant Number 884111

Future fuel production

- Dedicated plants producing one or a narrow range of fuels used close by (de-centralized production)
- Refinery type plants, utilizing renewable, stable intermediates from scalable technologies
  - Methanol from syngas
  - Hydrocarbons (e.g. via Fischer-Tropsch) from syngas
  - Bio-oil / -crude from thermal biomass treatment
  - Methane from digestions or CO_2-hydrogenation
- These intermediates can be produced and traded all over the world (where renewable energy and energy carriers are cheap)to be imported and adding value by their conversion into fuels and chemicals.

This project has received funding from the European Union Grant Number 884111

The ways to intermediates

Syngas
- Gasification of organic material
  (e.g. from lignocellulosic biomass
  $C_6H_8O_4 + 2\ O_2 \rightarrow 5.2\ CO + 2.8\ H_2 + 0.8\ CO_2 + 1.2\ H_2O$)
- Reverse water gas shift reaction: $CO_2 + H_2 \rightarrow CO + H_2O$
- Co-electrolysis: $CO_2 + H_2O \rightarrow CO + H_2 + ½\ O_2$
- Dry gas reforming: $CH_4 + CO_2 \rightarrow 2\ CO + 2H_2$

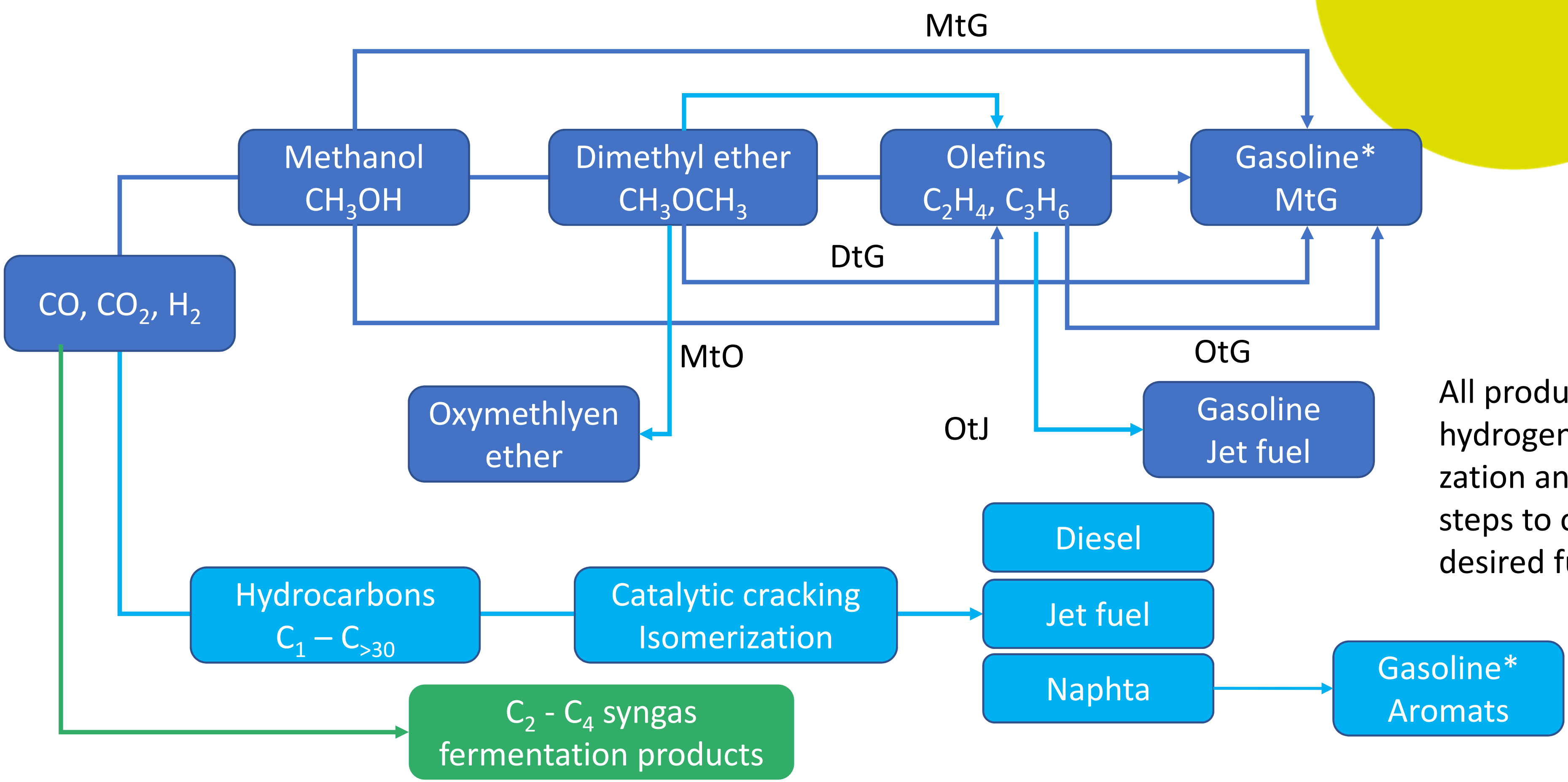
Methane
- Anaerobic digestion: $C_2H_{12}O_6 \rightarrow 3\ CH_4 + 3\ CO_2$
- Methanation: $CO_2 + 4\ H_2 \rightarrow CH_4 + 2\ H_2O$

Bio-oil/-crude
- Hydrothermal liquefaction
  (ca. 60% liquid products)
- Fast pyrolysis
  (max. 60% liquid products)

Carbohydrates
- Digestion of lignocellulosig biomass
  (20 – 45% glucose yield)

This project has received funding from the European Union Grant Number 884111

Syngas based fuels

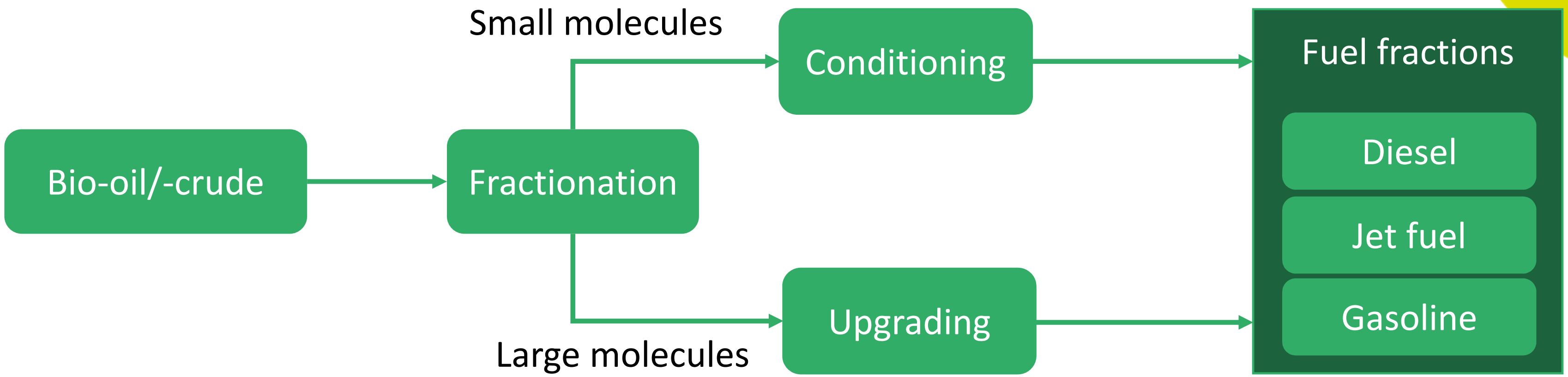


All products may require hydrogenation, isomeri-zation and fractionation steps to obtain the desired fuel quality

*containing aromats

This project has received funding from the European Union Grant Number 884111

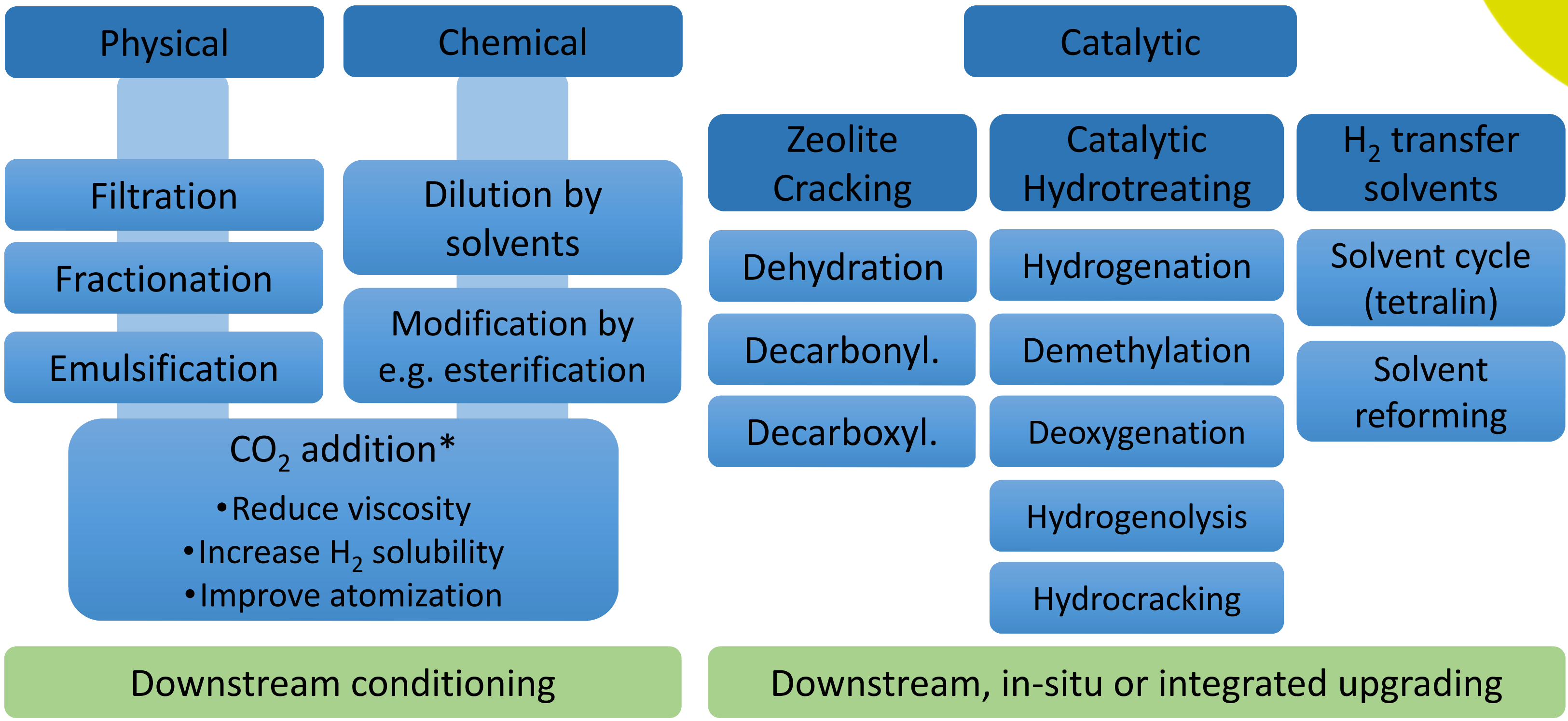
Bio-oil/-crude based fuels



– Bio-oil/-crude are complex multi-component mixtures
– Upgrading/conditioning aim at improved thermal and chemical stability, increased heating value, miscibility with hydrocarbons, reduced viscosity and acidity
– Mulit-step conditioning & upgrading processes are required

This project has received funding from the European Union Grant Number 884111

Bio-oil/-crude upgrading/conditioning

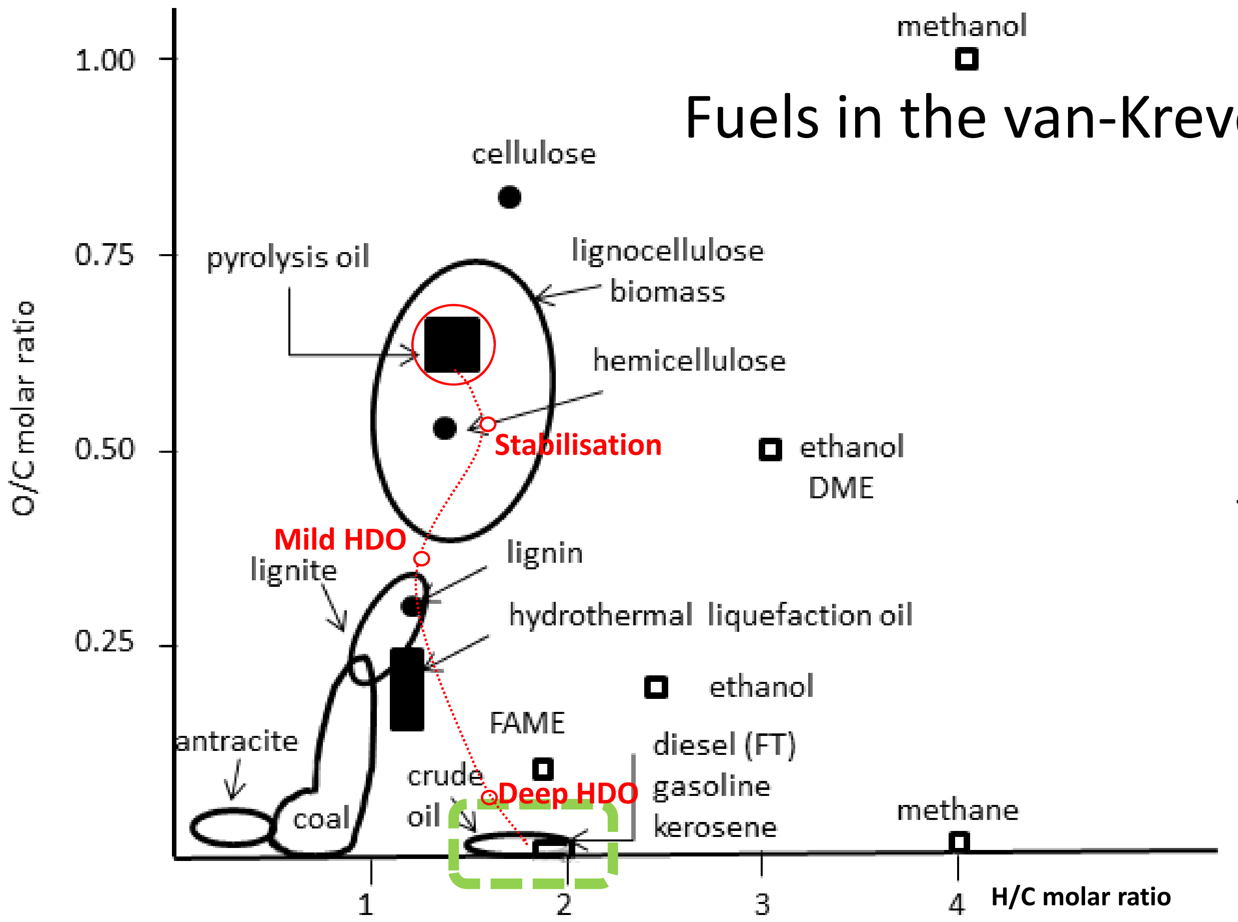


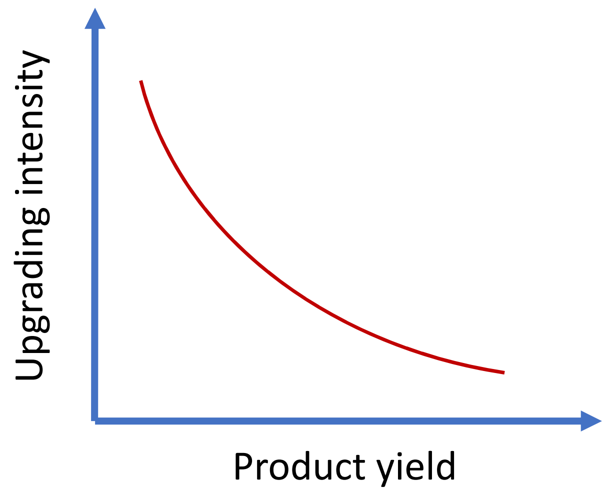
*W. Olbrich, C. Boscagli, K. Raffelt, H. Zang, N. Dahmen, J. Sauer, *Catalytic HDO of pyrolysis oil over Ni-catalysts under H_2 /CO_2 atmosphere,* Sustainable Chemical Processes 4 (2016) 1-8

This project has received funding from the European Union Grant Number 884111

Hydrodeoxygenation

Fuels in the van-Krevelen diagram

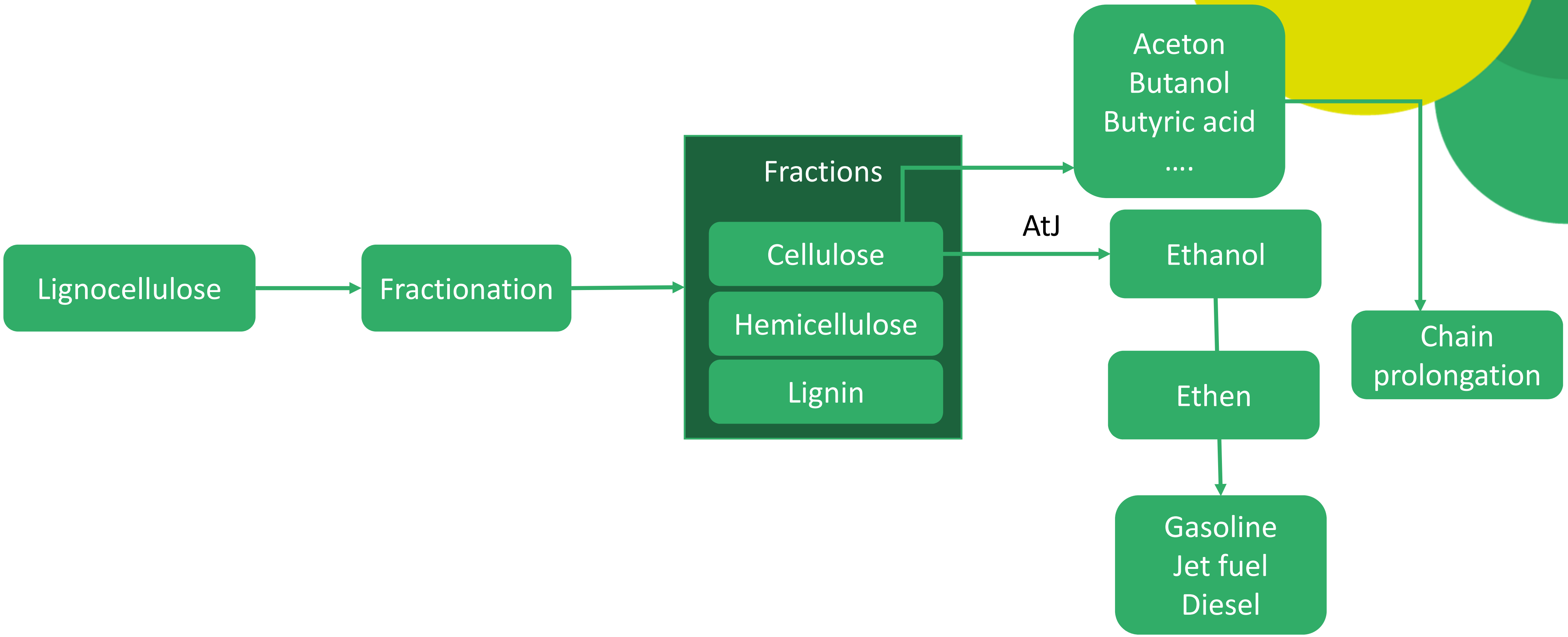




Adapted from S. Kersten et al., Options for Catalysis in the Thermochemical Conversion of Biomass into Fuels, pp. 119145

This project has received funding from the European Union Grant Number 884111

Fermentation/microbial fuels



This project has received funding from the European Union Grant Number 884111

Biomass de-polymerization principles

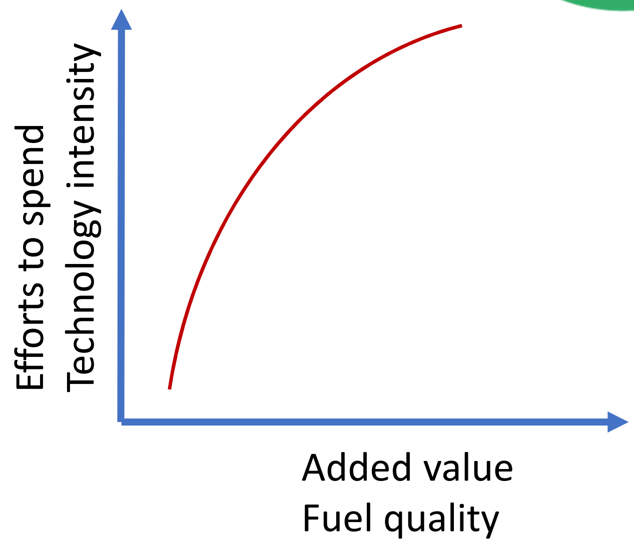
Biochemical	Chemical	Thermal	Catalytical
Cellulases	Alkaline	Solid heat carriers	Cracking
Gluconases	Acidic	Thermo-fluids	Hydrotreating
Cellulosomes	Org. solvents	Hydrothermal water	Deoxygenation
Laccases	Ionic liquids	Thermo-mechanic: steam explosion	
Carbohydrates and lignin		Bio-oil, biocrude, syngas	
		+ aqueous phase, + solids, + gas	

– Usually, combinations of these options are applied

This project has received funding from the European Union Grant Number 884111

Conclusions

- There are several types of renewable fuels and much more routes to produce them
- For proper choice and further development a number of issues need to be addressed
    - Feedstock / intermediate availability
    - Achievable fuel quality
    - State of development/time to market
    - Energy efficiency
    - CO_2 reduction potential/mitigation costs
    - Economics



This project has received funding from the European Union Grant Number 884111


bioliq plant
Projects
– refuels (www.refuels.de/index.php)
– Refineries for Future (https://ref4fu.de/)
– Innofuels
– H2mare (www.wasserstoff-leitprojekte.de/leitprojekte/h2mare)
– Kopernikus PtX (www.kopernikus-projekte.de/projekte/p2x)
– Namosyn (www.namosyn.de)
Energy Lab2.0
Picture M. Breig, KIT)

BL2F Partners:

This project has received funding from the European Union Grant Number 884111

Thank you!

Get in touch with the project:

- Coordinator: Prof. Dr. Tero Joronen, Tampere University
- Website: www.bl2f.eu

hello@bl2f.eu @BL2F_EU BL2F_EU

This project has received funding from the European Union Grant Number 884111