Fuel Science

Sustainable Mobility Based on Renewable Resources

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29.06.2022 | Workshop Alternative Kraftstoffe VI | Leer

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Institute for Thermodynamics of Mobile Energy Conversion Systems (TME)

Facilities and Research Areas: a Broad Variety from Fundamental to Applied Research

FSC
The Fuel Science Center

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H_2 Center for Sustainable Hydrogen Systems

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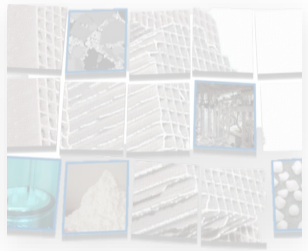
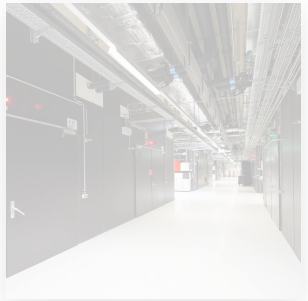


ACA
Center for Automotive Catalytic Systems

ACA | RWTH AACHEN UNIVERSITY



CMP
Center for Mobile Propulsion

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ECD
Emission Chassis Dynamometer

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ATC
Aldenhoven Testing Center

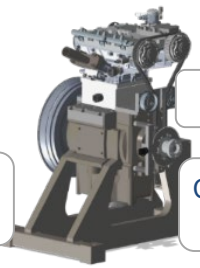
ALDENHOVEN testing center

Fundamental Research

Fuel Design

Chemistry Laboratories

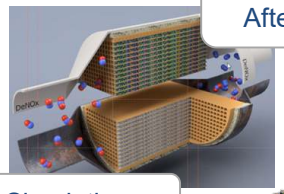
Laser Optical Measurements

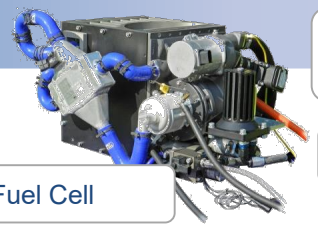


Simulation

Combustion System Development

Exhaust Gas Aftertreatment





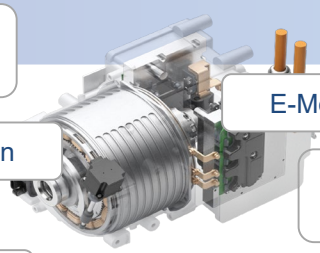
Fuel Cell

Hybrid

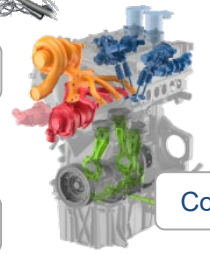
Battery

Real Time Network

Transmission



E-Motor



H_2

Combustion Engines

Applied Research

Vehicle

Real Driving Emissions

Powertrain & Vehicle Calibration

PEMS

Mechanics/Acoustics/NVH

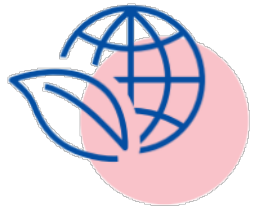
Autonomous Driving

Connected Vehicles / Car2X

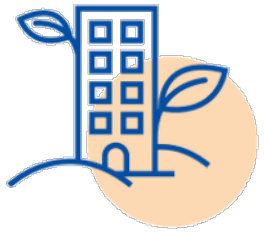
The European Green Deal: Improving the Well-Being of People

THE EU WILL:

Become climate-neutral by 2050

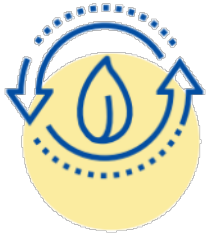


Help companies become world leaders in clean products and technologies



Protect human life, animals and plants, by cutting pollution

Help ensure a just and inclusive transition

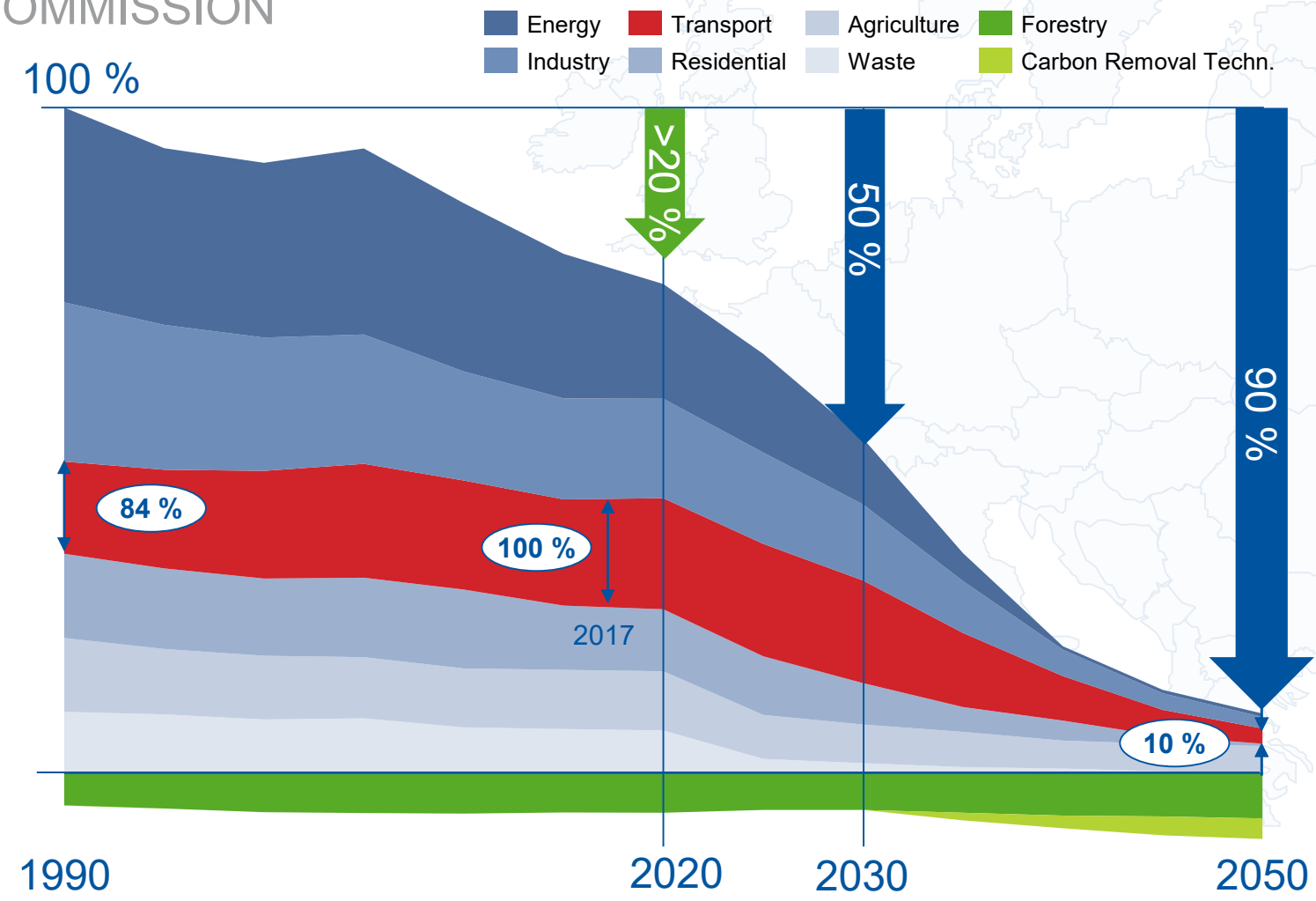


Source: European Commission, https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/actions-being-taken-eu_en

Preventing Rapid Climate Change Requires Dramatic Reduction of GHG Emissions in All Sectors: Transport, Power, Industry, Household, Farming

ROADMAP OF THE EUROPEAN COMMISSION

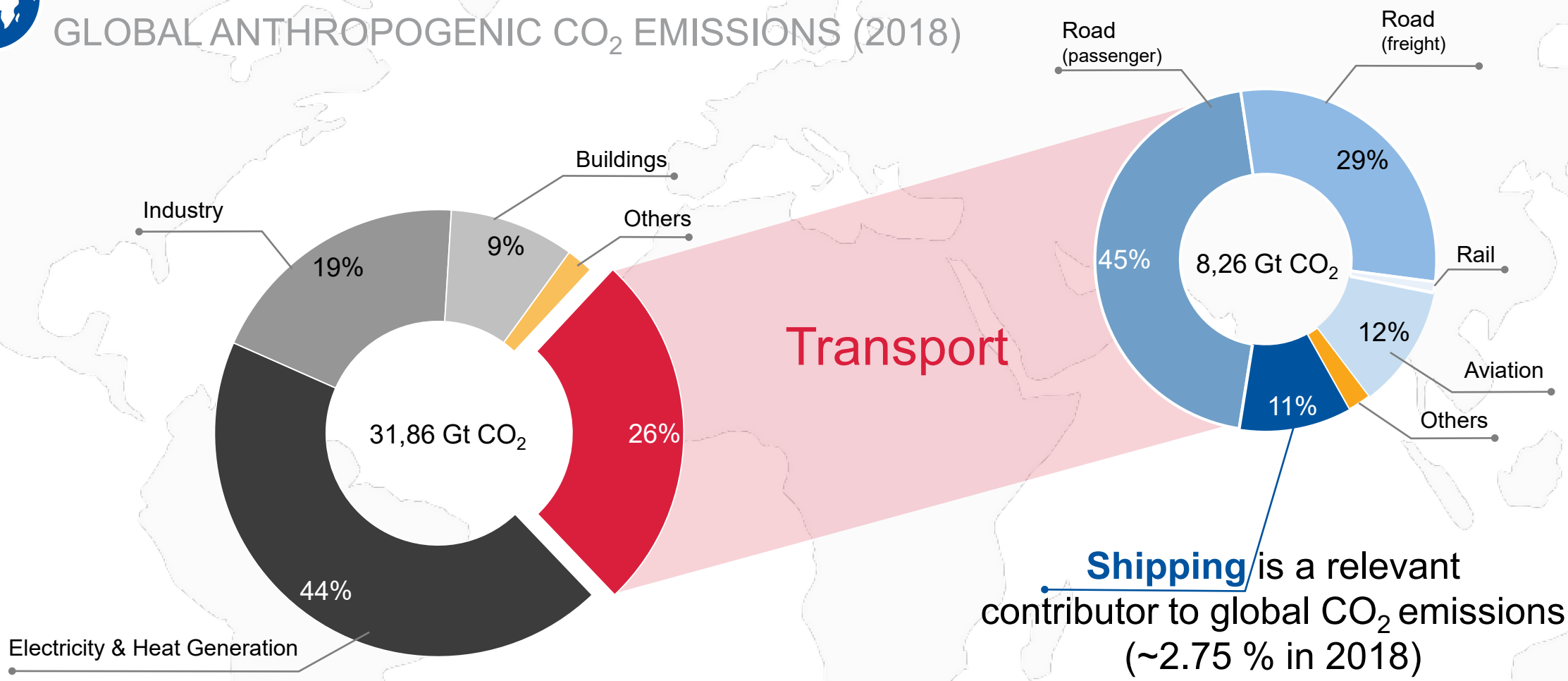
- Total GHG emission reduction
  - ~~80~~ -95 % until 2050
  - ~~40~~ -100 % until 2030
  - 20 % until 2020
- Additional Targets 2020
  - Ratio of renewable energy 20 %
  - Increase of energy efficiency 20 %
- Sector Targets 2050
  - Almost all electric power from regenerative sources (97 %)
  - Transport: GHG ~~-60~~ -85 % -90 %



Source: European Commission, 2050 low-carbon economy, Climate Action, 2018

Large Bore HS Engine Relevant Segments with Significant Contribution to Global CO_2 Emissions

GLOBAL ANTHROPOGENIC CO_2 EMISSIONS (2018)



Shipping is a relevant contributor to global CO_2 emissions (~2.75 % in 2018)

Source: IEA, ICCT

Large Bore HS Engine Relevant Segments with Significant Contribution to Global CO_2 Emissions

SELECTED REDUCTION INITIATIVES

International Maritime Organization targets

- IMO -50% GHG reduction target until 2050
- "Getting to Zero Coalition" – commercially viable deep-sea vessels with zero-CO_2 fuels until 2030

Market Push & Customer Pull

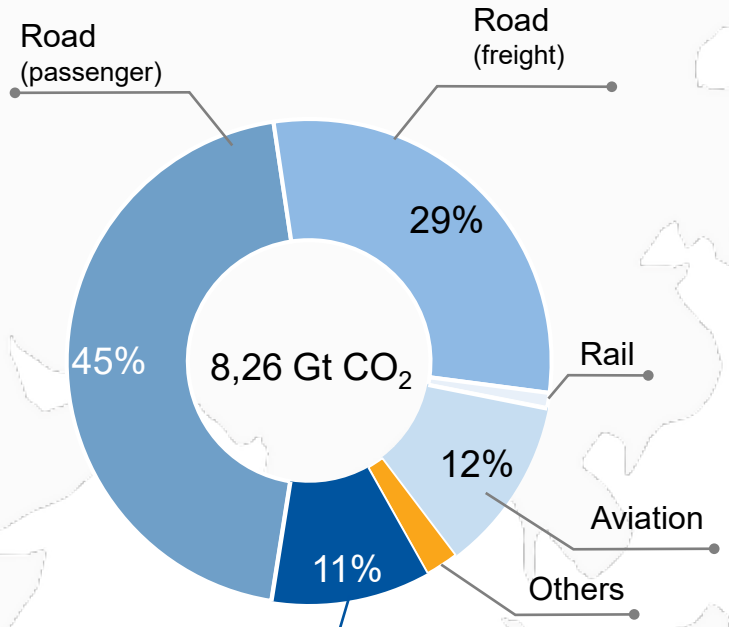
- Strong cost pressure from CO_2 permit prices
- OEM push for climate-neutral fuels (PtX, biofuels)
- Increasing customer demand for green energy

International Union of Railways targets

- Railway climate responsibility pledge signed by 34 members
- Commitment to become carbon neutral by 2050

Mine Operators & Investors

- More and more mining companies setting targets to reach net-zero emissions, mostly before 2050



Shipping is a relevant contributor to global CO_2 emissions (~2.75 % in 2018)

Source: IEA, ICCT

50% GHG Emission Reduction by 2050: Very Challenging for the Marine Industry

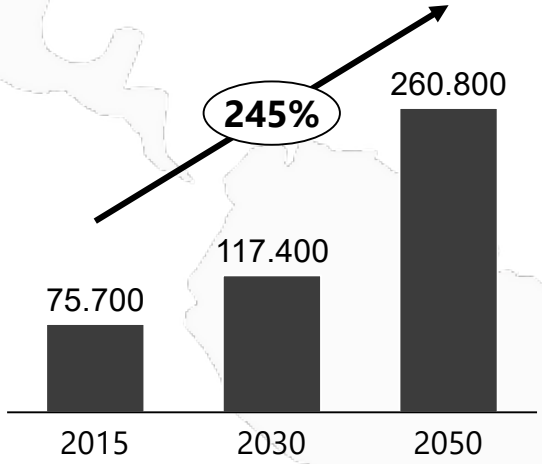
CO_2 WALK FOR SHIPPING

-50%

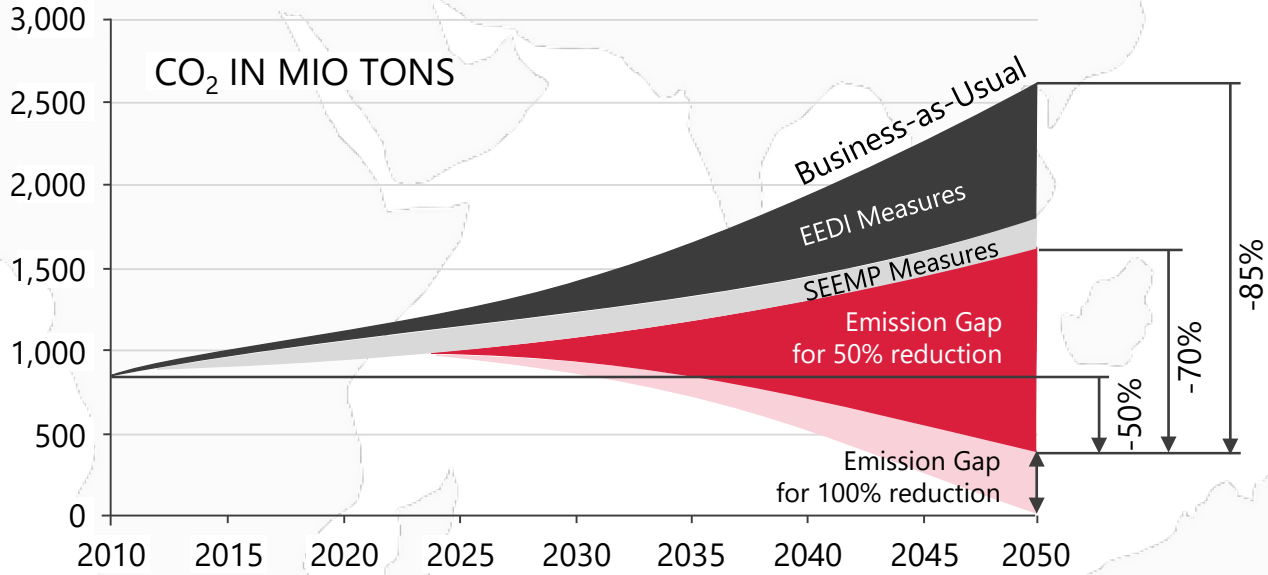
International Maritime Organization targets

- IMO -50% GHG reduction target until 2050
- "Getting to Zero Coalition" – commercially viable deep-sea vessels with zero-CO_2 fuels until 2030

GLOBAL SHIPPING IN BN TON-KM



High reduction of ~70% **on top of EEDI & SEEMP** required

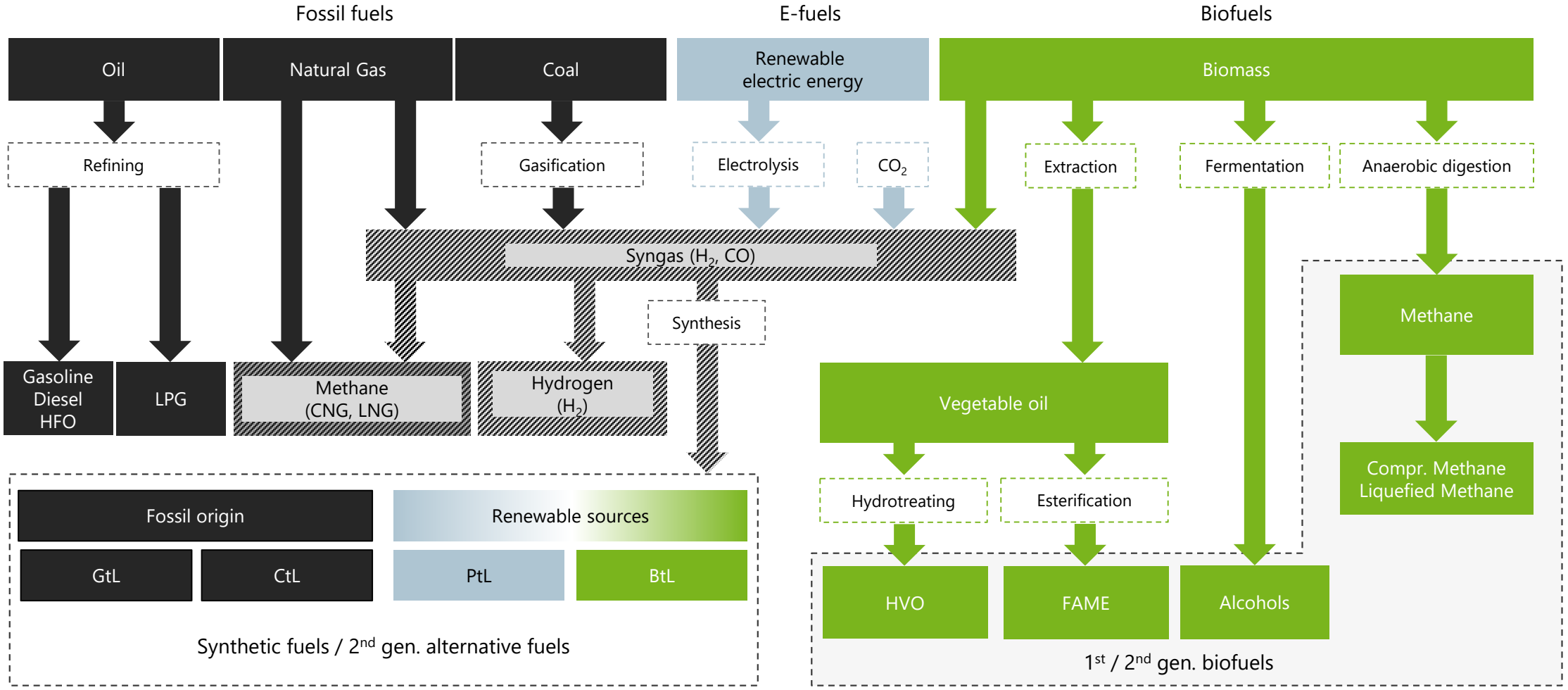


Target to cut global GHG Emissions by min 50 % **cannot be achieved with EEDI & SEEMP measures only**

» New technologies including **alternative fuels** are required

EEDI = Energy Efficiency Design Index, SEEMP = Ship Energy Efficiency Management Plan
Source: International Transport Forum (ITF), IMO

What fuels are we talking about?
Simplified Overview of Production Pathways for Different Fuel Types



Source: MTZ, TME, FEV

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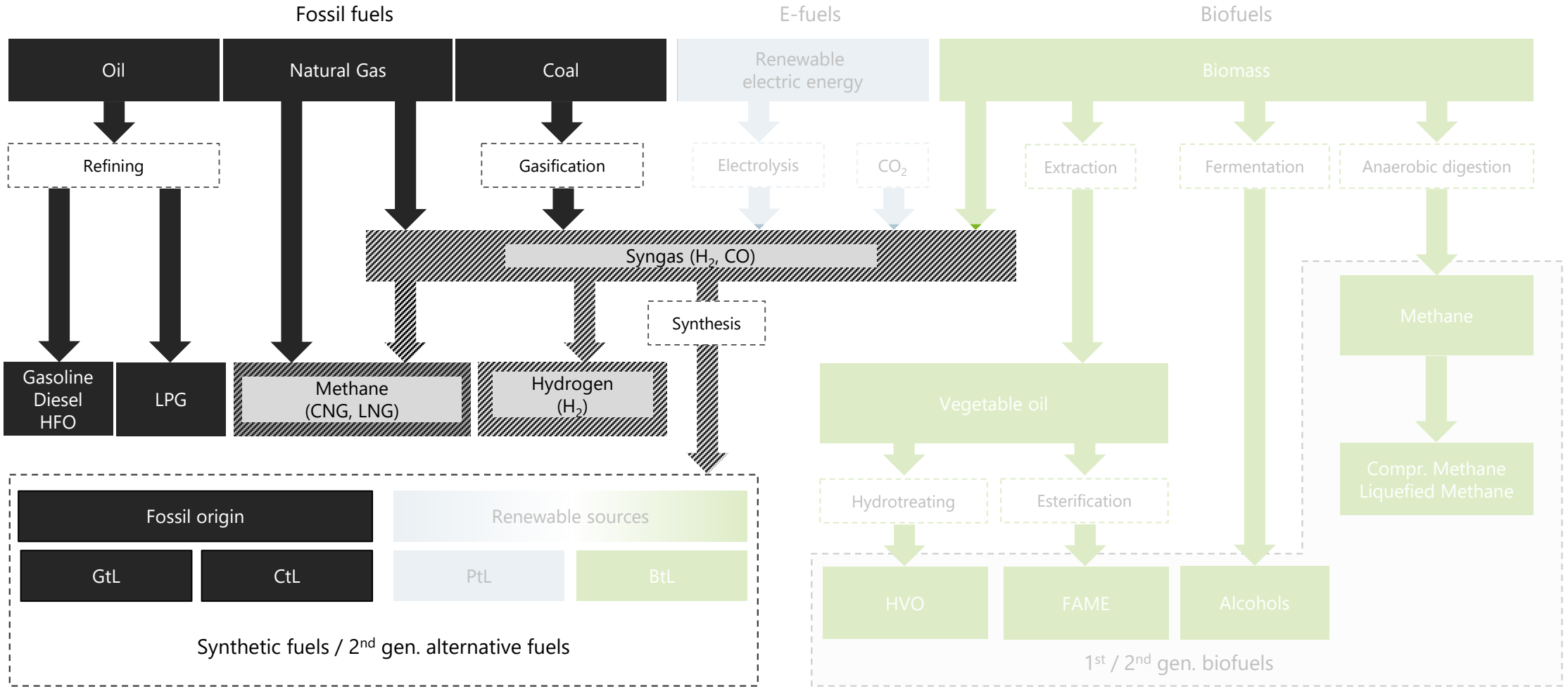

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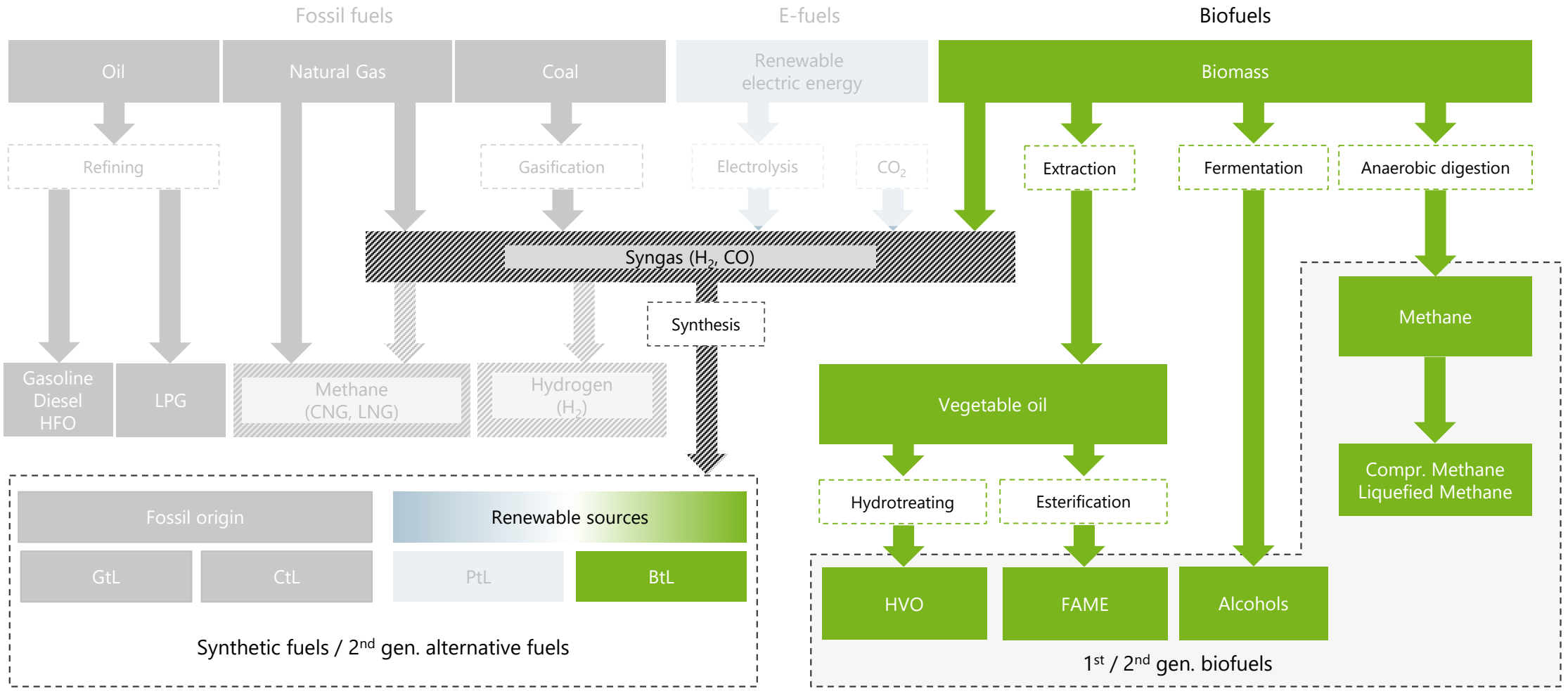

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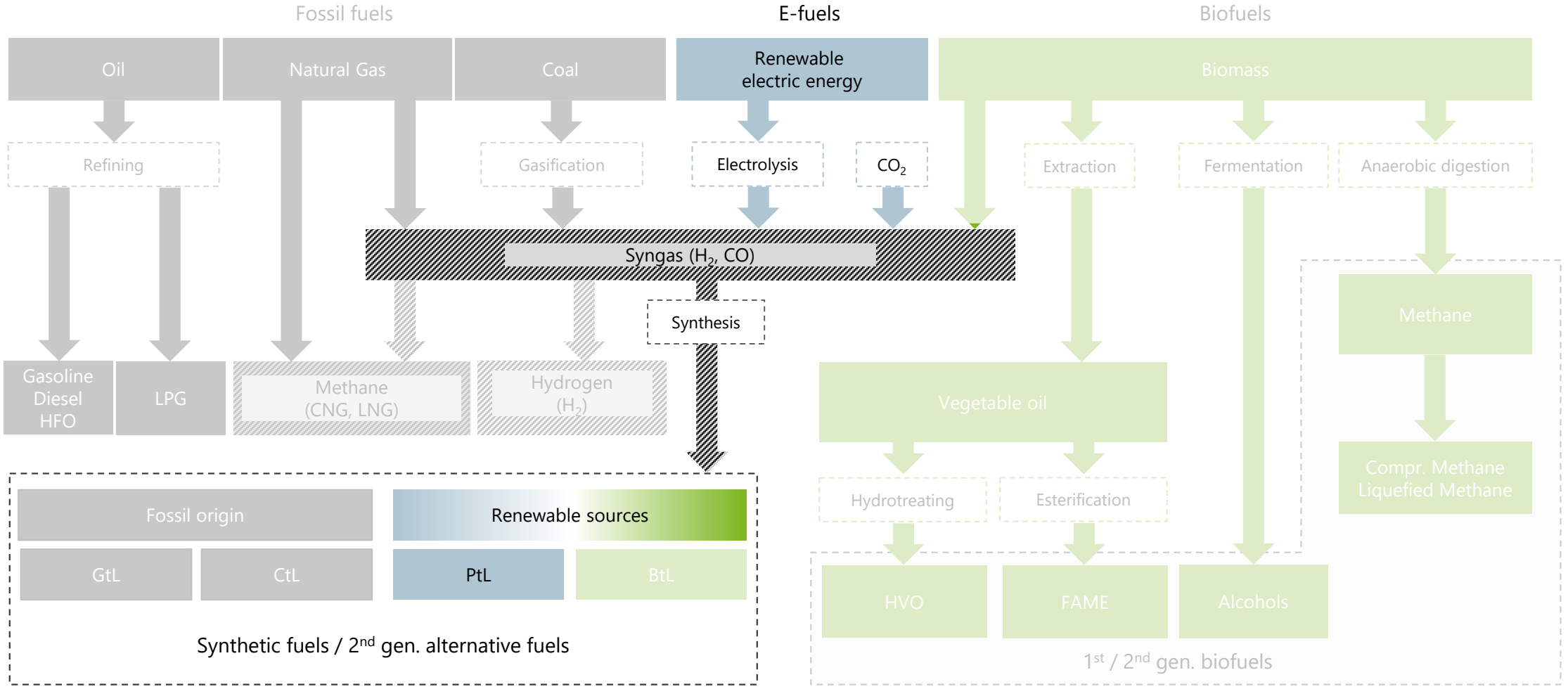
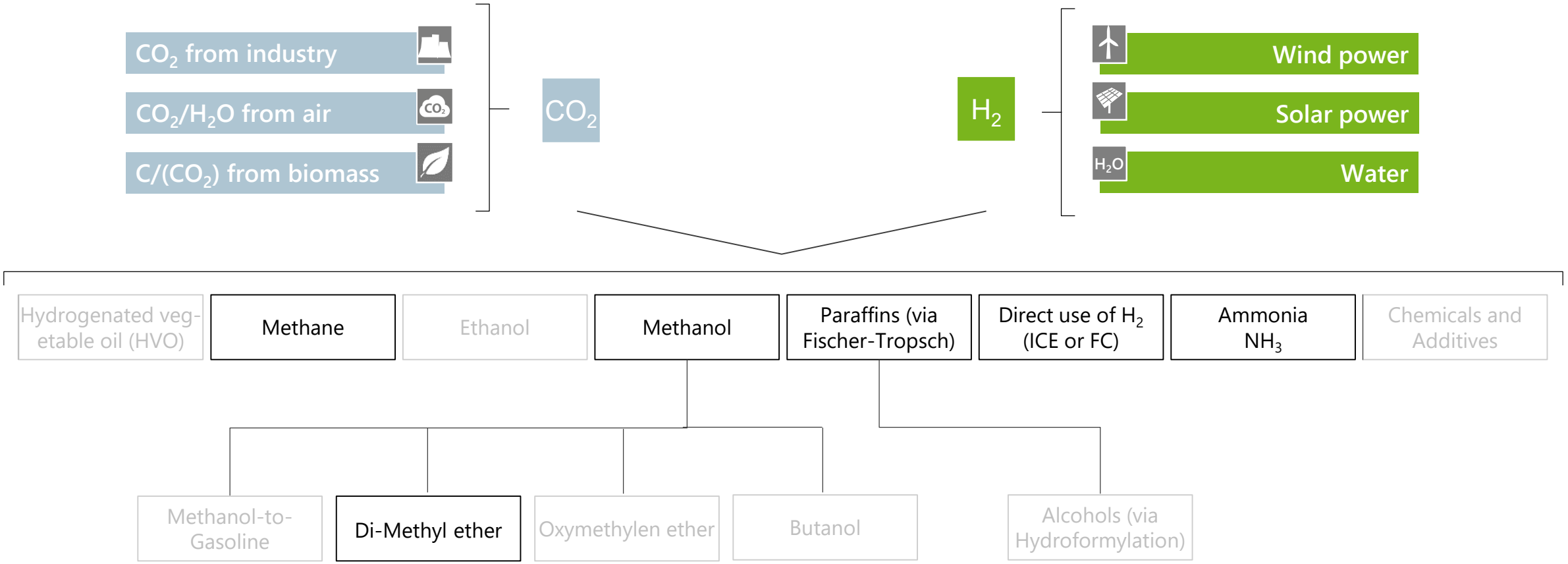


Source: MTZ, TME, FEV

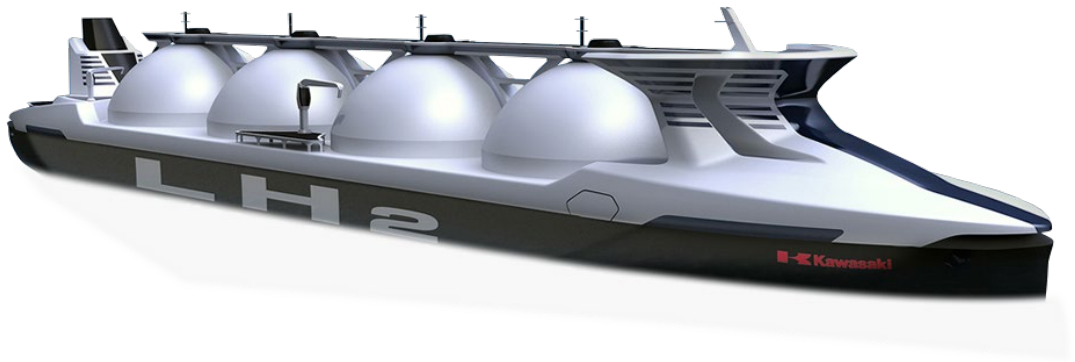
What fuels are we talking about?
Electricity Based Chemical Energy Carriers Show a Huge Variety



Hydrogen will be an important energy carrier of the future
First announcements for deep-sea hydrogen applications are being made

DEEP-SEA LIQUID HYDROGEN CARRIERS WILL USE HYDROGEN AS FUEL

H_2 POWERED CARGO SHIPS AND CARRIERS



- Liquid hydrogen carrier (160,000 m^3) planned by Kawasaki
- World's first zero-emission cargo ship "With Orca" – Powered by Nature shall go in operation in 2024 with a H_2 ICE

Source: Kawasaki

H_2 WILL BE A CENTRAL COMPONENT OF CO_2 NEUTRAL MOBILITY

- H_2 is the cheapest renewable chemical energy carrier
- H_2 is widely used already (mainly produced from nat. gas)
- (On-board) Fuel storage and distribution is challenging
- Available applications are very rare

Fuel costs	Availability	TRL fuel production	Fuel distribution	Compatibility with engines/ vehicles
+	o	+/o	-	-

- **Renewable H_2 will be available in large amounts**
- **Well-to-Wake: 0 g/CO_2**

Ammonia is an efficient hydrogen carrier and might become an interesting fuel for maritime applications

AMMONIA IS A PROBABLE ENERGY CARRIER FOR IMPORTING RENEWABLE ENERGY TO EUROPE

AMMONIA WAS USED AS FUEL ALREADY…

- Ammonia (NH_3) is inherently CO_2-free
- Ammonia is reluctant to ignition

MAJOR REDUCTION IN ENGINE OUT CO2

- N_2 provision is easier than CO_2 capturing resulting in cost benefits compared to other e-fuels
- Established product, mainly for fertilizers
- Handling and infrastructure is more complex amongst others due to high toxicity
- Initial full-engine tests just conducted

Fuel costs	Availability	TRL fuel production	Fuel distribution	Compatibility with engines/ vehicles
+	o/-	-	-	-

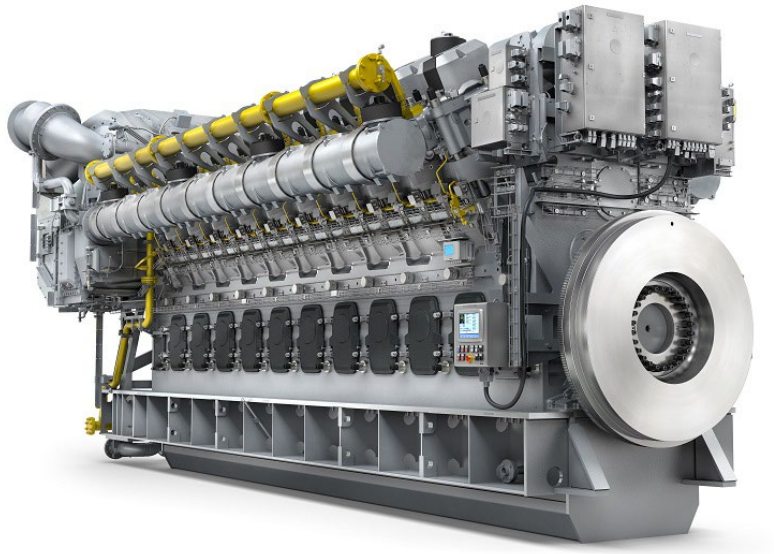
- **Ammonia is a future fuel for large bore applications**

Source: bigwheel

Natural gas (methane) enables a CO_2-reduction of up to 15% compared to Diesel – but also requires new combustion system

FINANCIAL AND LEGISLATIVE INCENTIVES FOR NATURAL GAS ENGINES

GAS ENGINES HAVE DIESEL-LIKE PERFORMANCE



- CNG and LNG engines in series production already for trucks, stationary power plants, and maritime applications
- Emissions and performance comparable to Euro VI

Source: MAN ES

GAS GRID IS ESTABLISHED FOR STORAGE AND DISTRIBUTION

- Natural gas (from fossil) is a cost-competitive fuel
- Biomethane and e-methane (Sabatier) are CO_2 neutral
- Additional hardware costs are often compensated by incentives
- Natural gas grid well established worldwide

Fuel costs	Availability	TRL fuel production	Fuel distribution	Compatibility with engines/ vehicles
+(/o)*	**+(/o/-)***	**+(/o)***	**+/o**	**o/-**

* From renewable sources

- **Natural gas is the only alternative fuel available on short-term in large scale**

Methanol is an already established platform molecule for the chemical industry / fuel production and an excellent fuel!

METHANOL IS A PROBABLE ENERGY CARRIER FOR IMPORTING RENEWABLE ENERGY TO EUROPE

METHANOL IS USED AS FUEL ALREADY

- Methanol used as fuel in all applications from passenger car to deep-see vessels already
- Methanol is sulphur free, ultra-low PM emissions
- Methanol is available in >100 harbors around the world

PROMISING ALTERNATIVE FOR SI AND CI ENGINES

- Methanol is easy to produce and liquid energy carrier
- Established product in chemical industry
- Handling and infrastructure is considered to be complex
- Available applications currently limited, but push from shipping agents and legislation, particularly in Asia

Fuel costs	Availability	TRL	Fuel distribution	Compatibility with engines/ vehicles
+(/o)	**+/o**	**+**	**+**	**o/-**

- **Methanol utilization in transport will significantly rise**

Fischer-Tropsch fuels can be blended into the infrastructure and engines almost without limitation

FUEL CHARACTERISTICS CAN BE TAILORED TO BE COMPLIANT TO CURRENT FUEL STANDARDS

FISCHER-TROPSCH ARE CLEAN BURNING FUELS

- Drop-In type fuel for all Diesel-engine applications in the world
- FT-fuels can be tailored to meet very high quality Diesel fuel norms such as EN590 and EN15940

FISCHER-TROPSCH IS WELL KNOWN TECHNOLOGY

- FT is more energy intense and costly to produce
- Technology is robust and widely known
- FT can be used in existing vehicle fleet and infrastructure
- Neat FT as fuel for airborne applications

Fuel costs	Availability	TRL	Fuel distribution	Compatibility with engines/ vehicles
o/-	**+/o**	**+/o**	**+**	**+**

- **Clean fuel for all applications relying on worldwide available infrastructure**

Source: MAN

Different Technology Options to Achieve CO_2 Targets in the Marine Sector

TECHNOLOGY PATHS

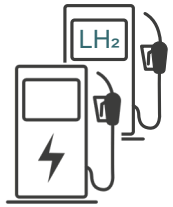
» NOT EXHAUSTIVE

	Zero CO_2 Potential[1)]	Zero Pollutant Potential
Engine Optimization	No	No
Hybrid	No	(Yes)
LNG / LPG (fossil)	No	No
PtX/BtX (diesel, LNG, etc.)	Yes (WtW)	No
Ammonia Engine	Yes (TtW)	No
Hydrogen Engine	Yes (TtW)	No
Battery Electric	Yes	Yes
Hydrogen Fuel Cell	Yes	Yes
Ammonia Fuel Cell	Yes	Yes
Sails	(Yes)	(Yes)

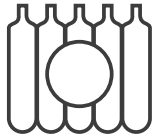
Engine Optimization, Hybrid & LNG/LPG are an important step, but **not enough** to reach 2030 targets

» **New energy carriers** will be required!

KEY CHALLENGES



INFRA-STRUCTURE



ENERGY STORAGE

NO JOINT FUEL STRATEGY

COSTS

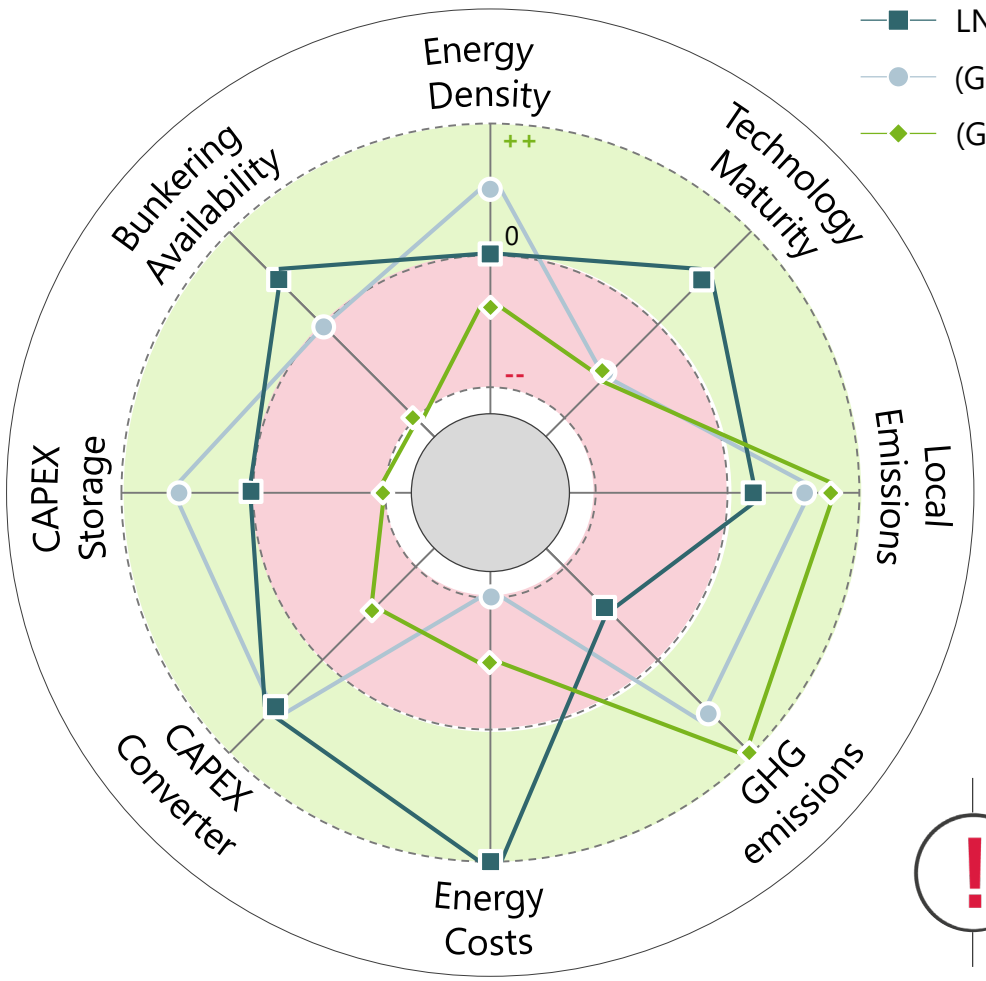
» We expect **different technology strategies**; Key challenge:
Find the right trade-off between application fit, infrastructure availability and costs

1) Zero-CO_2 potential "yes" based on the assumption that fuel / energy carrier is produced from renewables sources

It's important to find the right compromise between costs, package, and sustainability: H_2, CNG/LNG and Methanol are interesting solutions

2020 MARINE ALTERNATIVE FUELS EVALUATION (BASED ON DNV GL)

» NOT EXHAUSTIVE



RELEVANCE OF CRITERIA

	Commercial	Pleasure	Power Gen. (cont./prime)	Power Gen. (backup)	Rail
Energy density	●	◑	○	○	◑
Local emissions	◔	◕	◕	○	◕
GHG emissions	◕	◕	◕	○	◕
Energy costs	●	◔	●	○	●
CAPEX converter	◑	◑	◔	●	○
CAPEX storage	◔	◔	◔	●	◔
Bunkering availability	◕	◔	○	○	○

● High importance ◑ Medium importance ○ Low importance

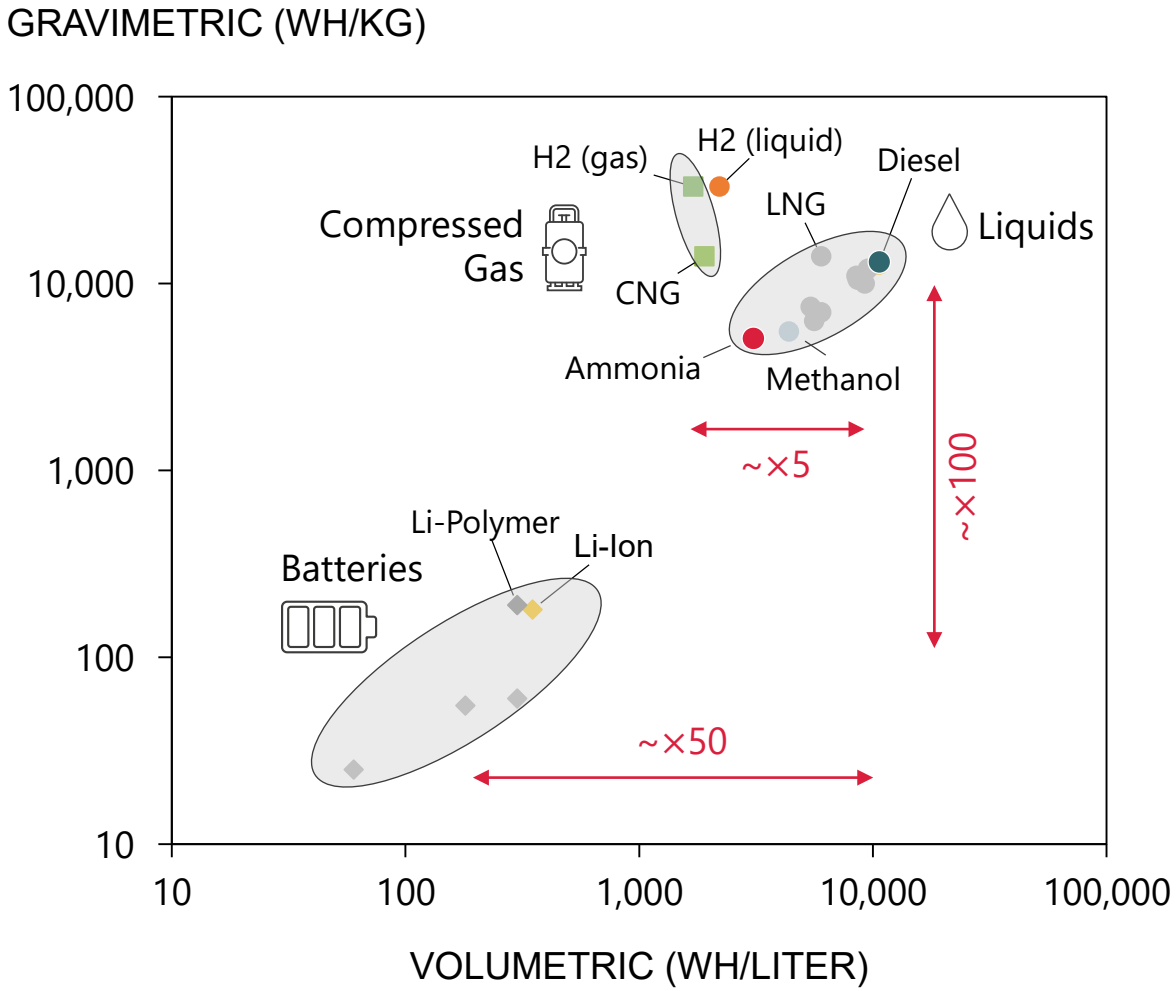
Even within application categories there are use-case specific criteria, e.g.

- Fuel cells for on-board electricity
- Hybrid for tugboats

» **No "one-fits-all" solution**
Find the right solution for your specific use case

Key Challenge for Marine Applications: Energy Storage

ENERGY DENSITY COMPARISON

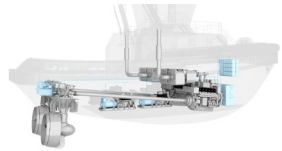


- Fully electric propulsion has a **significantly larger energy storage**
- **High costs** for applications that need long range
- Electric propulsion only suited for **selected use cases**

BATTERY-ELECTRIC USE CASES

Ferries with plannable routes

Hybrid or electric yachts (short routes)



Hybrid tugboats (short, but intense)

Electricity alone is **no replacement** for high-speed engines in most applications

Efficient energy storage is key for commercial use ⟫ **Alternative fuels** like H_2, Ammonia or Methanol **with drawbacks against diesel**

Pictures: Poland@Sea; EST-Floattech; MAN Energy Solutions

What fuel to choose for high-speed applications?
Summary of fuel characteristics

2020 MARINE ALTERNATIVE FUELS EVALUATION (BASED ON DNV GL)

» NOT EXHAUSTIVE

	FUEL TYPE					
	Hydrogen	Methane (CNG/LNG)	Methanol	Di-Methyl ether	Ammonia	Fischer-Tropsch
Volumetric energy density	◔	◔	◑	◕	◔	●
Local emissions	●	◕	◕	◕	◕	◑
GHG emissions renewable	●	◕	◕	◕	◕	◕
Energy costs	●	◑	◕	◕	◕	◔
CAPEX converter*	◕ / ◔	◕	◕	◕	◑	●
CAPEX storage	◔	◕	◕	◕	◑	●
Bunkering availability	◔	◑	◑	◔	◑	●

* For H_2: ICE / FC

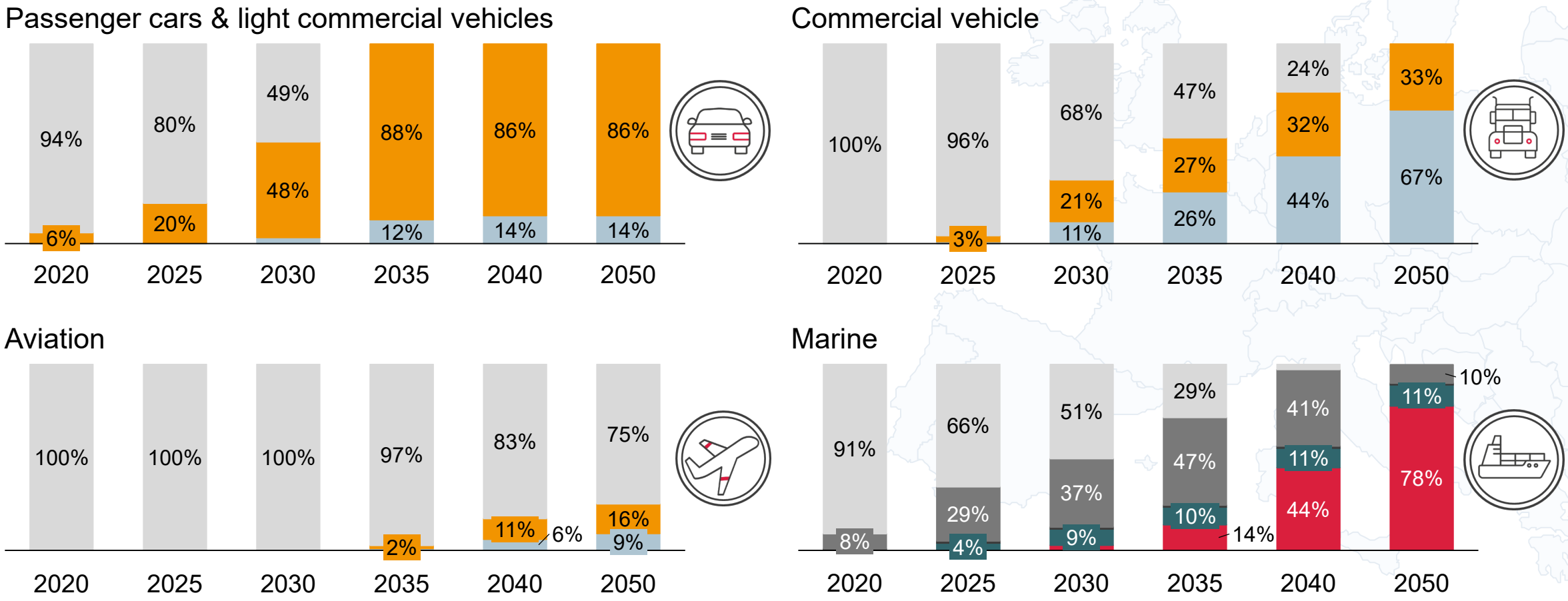
● Very good/positive/beneficial

◔ Very bad/negative/not beneficial

» **No "one-fits-all" solution**
Find the right solution for your specific use case

Today, the Transport Sectors Share the Combustion of Liquid Energy Carrier This Will Change Drastically in the Future!

SALES FORECAST

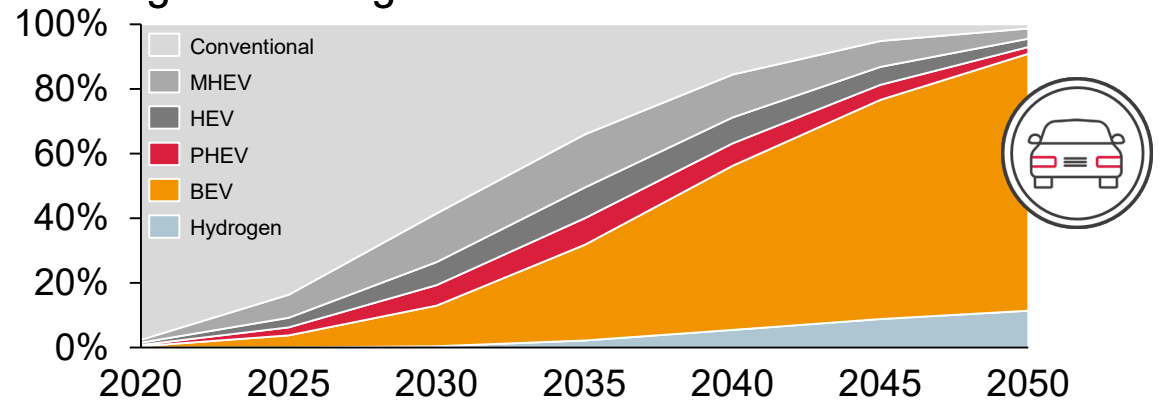


Source: FEV CONSULTING

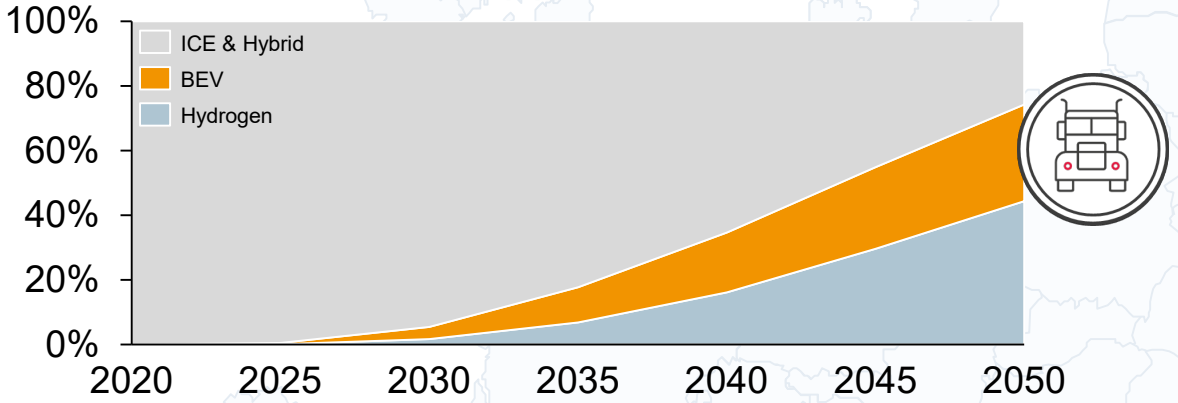
Today, the Transport Sectors Share the Combustion of Liquid Energy Carrier This Will Change Drastically in the Future!

SALES FORECAST

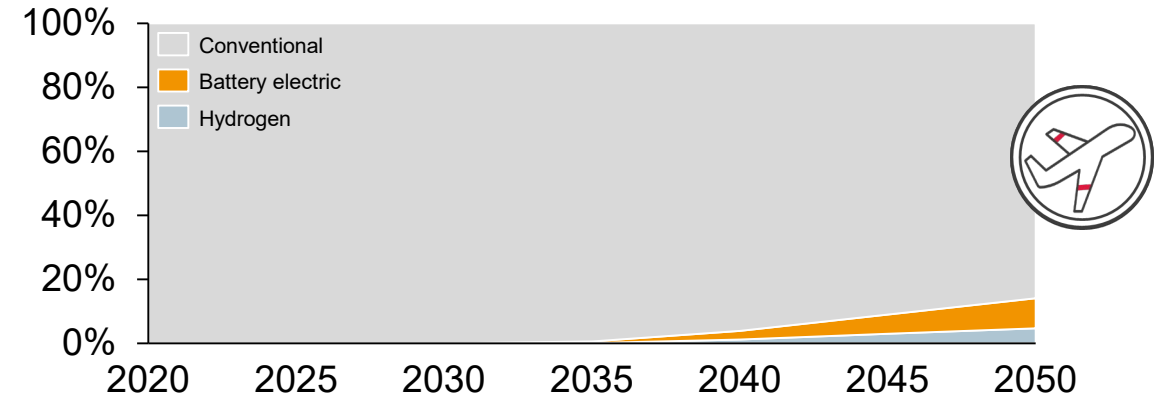
Passenger cars & light commercial vehicles



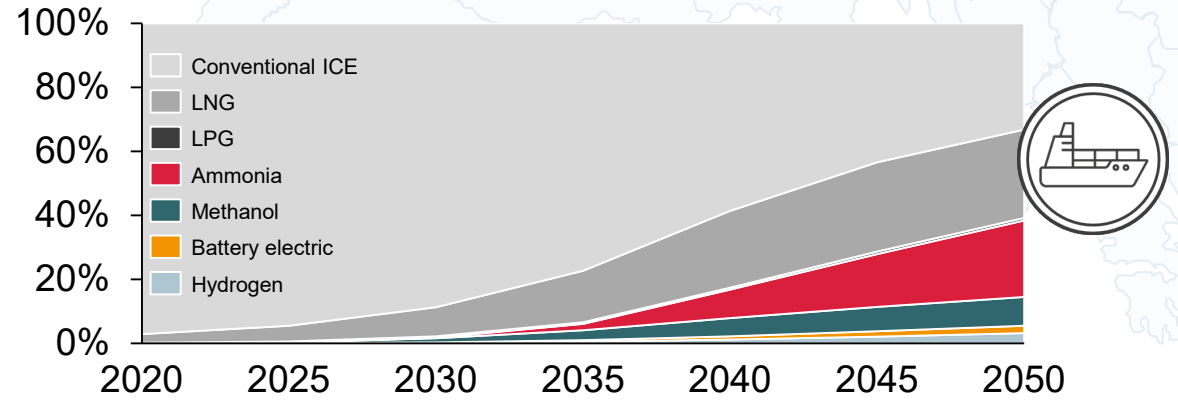
Commercial vehicle



Aviation



Marine



Source: FEV CONSULTING

URGENT APPEAL

Liquid energy carrier based on renewable resources have to* make a significant contribution to climate change mitigation!

* (be allowed to)

- Multiple drop-in fuel options are available today already
- Recognition of CO_2-neutral fuels as a climate measure required
- Energy import and sector coupling have to be taken into account
- Discussion on “most efficient” synthesis pathways and “costs” is useless, because all pathways are required

→ Decisions have to be made today to ensure significant amounts in 2050

→ Scale-up of known processes has to start today

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Public Outreach

HOMEPAGE – NEWSLETTER – SOCIAL MEDIA

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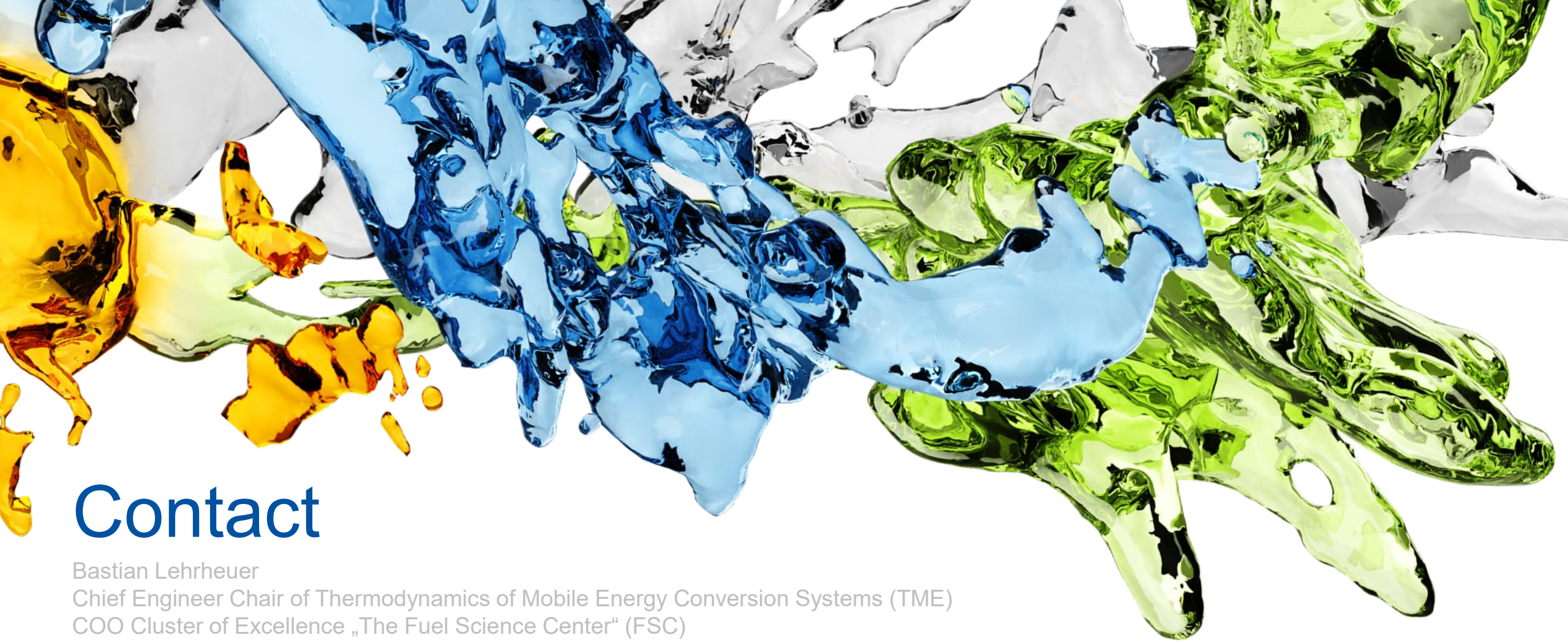

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