„How to turn on-/of-road transport to green fuels? “

Dr. Klaus Lucka

04.11.2025

E-Meeting: Closing the Gaps in Bio/E-Fuels — Standards, Regulation, and Market Readiness

Competence Center for Fuels and Energy

en2x Wirtschaftsverband Fuels und Energie e.V.

Association for Fuels and Energy

Advocacy for the Petroleum Industry in Germany

- Fuels and Energy
- Technology
- Innovation
- Dialogue
- Member of „Fuels Europe“

https://www.en2x.de

Products and application-oriented Services

Fuels and Application Technologies

- Testing
- Engineering
- Technical Consulting
- Fuel-Check

https://www.tec4fuels.com

Science4Fuels OWI an der RWTH Aachen

Research and Development

Publicly funded Research Projects

- Fuels and Lubricants
- Efficiency Technologies
- High-temperature Technologies

https://www.owi-aachen.de

en2x members

Key areas of activity @ TEC4FUELS

Automotive fuels (e-Fuels/bio based) with focus on renewable gasoline (**M**ethanol **t**o **G**asoline)

- C³ Mobility http://www.c3-mobility.de/
- „E20“ Fuels

Marine fuels

- IDEALfuel https://idealfuel.eu/
- Methanol Standard
- NH_3

Key areas of activity @ TEC4FUELS

Productions processes - Pilots, Scaling, Engineering

- Methanol (GeFP, GreenBee, Water, …)
- DME (IGSTC „waste to wealth“, …)
- Pyrolyseoils (IGSTC „waste to wealth“, …)

Projects within the BEniVer Cluster

Verbund	Förderung in Mio. €	Forschungs-bereiche	Untersuchte Kraftstoffe	Sektoren
NAMOSYN*	20,6	Herstellung, Anwendungen	OME	Straße
MethQuest	17,7	Herstellung, Anwendungen, Systemanalyse	Methan, Methanol, Wasserstoff	Straße, Schiff, Rückverstromung
C3-Mobility	15,7	Herstellung, Anwendungen, Systemanalyse	Synth. Benzin, DME, OME_{3-5}, Methanol, Butanol, Oktanol	Straße, Schiff
E2Fuels	13,9	Herstellung, Anwendungen, Systemanalyse	Methanol, OME_{3-5}, Methan, HCNG (Wasserstoff+Methan)	Straße, Schiff, Rückverstromung
SynLink	7,7	Herstellung, Systemanalyse	Synth. Diesel, Synth. Kerosin, Methanol, höhere Alkohole	Straße, Luft
KEROSyN100	4,6	Herstellung, Systemanalyse	Synth. Kerosin	Luft
MEEMO	3,0	Anwendungen	Methanol	Straße
PowerFuel	2,6	Herstellung, Systemanalyse	Synth. Kerosin	Luft
MENA-Fuels	2,2	Systemanalyse	(Kraftstoffe in BEniVer, ausschließlich Systemanalyse)	
FlexDME	2,0	Herstellung	DME	Straße, Schiff, Rückverstromung
SHARC	1,9	Systemanalyse	(keine Kraftstoffe / „Smartes Hafen-Applikationskonzept“)	
ISystem4EFuel	1,5	Anwendungen	Synth. Diesel, OME_{3-5}	Schiff, Rückverstromung
LeanStoicH2	1,5	Anwendungen	HCNG (Wasserstoff+Methan)	Rückverstromung
CombiFuel	1,3	Herstellung, Anwendungen	HCNG (Wasserstoff+Methan)	Straße
SolareKraftstoffe	1,3	Anwendungen, Systemanalyse	Synth. Benzin	Straße
PlasmaFuel	1,2	Herstellung	Synth. Diesel	Schiff

Herstellung | Anwendungen | Systemanalyse | Straße | Luft | Schiff | Rückverstromung

* Förderung durch BMBF

BEniVer
Begleitforschung Energiewende im Verkehr

https://www.energiesystem-forschung.de/foerdern/energiewende_im_verkehr/verkehr_begleitforschung

Evaluation of fuels within BEniVer - NormAKraft

BEniVer
Begleitforschung Energiewende im Verkehr

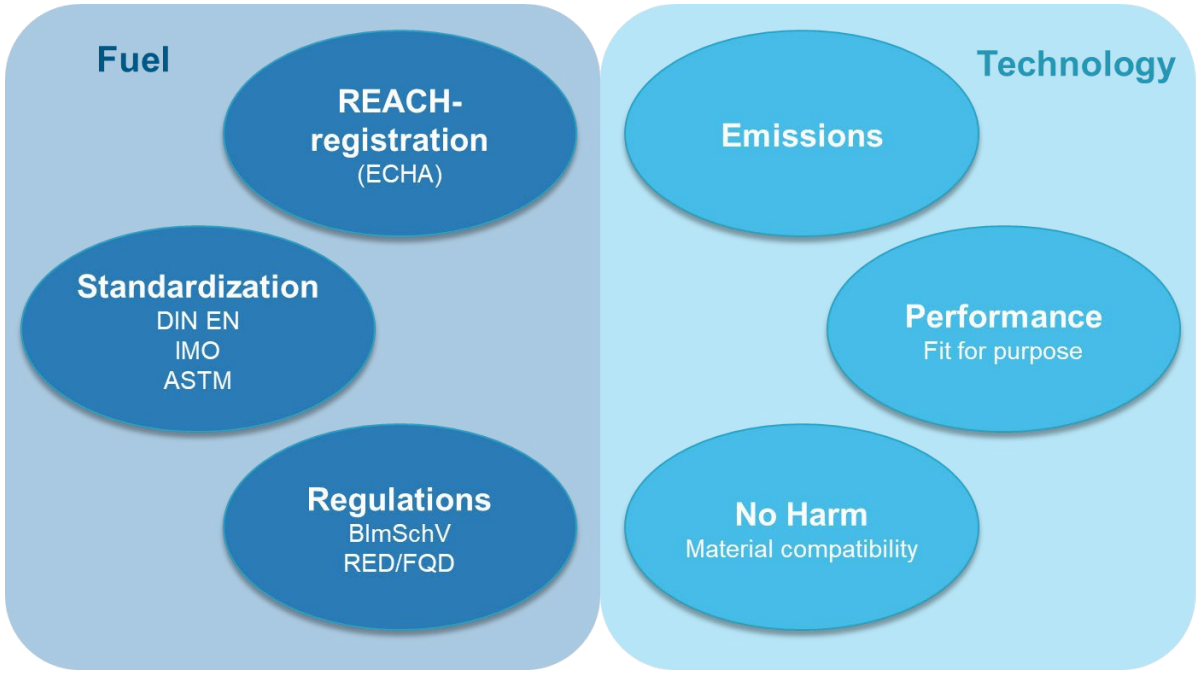
Subproject: **NormAKraft -** Conformity to standards of alternative fuels

- January 2020 - Dezember 2022 (3 years)
- Funded by BMWi
- Funded Partners:

DECHEMA Gesellschaft für Chemische Technik und Biotechnologie e.V.
DGMK
Science4Fuels OWI an der RWTH Aachen
DBFZ
DLR

- Subcontractors:

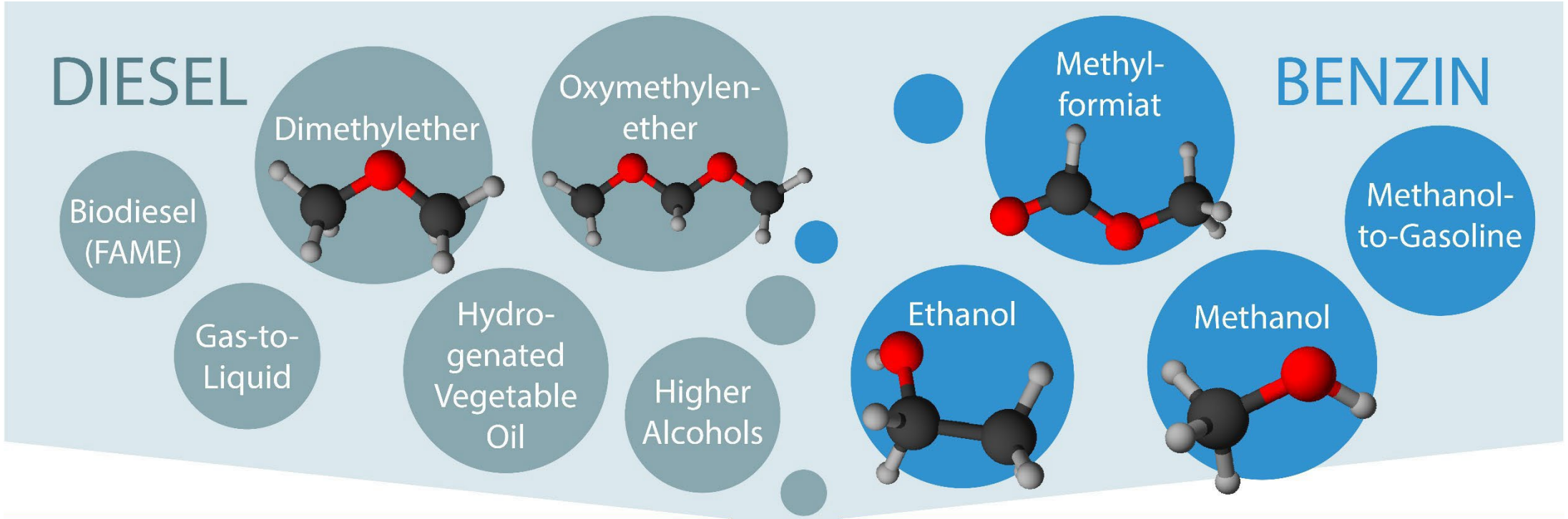
GMA Gesellschaft für Mineralöl-Analytik und Qualitätsmanagement mbH + Co. KG



- Evaluation of: **synthetic FT-Diesel, MtG, Jet-Fuel, MeOH, DME, OME, DMC/MeFo, Methane, H_2 and „Hythane“**

Contact: Dr. Jens Artz & Dr. Philip Ruff, Tel.: +49 (0) 69 7564 - 419, E-Mail: normakraft@dechema.de

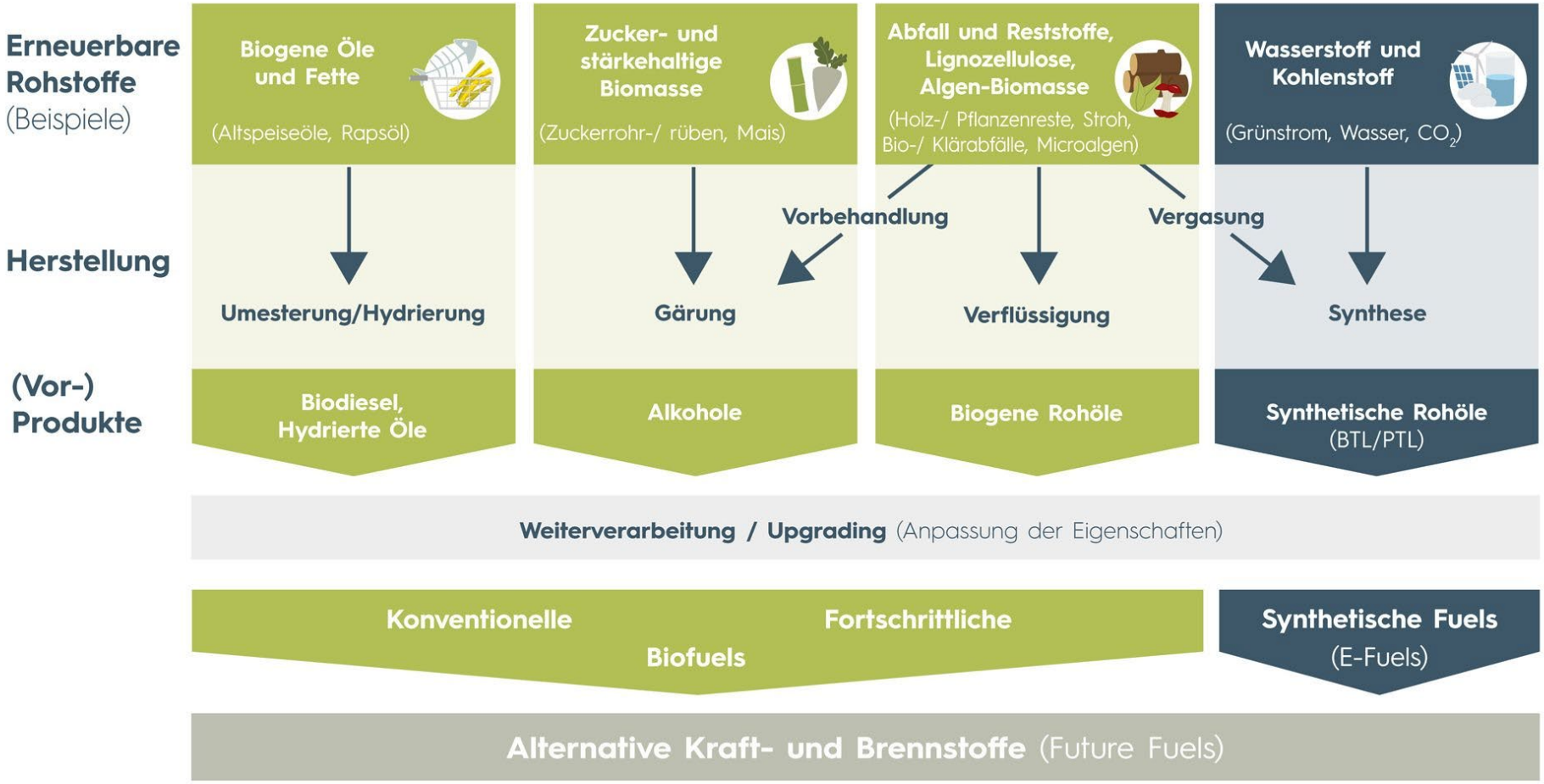
Focussing on fuel diversity is important



DME-Norm: M-DIN 51698 OME-Norm: M-DIN 51699	in Arbeit
FAME: DIN EN 14214 GtL, HVO: DIN EN 15940 Diesel: DIN EN 590	existierend

Methanol-Norm	in Arbeit
Benzin: DIN EN 228 Ethanol: DIN EN 15376	existierend

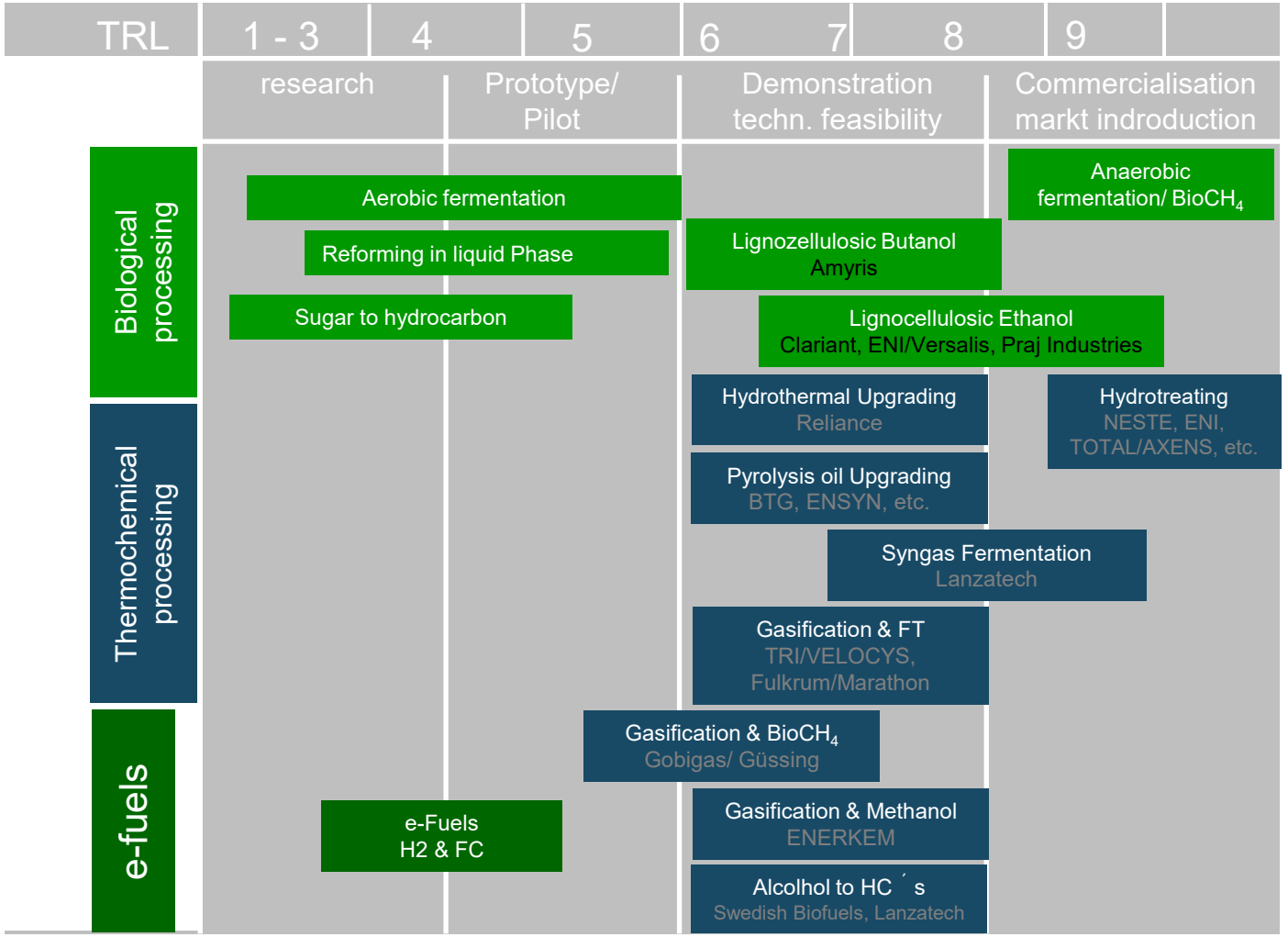
Production pathways for advanced alternative fuels



Quelle: en2x; Grafik (Nr. 014b_FF): en2x

Production pathways for advanced Biofuels

Current state of the art – status of technology readiness



Quelle: Concawe

Produktion pathways for advanced Biofuels

Raw materials and sustainability criteria

Detailed list of biomass from waste and residual materials based on the DBFZ Biomass Potential Study 2015

	RED II
Wood and forestry residues Forest residues, sawmill by-products, wood shavings, black liquor, waste wood, other industrial wood residues, bark	✓
Agricultural by-products Cereal straw, liquid manure from cattle/pigs, solid manure from cattle/pigs/chickens	✓
municipal waste Used cooking oil, oil separated during water treatment, market waste, kitchen and canteen waste, old textiles, mixed packaging, organic waste (brown bins, green waste, biogenic portion of household waste, commercial food waste)	✓
Industrial waste materials Glycerin from biodiesel production, from the processing of animals, fish, fruit, vegetables, milk, from the production of vegetable/animal oils, fats, starch products, baked goods, pasta, beverages, mixed feed, production of sugar, confectionery, coffee, tea, tobacco residues, biotechnology industry	✓
Residual materials from other areas Straw and woody biomass from landscape management (green spaces, cemeteries, orchards, heathland, moorland, vineyards, roadside areas) Wood from riverbanks, wood from railway embankments, flotsam/driftwood	✓

Produktion pathways for advanced Biofuels

Raw materials and sustainability criteria

Detailed list of biomass from waste and residues (DBFZ) in comparison between atmosfair and RED II Annex IX A and B

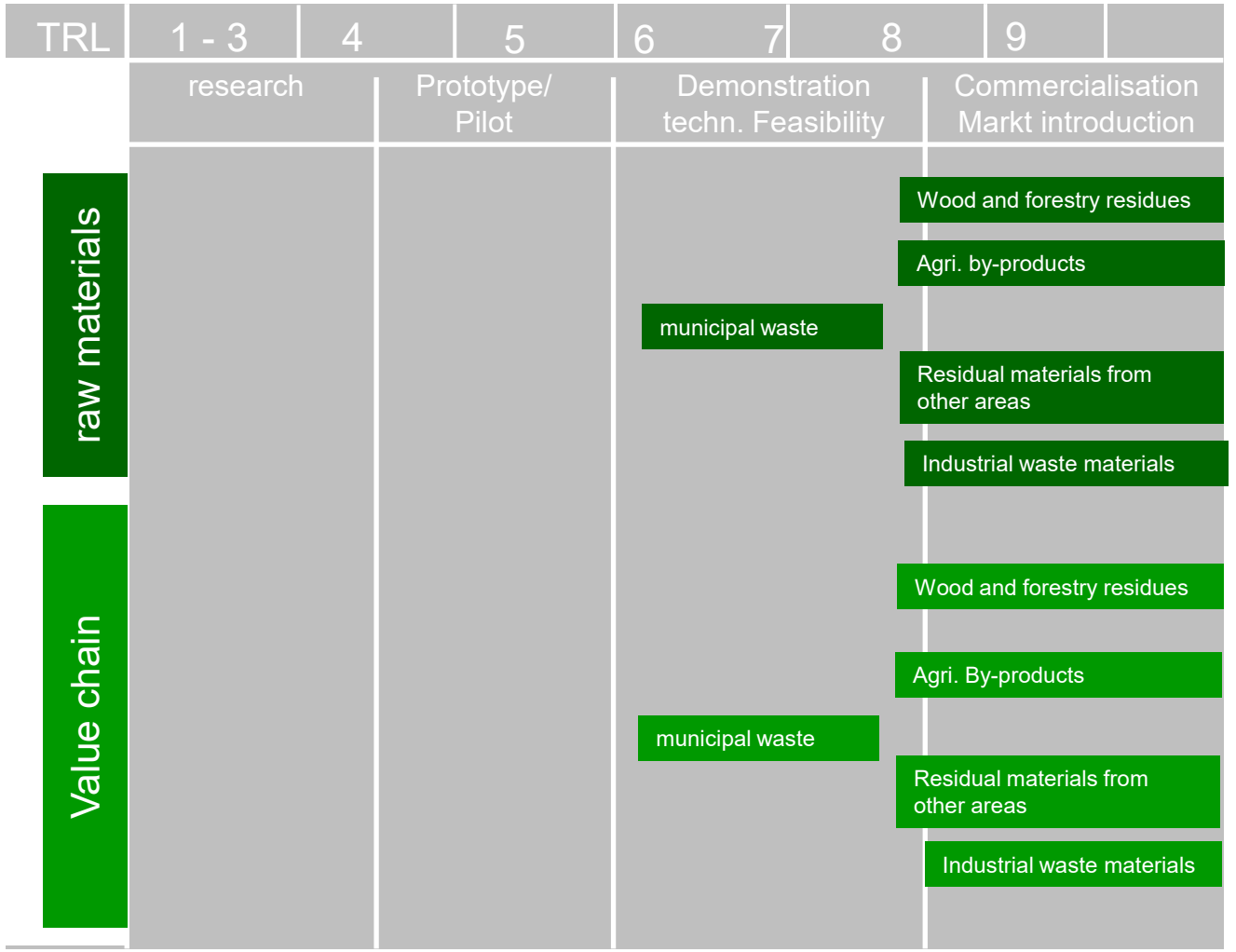
	RED II	atmosfair
Wood and forestry residues Forest residues, sawmill by-products, wood shavings, black liquor, waste wood, other industrial wood residues, bark	✓	✓
Agricultural by-products Cereal straw, liquid manure from cattle/pigs, solid manure from cattle/pigs/chickens	✓	✓
municipal waste Used cooking oil, oil separated during water treatment, market waste, kitchen and canteen waste, old textiles, mixed packaging, organic waste (brown bins, green waste, biogenic portion of household waste, commercial food waste)	✓	✓
Industrial waste materials Glycerin from biodiesel production, from the processing of animals, fish, fruit, vegetables, milk, from the production of vegetable/animal oils, fats, starch products, baked goods, pasta, beverages, mixed feed, production of sugar, confectionery, coffee, tea, tobacco residues, biotechnology industry	✓	✓
Residual materials from other areas Straw and woody biomass from landscape management (green spaces, cemeteries, orchards, heathland, moorland, vineyards, roadside areas) Wood from riverbanks, wood from railway embankments, flotsam/driftwood	✓	✓

Biomass in green font is generally suitable for the production of paraffinic fuels through hydrogenation or the Fischer-Tropsch process.

Produktion pathways for advanced Biofuels

Technological maturity and availability of raw materials and value chains from 2030 onwards

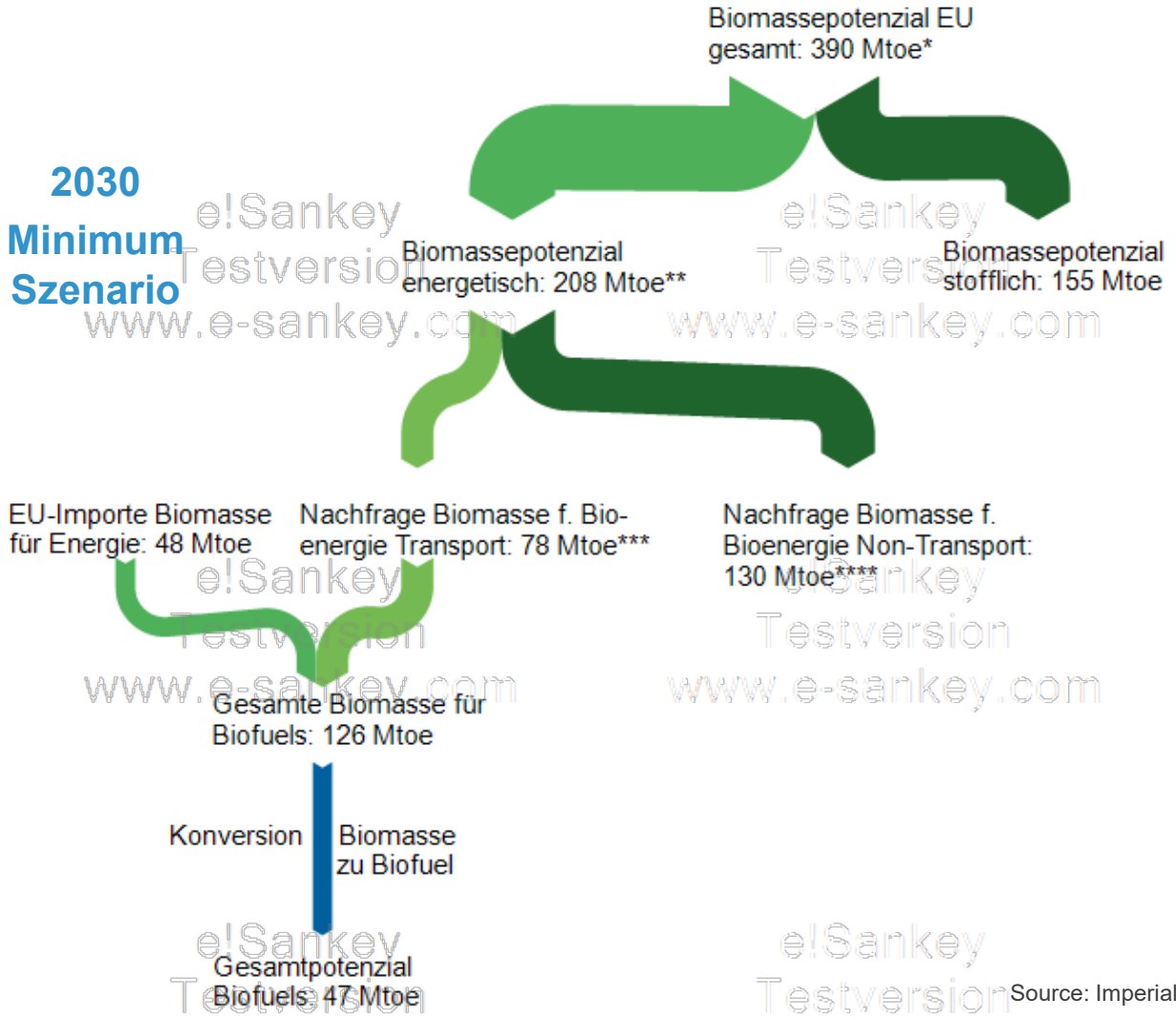
is to be expected in the area of market launch and commercialization. Exceptions are biowaste from municipal waste and lignocellulosic plants from cultivated biomass.



Source: Concawe

Use of bioenergy in the EU by sector

From biomass potential to biofuel potential



* Potential already partially exploited

** Electricity, industry, road transport, aviation, shipping, services/agriculture, residential buildings (approx. 45 Mtoe in 2015, virtually constant from 2030 to 2050 in the PRIMES model), others

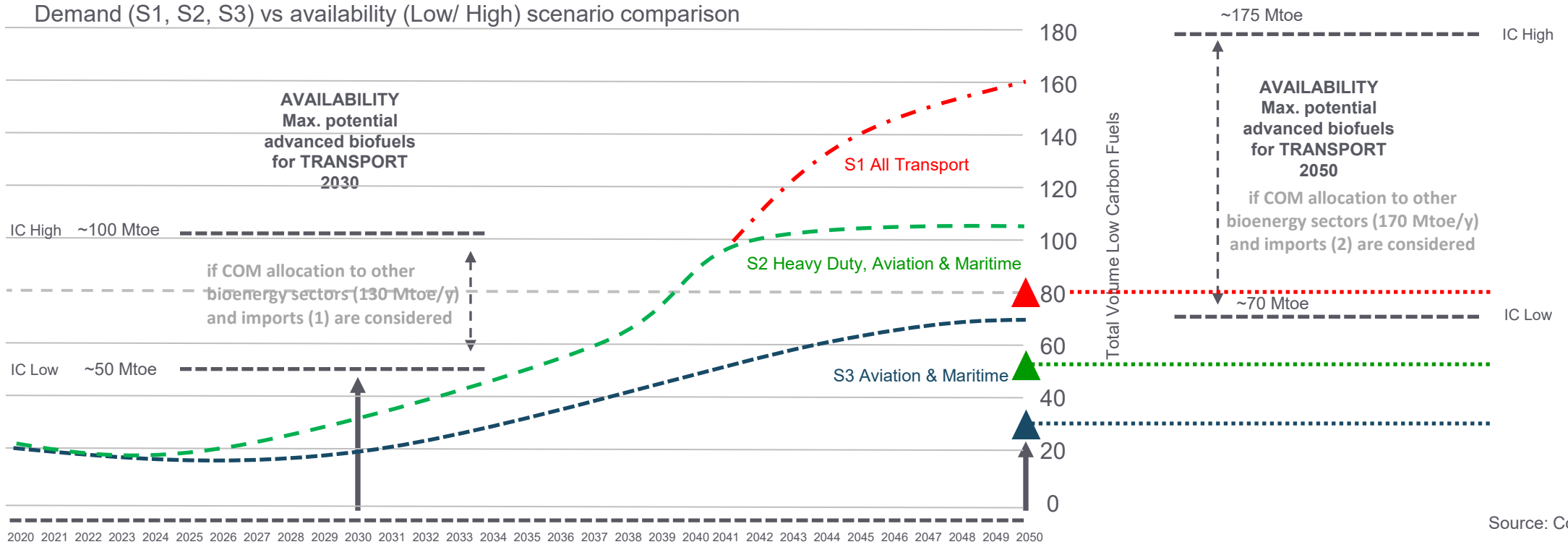
*** Road transport, air transport, shipping

**** Electricity, industry, services/agriculture, residential buildings, other

Source: Imperial College London

Supply and demand for bioenergy in the EU Mobility

Enough sustainable biomass for road, aviation and marine biofuels



Source: Concawe

(1) Biomass imports potential in 2030 50 Mtoe/y 20 Mtoe/y of biofuels) COM allocation to other bioenergy sectors 130 Mtoe/y) would imply 50 Mtoe/y of biofuels

▲ BIOFUELS Concawe Scenarios (2050)
Initial estimate / flexible allocation: ~ ½ efuels / ½ biofuels

(2) Biomass imports potential in 2050 60 Mtoe/y 40 Mtoe/y of biofuels) COM allocation to other bioenergy sectors 170 Mtoe/y) would imply 120 Mtoe/y of biofuels

Project: REDIFUEL

REDIFUEL Robust and Efficient processes and technologies for Drop In renewable FUELs for road transport

- Acronym: REDIFUEL
- Duration: 42 months
- Start date: 1 October 2018
- Total budget: 5 M€
- EC Funding: 5 M€

https://redifuel.eu/

Project: REDIFUEL

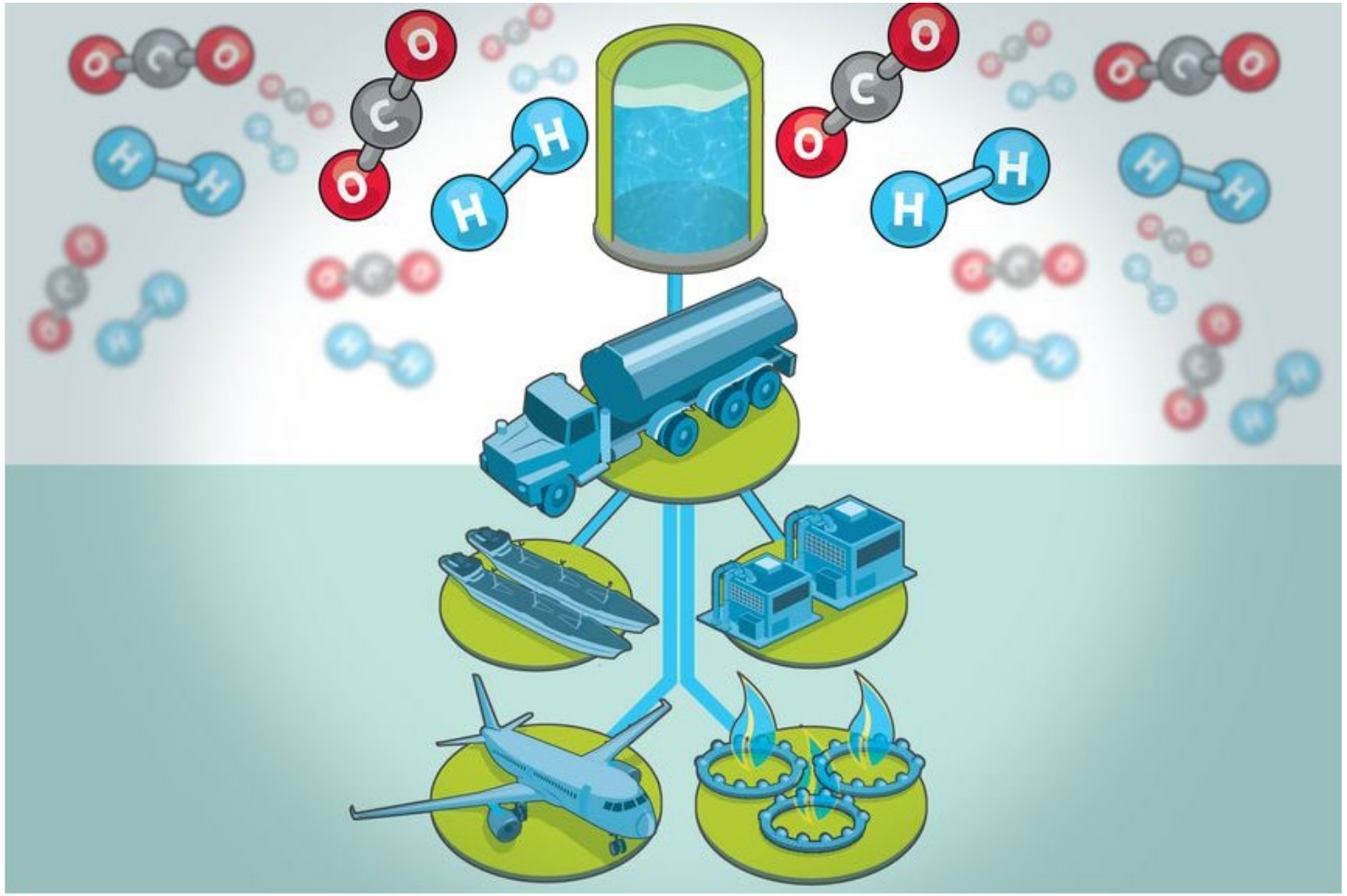
REDIFUEL

*The overall **objective of REDIFUEL** is to enable the utilization of various biomass feedstock for an ultimate renewable EN590 diesel biofuel*

https://redifuel.eu

Project Goals:

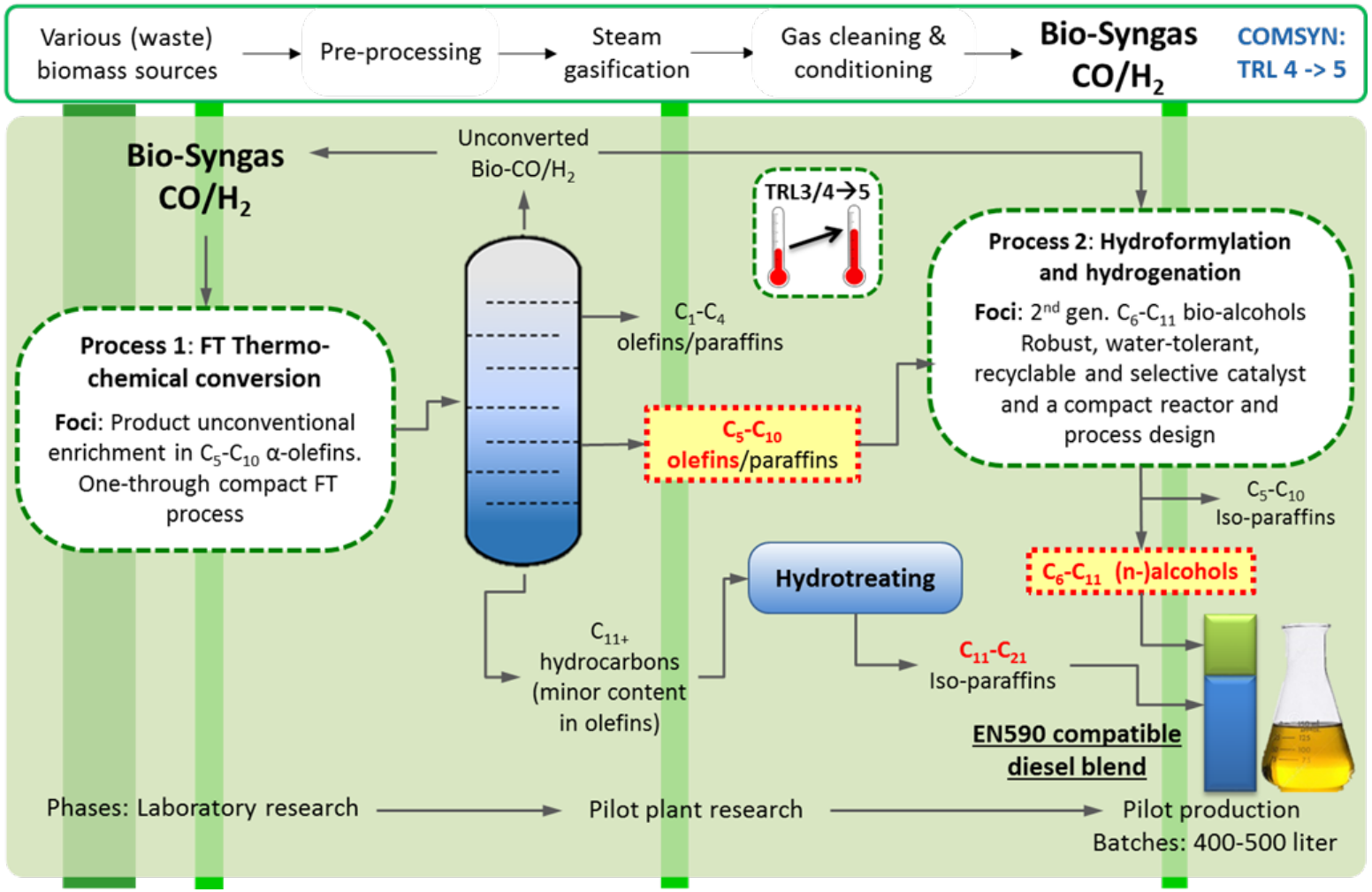
- **Drop-in** capable Renewable Fuel
- 100 % **Miscibility** with the Fossil fuels
- Compatible with **EN590** Standards
- highly competing production cost level of **€ 0.80 - 1.00 per liter**



Source: https://www.wsj.com/articles/can-e-fuels-save-the-combustion-engine-11621037390

Project: REDIFUEL

*REDIFUEL project has received funding from the European Union's Horizon 2020 research and innovation program under Grant Agreement no. 817612.



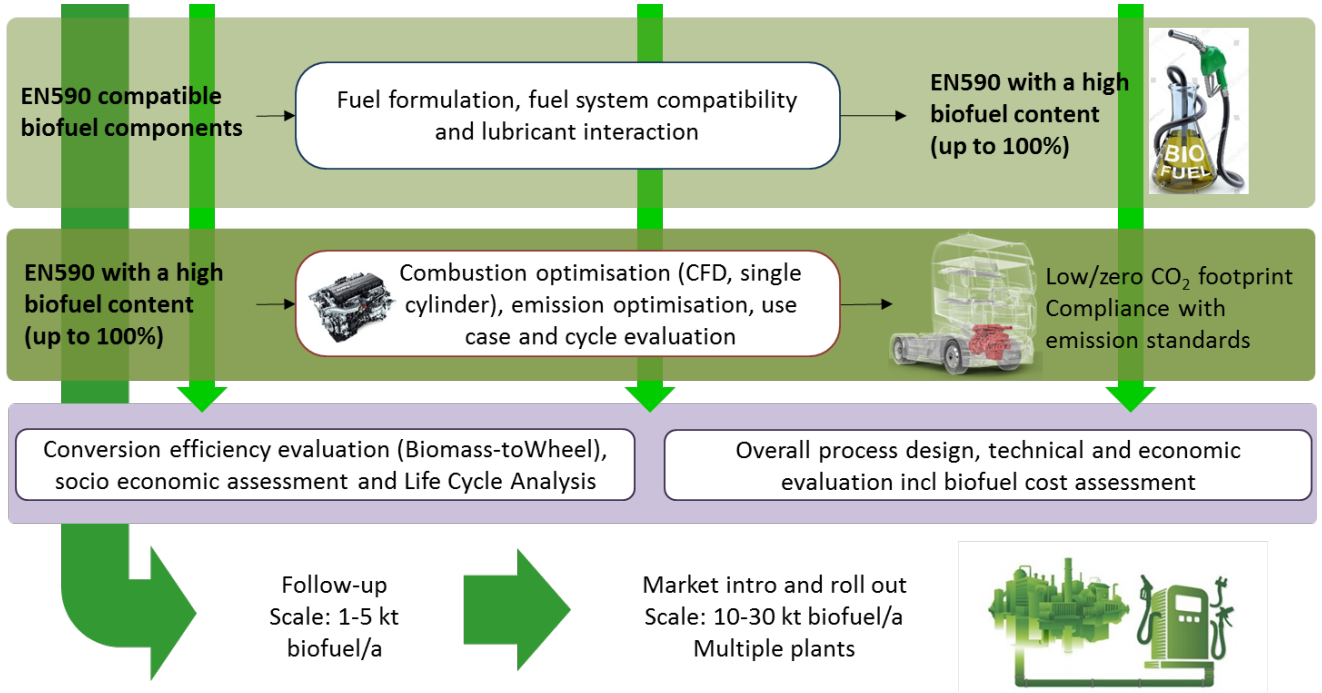
Project: REDIFUEL

- **Fuel formulation:** Mixture of paraffinic components and alcohols (C6 - C11)

- To Accelerate the testing: All tests were performed with surrogate fuels.
  - Scale-up and final product were produced by the end of the project

- On-road testing was performed by FEV in both Passenger car and Heavy-duty trucks.
  - reduced **CO2 emissions (up to 56%)** compared to mineral oil-based diesel
  - had a slightly **higher combustion efficiency** (about 3%)
  - **soot emissions** even decreasing by **10 to 15 %.**

- LCA resulted in an estimated product price of less than 1 euro per liter in 2050.



Closed Carbon Cycle

MOBILITY

http://www.c3-mobility.de

Source: C³ - Mobility

Closed Carbon Cycle Mobility – C³-Mobility

PROJECT OVERVIEW

KEY FACTS

- Funding initiative „Energy Transition in the Transport Sector“ by the German Federal Ministry for Economic Affairs and Energy

Supported by:

Federal Ministry for Economic Affairs and Energy

on the basis of a decision by the German Bundestag

Projektträger Jülich Forschungszentrum Jülich

TÜVRheinland® Genau. Richtig.

- Total project budget >25 Mio€; Funding ~16 Mio€
- Project duration: August 1st 2018 – November 30th 2021
- 32 partners from
  - Energy sector
  - Mineral oil industry
  - Automotive industry (OEMs, suppliers, engineering services)
  - Research institutes

C³-MOBILITY – THE TEAM

Until 03/2020

subcontracted

subcontracted

MtG as CO_2-neutral fuel for defossiliziation of the vehicle fleet w/o limitation

BACKWARDS COMPATIBILITY IS THE MOST CRUCIAL FACTOR FOR LARGE-SCALE USAGE OF SYNTHETIC FUELS

PRODUCTION OF >40 M³ MTG @ TU BAF

MTG HAS VERY PROMISING CHARACTERISTICS

- Methanol-to-Gasoline process is energy efficient and cheap
- Process is known and developed
- Compliant with existing infrastructure and fleet
- Application almost unrestricted, but product quality of neat MtG not yet “premium” class (needs additives/ blending with e.g. ethanol)

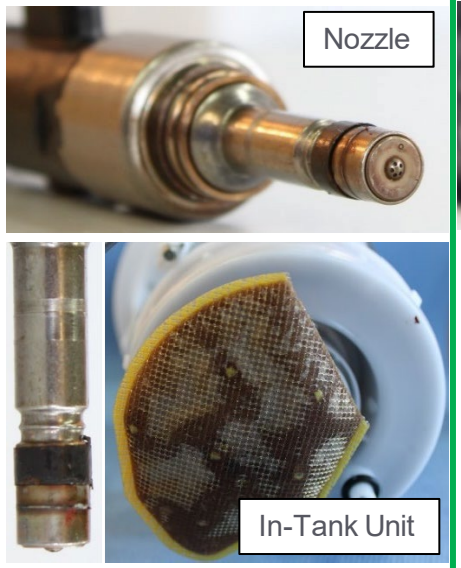
- **Two test campaigns**, in total >40m³ renewable MtG
- Blending with 10% v/v bio-ethanol enabled an **EN 228 compatible fully renewable gasoline fuelMtG is a highly interesting CO_2-neutral drop-in gasoline fuel**

Source: C³-Mobility, Courtesy of TU Bergakademie Freiberg

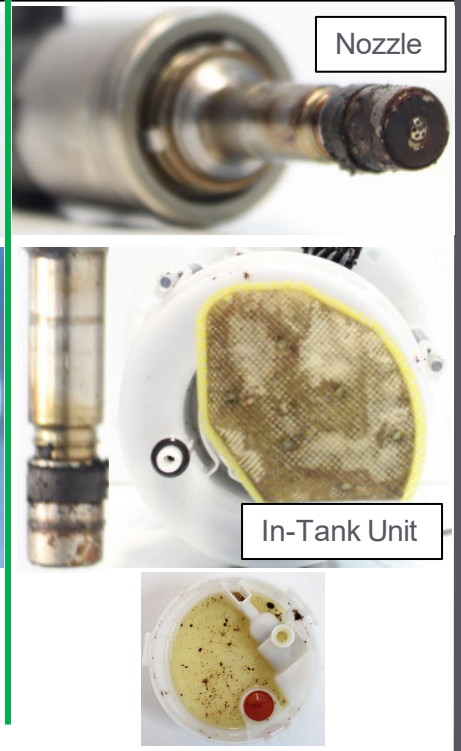
MtG fuel – TEC4FUELS HiL Fluid conditioning of FIE

EU6 HO

Fresh



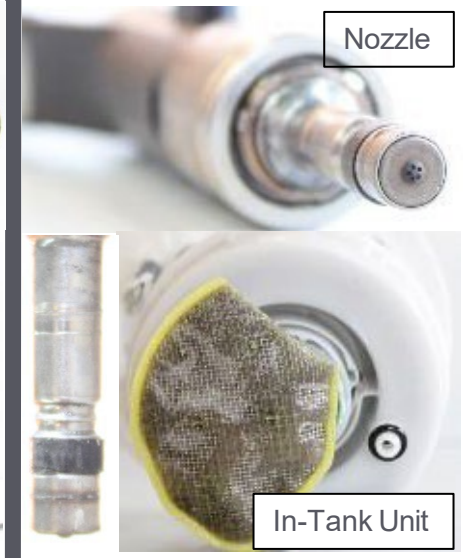
Stressed (24 h 95 °C)



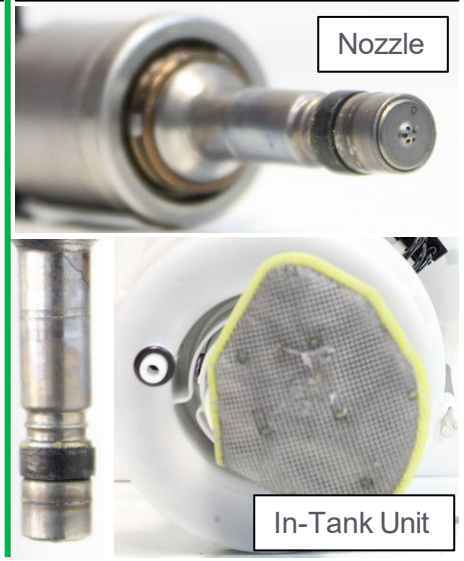
- Fresh EU6 Gasoline showed some brownish color change on nozzle tip
- Stressed EU6 led to **deposit formation** on injector and **particles** in the fuel

Methanol-to-Gasoline (MtG)

Fresh



Stressed (24 h 95 °C)



- Fresh MtG showed some **white color change** on injector tip
- System with stressed MtG showed **no abnormalities**

TEC4FUELS – Methods for HiL Fluid conditioning

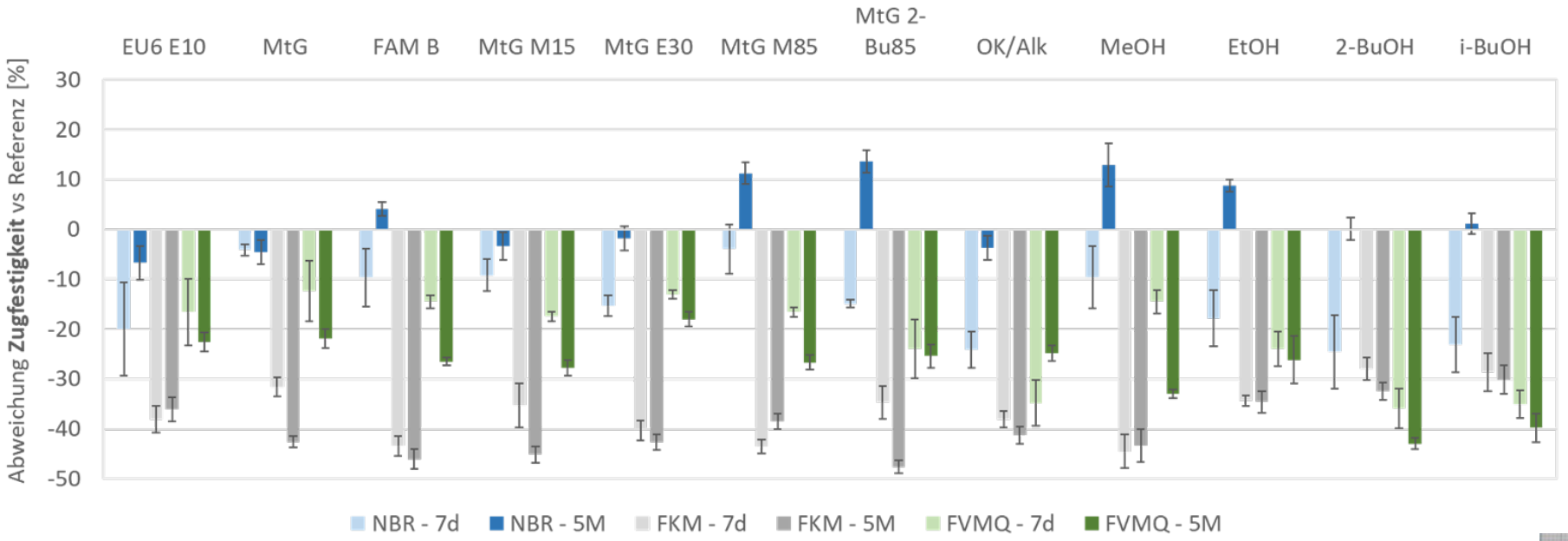
Static Tests

- Storage of elastomers and thermoplastics and system components
- Conditions:
  - 60 °C for elastomers and system components
  - 80 °C for thermoplastics
  - Duration:
    - Elastomers/Thermoplastics: 7 d and 5 m
    - System components: 5 m and 9 m

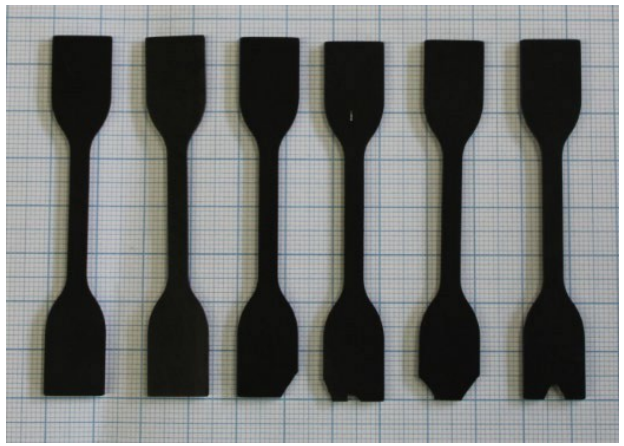
Dynamic Tests (Hardware-in-the-Loop)

- Complete Fuel system
  - Tank
  - In-Tank Unit
  - High pressure pump
  - Rail
  - Injector
- Single component test
  - In-Tank-Unit Stress test

Static Tests – Tensile Strength Elastomers



Referenzwerte NBR: 9,5 N/mm² Zugfestigkeit
Referenzwerte FKM: 19,9 N/mm² Zugfestigkeit
Referenzwerte FVMQ: 10,8 N/mm² Zugfestigkeit



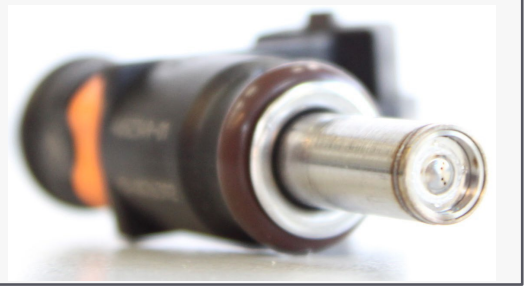
Elastomers

- Decrease of tensile strength
- Similar behavior of the fuel blends – most effects with FVMQ
- No incompatibility

Static Tests – High pressure Injector

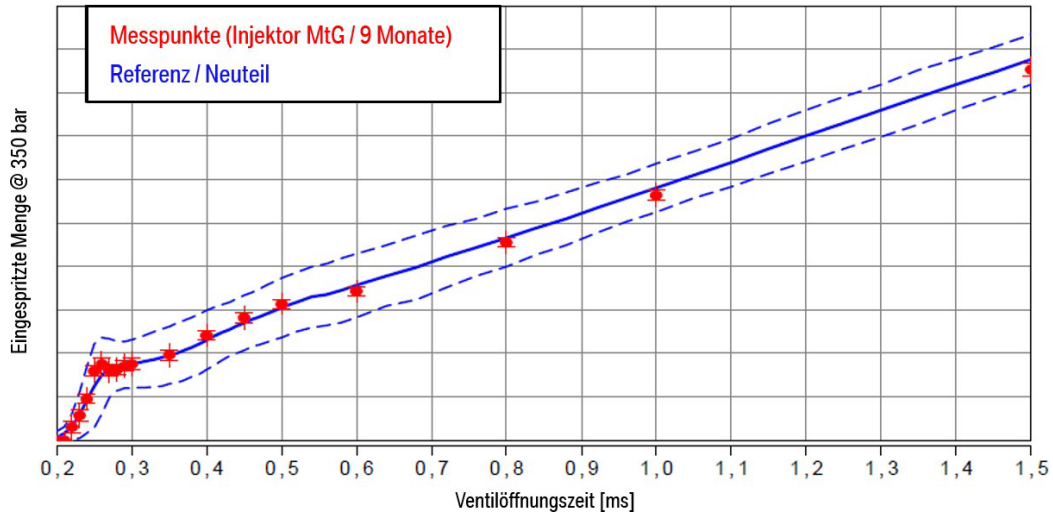
ND-Injectors

- No abnormalities



HD-Injectors

MtG free Fuels						
Fuel	EU6 E10		OK/Alc.		FAM-B	
Storage Time	5 month	9 month	5 month	9 month	5 month	9 month
Leackage test	i.O	i.O	i.O	i.O	i.O	i.O
Flow	i.O	i.O	i.O	i.O	i.O	i.O
Characteristic curve measurement	i.O	i.O	i.O	i.O	i.O	i.O



MtG containing Fuels										
Fuel	MtG		MtG E30		MtG M15		MtG M85		MtG 2-Bu85	
Storage Time	5 month	9 month	5 month	9 month	5 month	9 month	5 month	9 month	5 month	9 month
Leackage test	i.O	i.O	i.O	i.O	i.O	i.O	i.O	i.O	i.O	i.O
Flow	i.O	i.O	i.O	i.O	i.O	i.O	i.O	i.O	i.O	i.O
Characteristic curve measurement	i.O	i.O	i.O	i.O	i.O	i.O	i.O	i.O	i.O	i.O

MtG fuel shows no indication of criticality with regards to FIE

RESULTS OF DYNAMIC AND STATIC STRESS TESTS OF MTG FUEL COMPARED TO FOSSIL REFERENCE FUELS

	Elastomers 60 °C 7d / 5 months	Thermoplasts 80 °C 7d / 5 months
NBR		
FKM		
FVQM		
POM CoPo		
PA 12		
PA610 GF30		
PBT GF30		
PA610		
PA6 GF30		

Results compared to a fossil base fuel based on reference storage

x ≤ -10%	-10% ≤ x ≤ 10%	10% ≤ x

Static stress test

Full system stress test

Static component stress test

60 °C

	5 months	9 months
Injectors		
High-pressure pump		
Tank unit		*

* Results pending

Dynamic full system stress test

500 h/ 250 bar/ 150 °C

full system test bench	

Results compared to a fossil base fuel

lower stress	neutral	higher stress

Source: Prof. Garbe, VW, C³-Mobility Final Event, November 25th 2021

Bundesministerium für Wirtschaft und Technologie

Companies and associations along the whole MtG value chain – from power production to the customer – expressed their interest in a follow-up project

DEMONSTRATING A CIRCULAR CARBON ECONOMY IN TRANSPORT ALONG THE VALUE CHAIN – „DECARTRANS“

FEV
TECHNISCHE UNIVERSITÄT BERGAKADEMIE FREIBERG
Die Ressourcenuniversität. Seit 1765.
C·A·C
ALWAYS AN IDEA AHEAD
MAN Energy Solutions
Future in the making
SIEMENS energy
CLARIANT
JÜLICH Forschungszentrum
OMV

FEV
dena Deutsche Energie-Agentur
VDMA
VDA Verband der Automobilindustrie
en2x Wirtschaftsverband Fuels und Energie e.V.
UNITI Bundesverband mittelständischer Mineralölunternehmen e.V.
ADAC
bp
أرامكو السعودية saudi aramco
Ford
BMW GROUP
Rolls-Royce
PORSCHE
STELLANTIS
HYUNDAI MOTOR GROUP
Tec4Fuels
Science4Fuels OWI an der RWTH Aachen
BOSCH
RWE
DECHEMA
HOCHSCHULE COBURG
LOTHER GRUPPE
JÜLICH Forschungszentrum
NESTE
SWL
Physico-Chemical Fundamentals of Combustion
vka
RWTH AACHEN UNIVERSITY
MABANAFT
CLASSIC
CORYTON FOR A CLEANER FUTURE
RICARDO

Thank you for your attention!

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