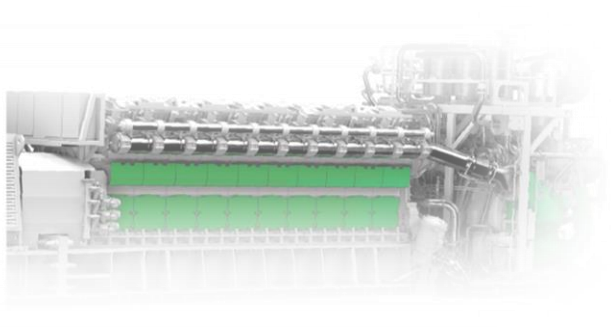
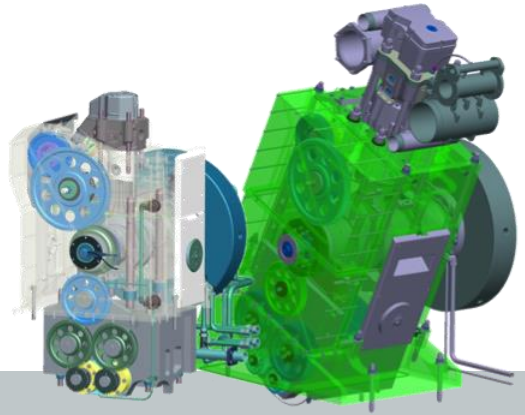
Large Engines Competence Center

# E-Fuels | The Key to Climate Neutrality in the Large Engine Area



January 18, 2023 • Andreas Wimmer

# Contents

## **E-Fuels** | The Key to Climate Neutrality in the Large Engine Area

**1**

### Introduction

➔ Large engine applications
➔ Short introduction to the LEC

**2**

### Future trends and challenges

➔ GHG reduction potential
➔ Future energy and transportation demand
➔ Current fuels for large engines

**3**

### Green Transformation

➔ Pathways to green transportation
➔ Power plant of the future
➔ E-fuels for large engine applications

**4**

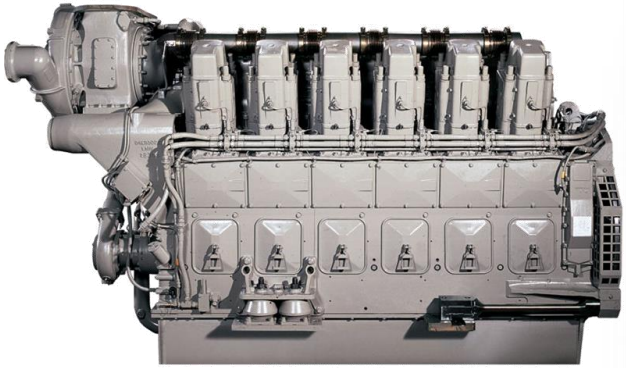
### Summary

➔ Future role of large engines

# Application Example - Mining Truck

| | |
|---|---|
| Engine | **MTU DD 20V 4000** |
| Displacement | 90 liters |
| Bore x Stroke | 165 x 210mm |
| Power output | 2,720 kW |
| Engine speed | 1800 rpm |
| Torque | 14.457 Nm |
| Transmission | Diesel-electric (System Siemens/Liebherr) |
| Max. operating weight | 652.5t |
| Volume of dump body | 220m$^3$ |
| Fuel consumption | 4,176 liters Diesel per day |

# Application Example - Locomotive

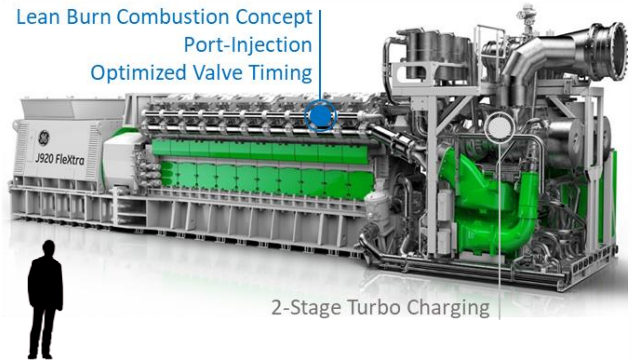


| | |
|---|---|
| Engine | **GEVO V12** |
| Displacement | 188.5 liters |
| Bore x Stroke | 250 x 320 mm |
| Power output | 3,360 kW |
| Engine speed | 1,050 rpm |
| Weight | 19.5 t |

# Application Example – Marine

| | |
|---|---|
| Engine | **WinGD RTFlex** |
| Number of cylinders | 6 to 14 cylinders |
| Bore x Stroke | 960 x 2,500 mm |
| Engine speed | 22 – 120 rpm |
| Power | 34,320 – 80,080 kW total |
| Torque | Up to **7,603,850 Nm** @ 102 rpm |
| Fuel consumption | up to 250 tons of fuel per day |
| Crankshaft weight | 300 tons |

# Application Example – Power Generation




**Performance Data**

| | |
|---|---|
| Engine Speed | 1000 rpm (50 Hz) |
| Electrical Output | 9,500 kW |
| Electrical Efficiency | **up to 50%** |
| Heat Rate | 7,392 kJ/kWh |
| Thermal Output | 8,100 $kW_{th}$ |
| Total Efficiency | **> 90%** |

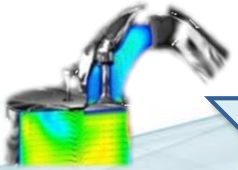


**Source:** www.stadtwerke-kiel.de/ueber-uns/kuestenkraftwerk

# LEC History

94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23

- 94: Establishment LE Research @ TU Graz
- 02: Foundation LLC ($K_{IND}$)
- 02: Trademark LEC
- 02: New Facilities @ Campus Inffeldgasse
- 10: Transfer TU Graz
- 15: Foundation LEC GmbH (LLC)
- 15: Start **LEC EvoLET**
- 21: **LEC GETS**
- 21: Proposal 2023+



CD Laboratory*

LE Research

**LEC $K_{IND}$****
(Kompetenzzentrum für umweltfreundliche Stationärmotoren GmbH)

LE Research @ TU Graz

LEC / TU Graz

**COMET K1 Center**
**LEC EvoLET**

**COMET Module**
(2020-2023)

**FP 1**
(2015-2018)

**FP 2**
(2019-2022)



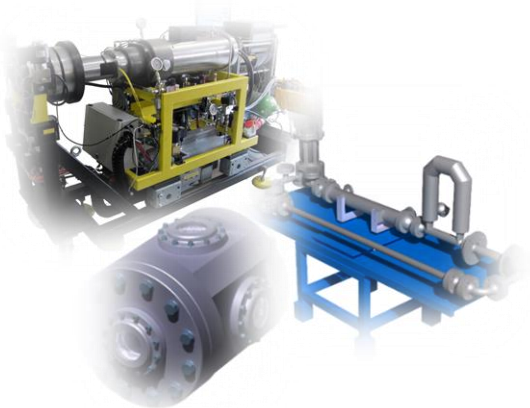
)* Christian Doppler Laboratory
)** Industrial Competence Center
)*** Research Company @ TU Graz

# LEC Infrastructure

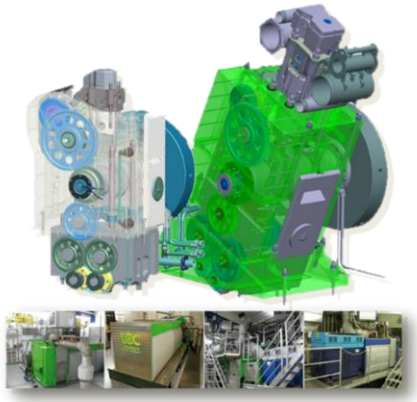
**LEC Laboratory at the Graz University of Technology Campus**
(Suitable for a wide range of fuels such as $H_2$, CO, MeOH, ammonia, etc. and all types of conventional fuels)

Test Rig Investigations → SCE Experiments → MCE Experiments → System Validation

**IIC Laboratory**
(Injection, Ignition and Combustion)

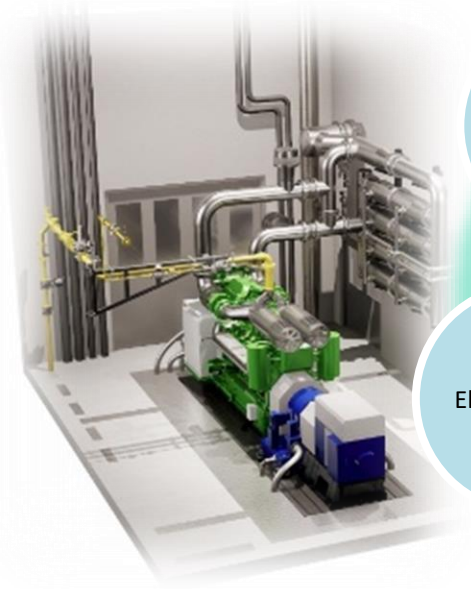


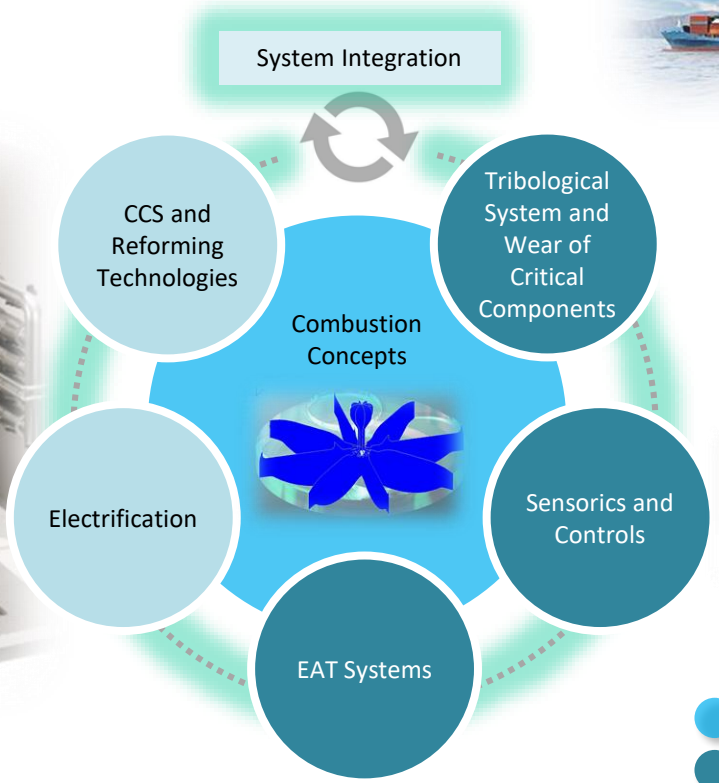
**4 SCE Test Beds**
(up to 900 kW)

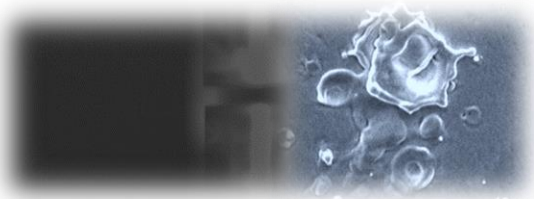


**MCE and System Test Bed**
(up to 3,500 kW)

# LEC Research Focus



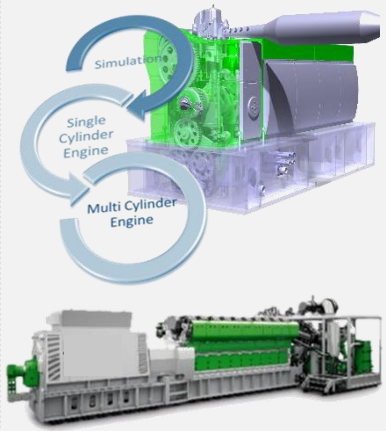


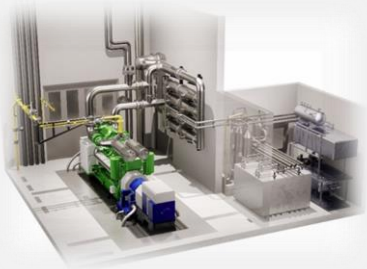



- Key competence – comprehensive consideration at all levels
- Comprehensive consideration at certain levels
- Primarily at system level

# LEC Research Areas

Technology Areas



Digitalization Areas as Enabler

Data Analytics and Controls

Simulation-based Development

Combustion and Fuels

Engine Components and Sensorics

Integrated Systems

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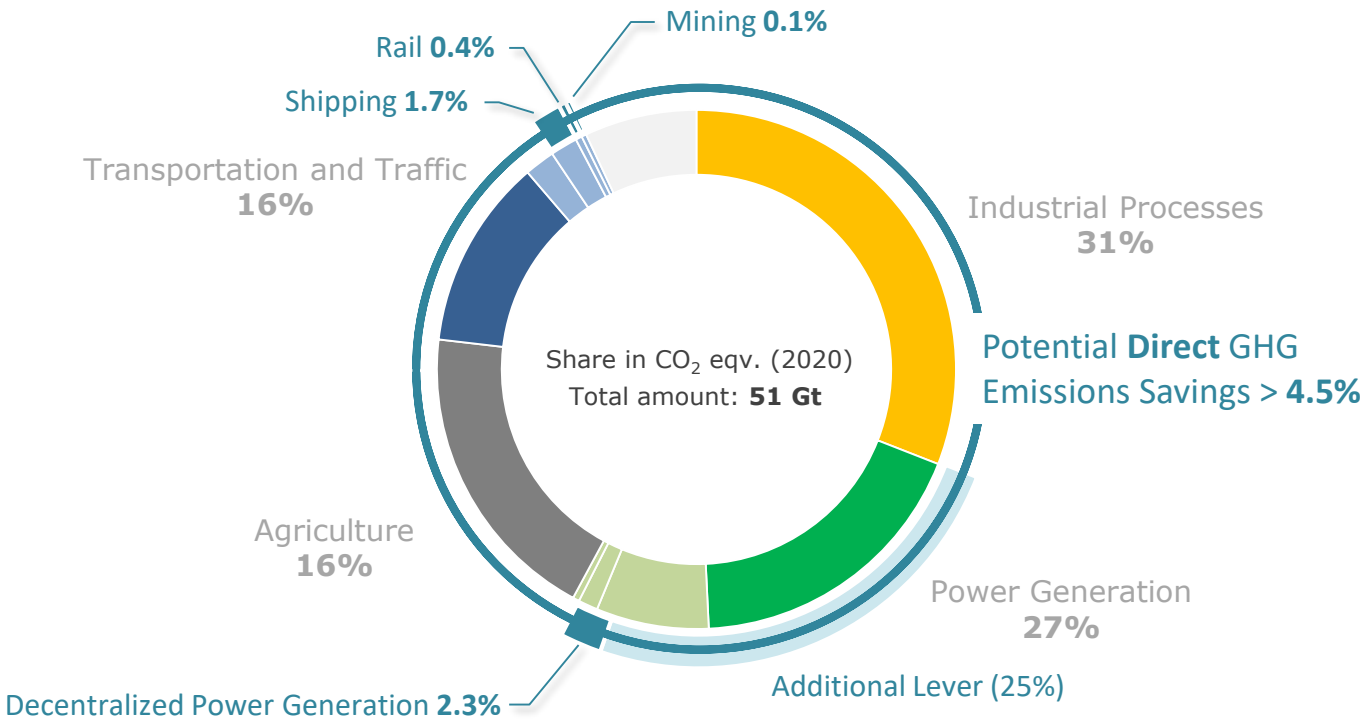
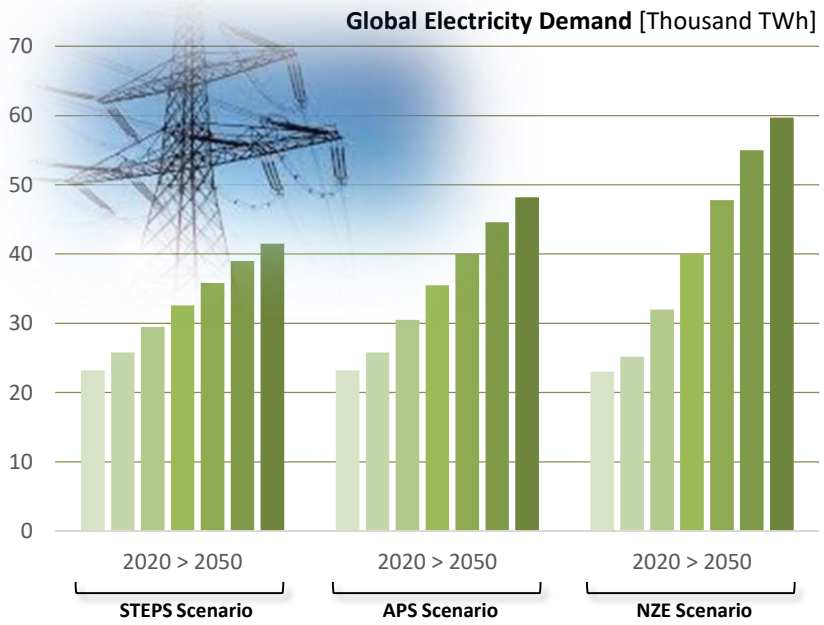
# GHG Reduction Potential | Large Engine Area



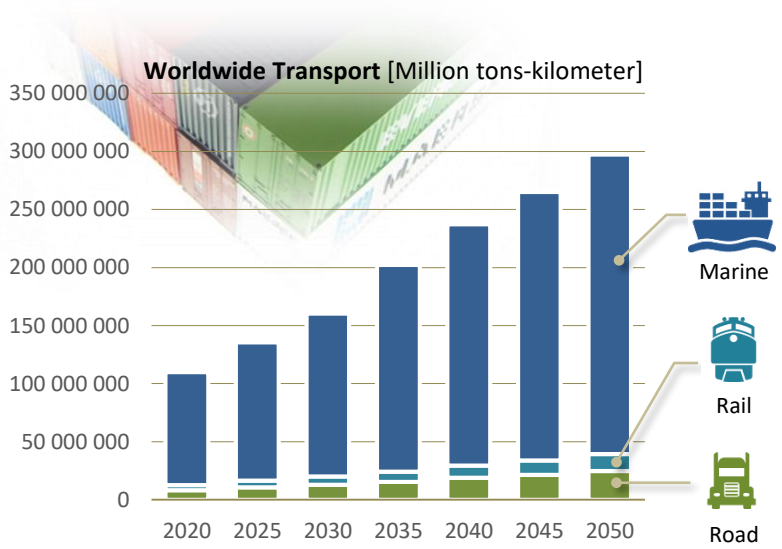



**Sources:** https://ourworldindata.org/emissions-by-sector#energy-electricity-heat-and-transport-73-2
BP Statistical Review of World Energy 2020
LEC research

# Increasing Demand | Power Generation and Transport

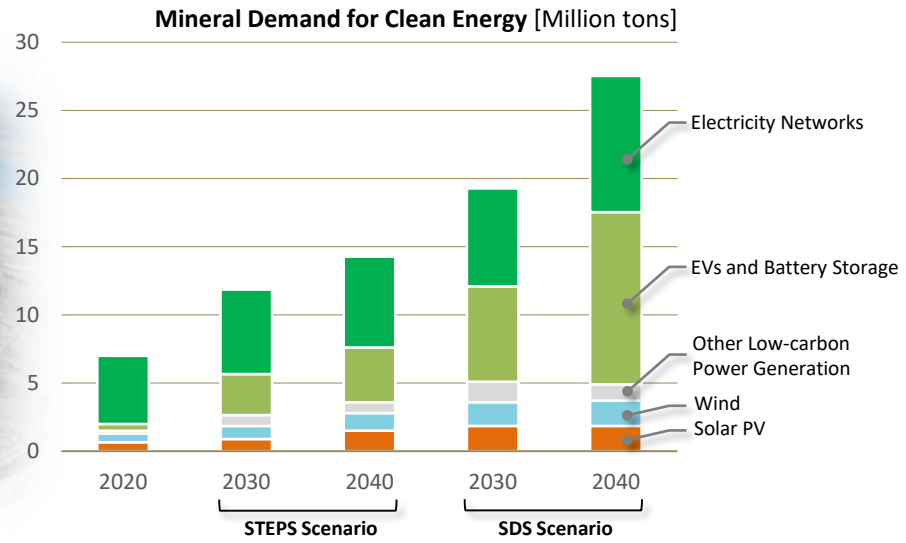



**Source:** IEA World Energy Outlook 2021



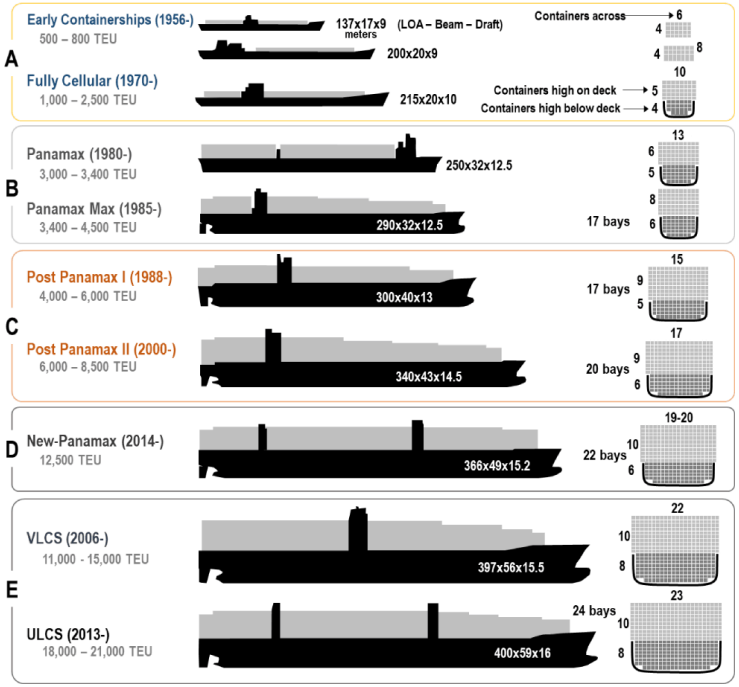

**Source:** ITF International Transport Forum 2021

# Increasing Demand for Rare Materials




**Source:** IEA World Energy Outlook Special Report 2019

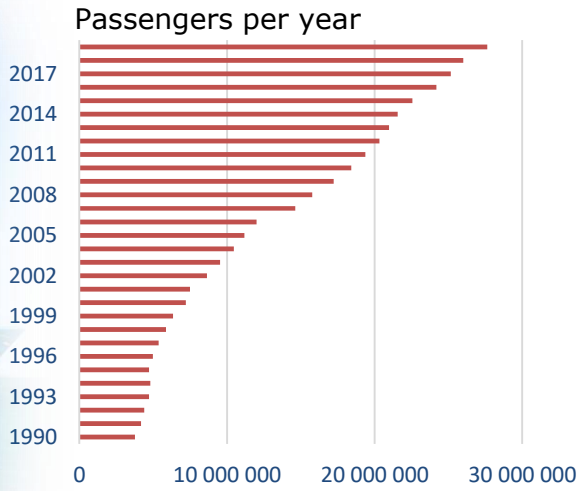
# Increasing Size of Container Vessels





https://transportgeography.org/contents/chapter5/maritime-transportation/evolution-containerships-classes/

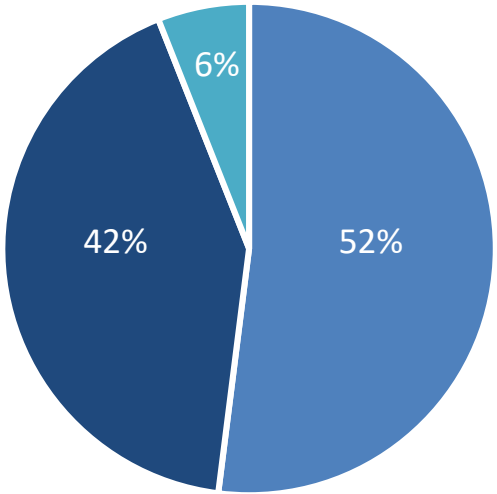
# Boom in the Cruise Industry


https://www.kreuzfahrtklick.de/blog/kampf-der-giganten-das-sind-die-10-grossten-kreuzfahrtschiffe-der-welt

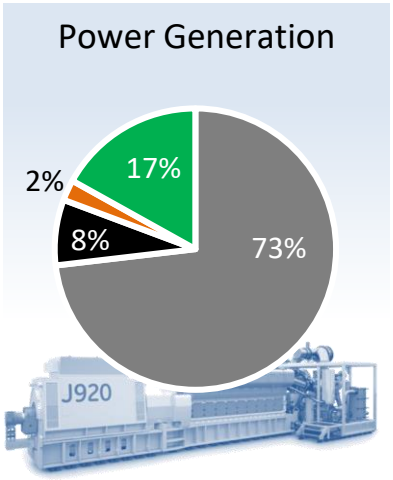
# Fuels for Large Engines

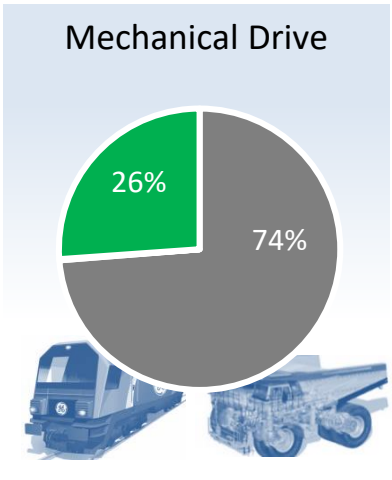
## Applications

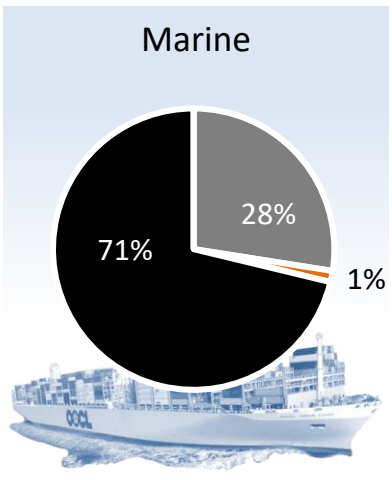



Mechanical Drive
Power Generation
Marine

## Fuels



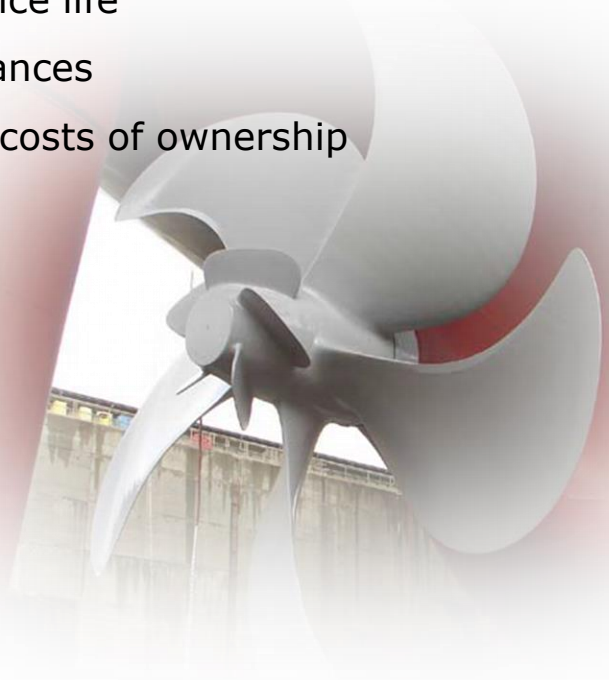

NG
Dual Fuel (NG/Diesel)
Diesel
HFO



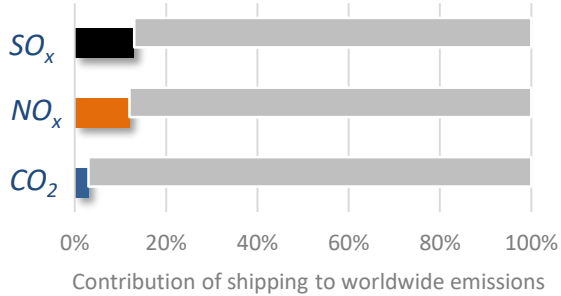
Engines > 1MW (Average values 2010 – 2016)
**Source:** Diesel & Gas Turbine Worldwide 2011 - 2017

# ICEs for Marine Propulsion

- ✚ Proven and extremely reliable technology
- ✚ Long service life
- ✚ Long distances
- ✚ Low total costs of ownership
- ✚ …



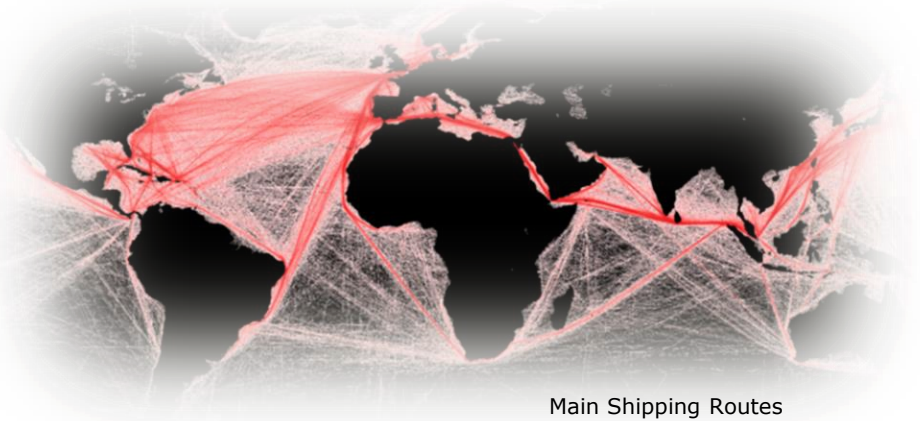
- – Emissions




*"Carnival cruise ships more polluting than all of Europe's cars"*
*(Financial Times, June 2019)*

*"We need to bring forward the ban on internal combustion engines"*
*(Forbes, September 2020)*

# Shipping Emissions | International Regulations



Main Shipping Routes

1

**Emission Control Areas (ECAs)**


IMO

**October 2016**

2 **Global Sulphur Cap 2020**

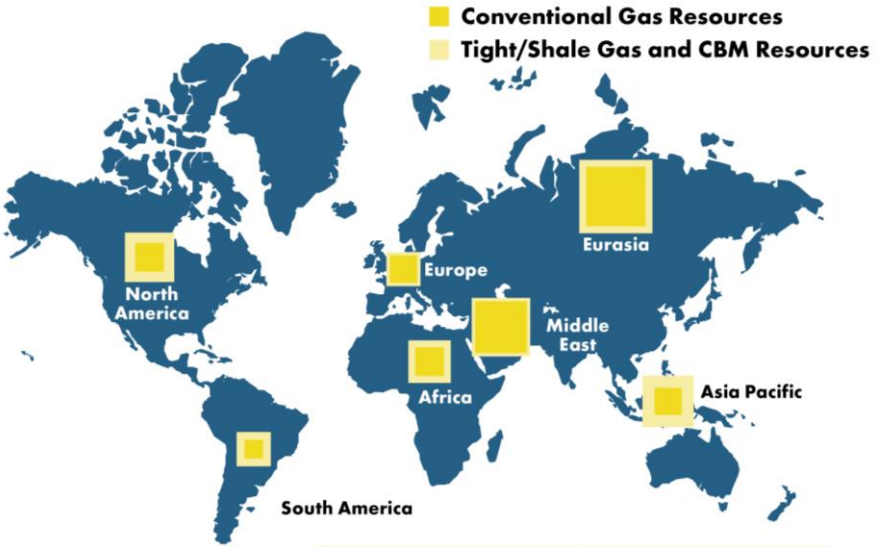
… the decision to implement a global sulphur limit of 0.50% m/m (mass/mass) in 2020 …

**April 2018**

3 **GHG Target 2050**

… to reduce the total annual GHG emissions by at least 50% by 2050 compared to 2008 …

# Dual Fuel Engines



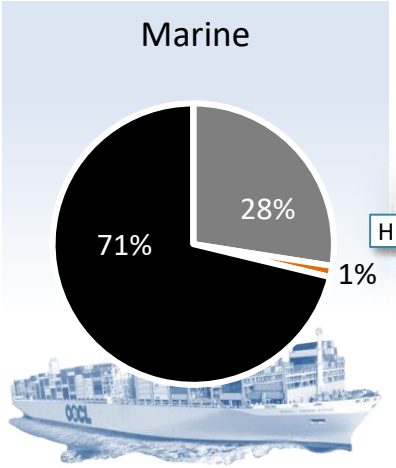

| | Remaining recoverable resources (tcm, trillion cubic meter) | Equivalent in years of current production (years) |
|---|---|---|
| Conventional Gas | 404.5 | 130 |
| Tight / Shale Gas and CBM Resources | 380.5 | 123 |
| **Total** | **785** | **253** |

Source: IEA World Energy Outlook, WoodMackenzie, Shell Interpretation

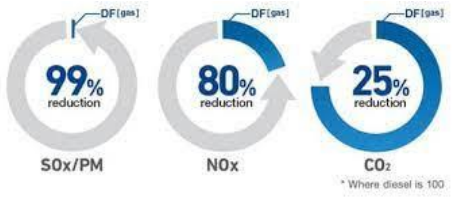
## LNG – Liquefied Natural Gas

- LNG is transported in specifically designed tanks integral to LNG tankers at -163 °C / 1 bar
- Boil-Off Gas (BOG) is used in dual-fuel marine diesel engines
- The technology enables the engine to be operated on either natural gas or Diesel/HFO
- Switching between fuels can take place seamlessly during operation, without loss of power or speed
- This ensures safety and continuous installation operability

# Dual Fuel Engines | Dual Fuel Engines (NG/Diesel)





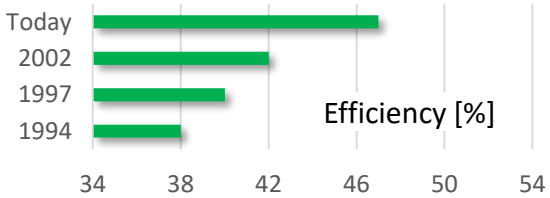


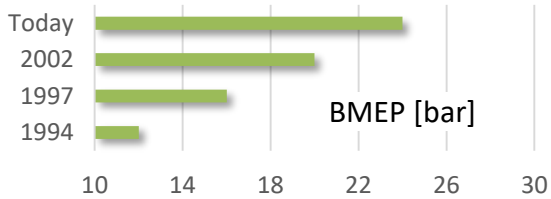

https://www.yanmar.com/global/marinecommercial/products/dual_fuel_engine/

- Dual Fuel (NG/Diesel)
- Diesel
- HFO

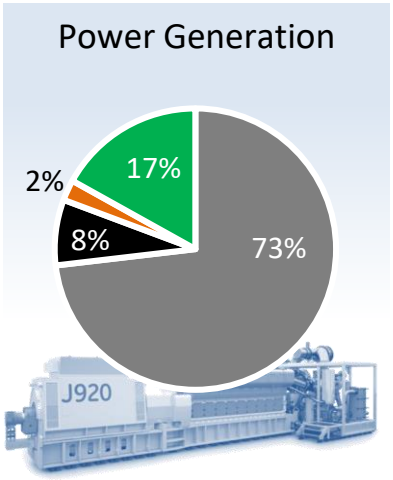
# Fuels for Large Engines

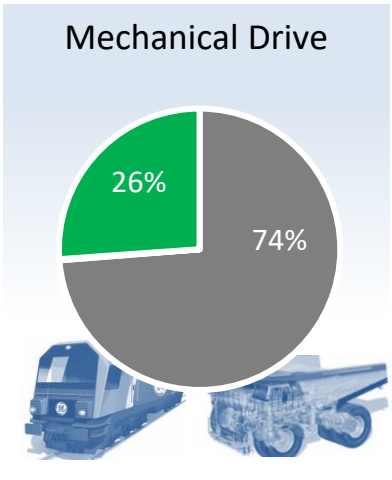
**INNIO Jenbacher Type 6 Gas Engine**
(4 MW range)

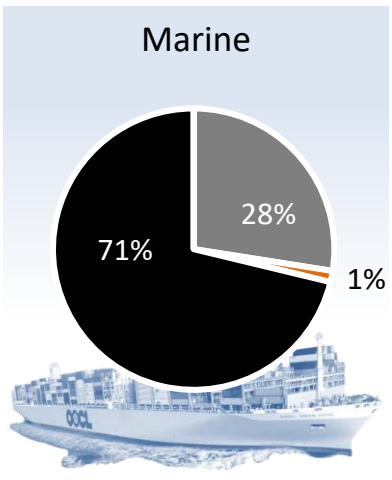



## Fuels




NG
Dual Fuel (NG/Diesel)
Diesel
HFO



Engines > 1MW (Average values 2010 – 2016)
**Source:** Diesel & Gas Turbine Worldwide 2011 - 2017

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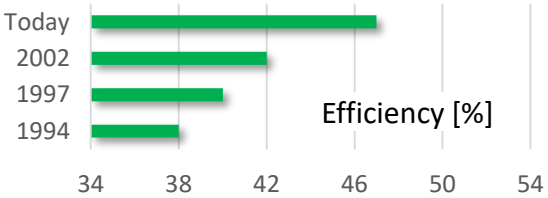
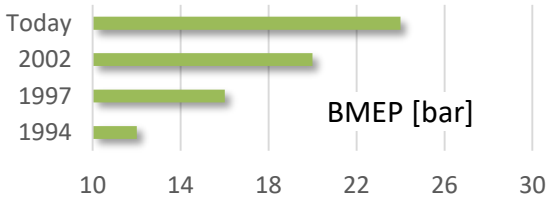
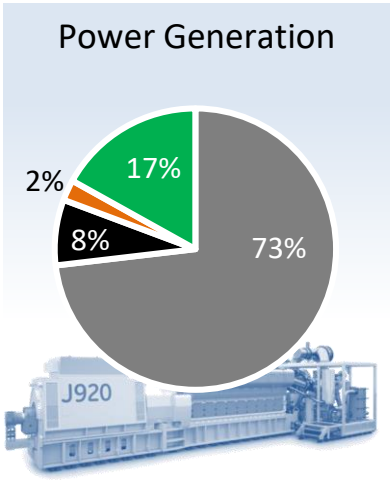



Hydrogen

*"World's first 1MW large-scale gas engine begins hydrogen field test"*
*(PEI – Power Engineering International, December 2020)*

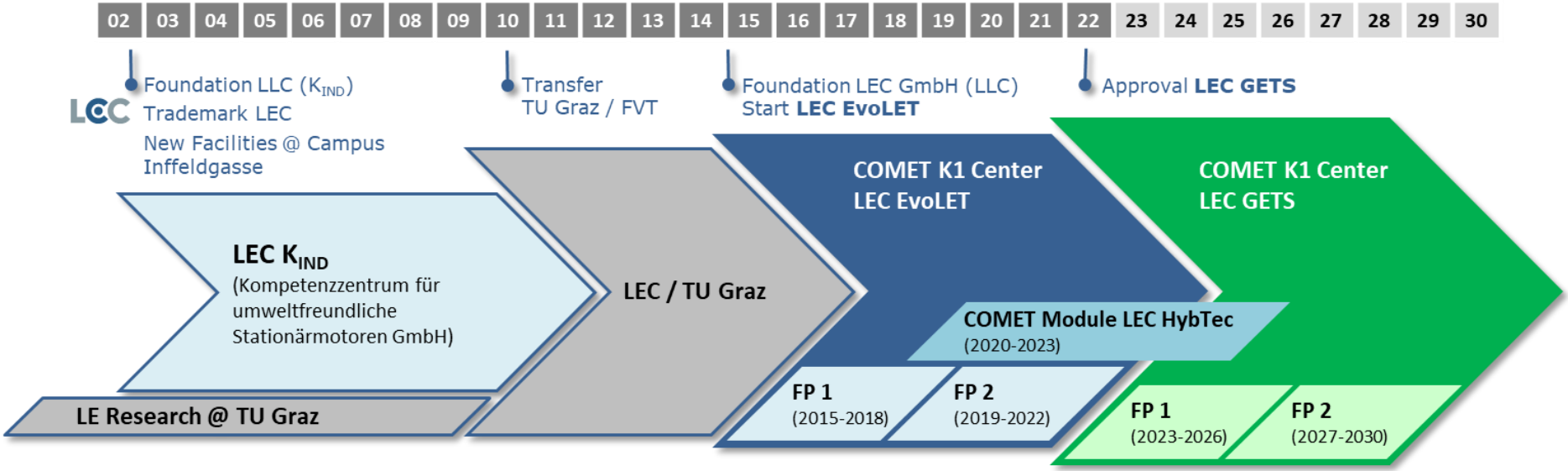
*www.hansewerk.com*
*www.innio.com*

- NG
- Dual Fuel (NG/Diesel)
- Diesel
- HFO



Engines > 1MW (Average values 2010 – 2016)
**Source:** Diesel & Gas Turbine Worldwide 2011 - 2017

# LEC GETS | Green Energy and Transportation Systems



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➔ E-fuels for large engine applications

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➔ Future role of large engines

# Battery-electric Marine Propulsion

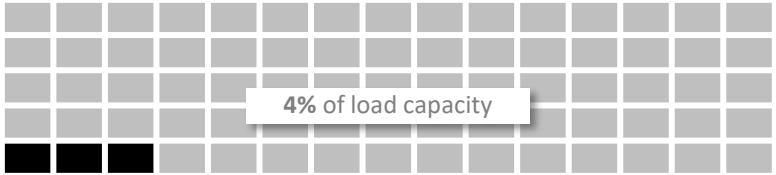
- Container Vessel **Emma Maersk**
  - Containers **14,770** TEU
  - Deadweight tonnage **156,000** tons
  - Fuel consumption **325** tons/day


Trip Asia - Europe

**HFO**

11.8 kWh/kg

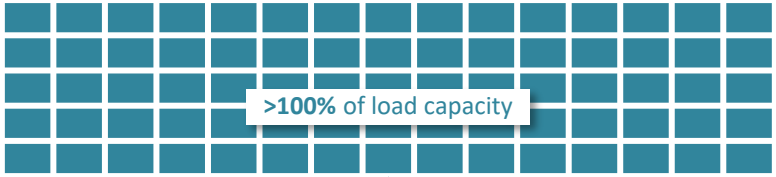
7,000 t




**Battery-electric**

0.25 kWh/kg

160,000 t




1 GW*

*) Charging time 48 hours

# Pathways to Green Transportation

Fossil Fuels

+ CC Post-combustion

Direct Use

➔ *Not sustainable, only for transition*

Biofuels

Direct Use

➔ *Limited*

Green Electricity

Batteries

➔ *Low storage density*

**E-fuels** (PtX)

➔ ***Main path***

Direct Use

➔ *Not everywhere, not always*

$CO_2$

Carbon-based

**FT fuels** **$CH_4$** **MeOH**

Carbon-free

**$NH_3$** **$H_2$**

$N_2$

# Pathways to Green Transportation

Fossil Fuels

Biofuels

Green Electricity

+ CC Post-combustion

Direct Use

➔ *Not sustainable, only for transition*

Direct Use

➔ *Limited*

Batteries

➔ *Low storage density*

**E-fuels** (PtX)

➔ ***Main path***

Direct Use

➔ *Not everywhere, not always*

CC Direct Air Capturing

$CO_2$

Carbon-based

Carbon-free

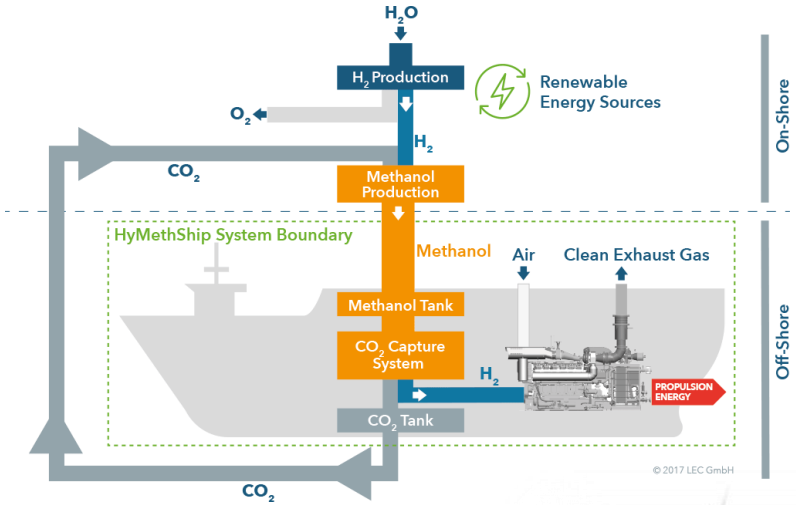
**FT fuels** **$CH_4$** **MeOH** **$NH_3$** **$H_2$**

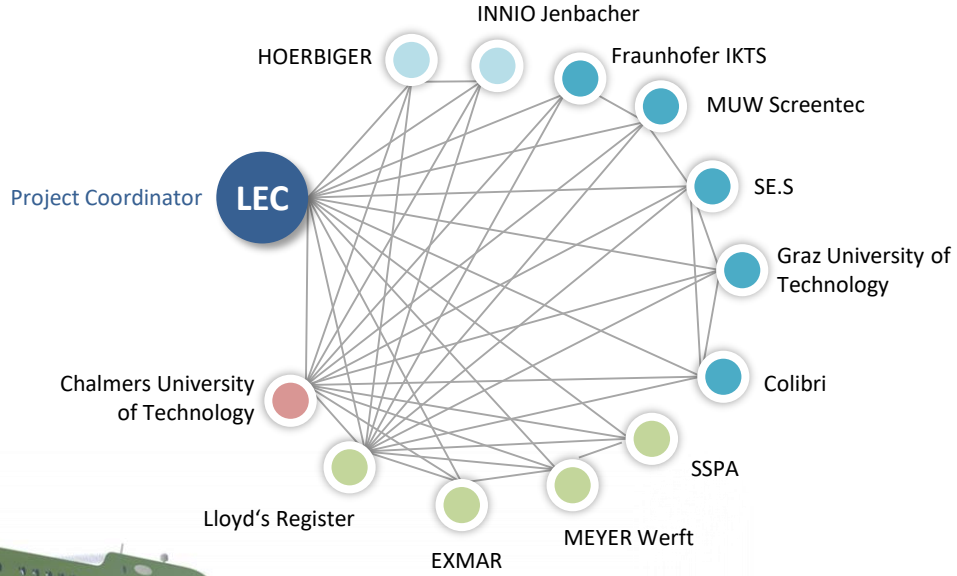
CC Pre-combustion

CC Post-combustion

$N_2$

# LEC System Approach | Example HyMethShip

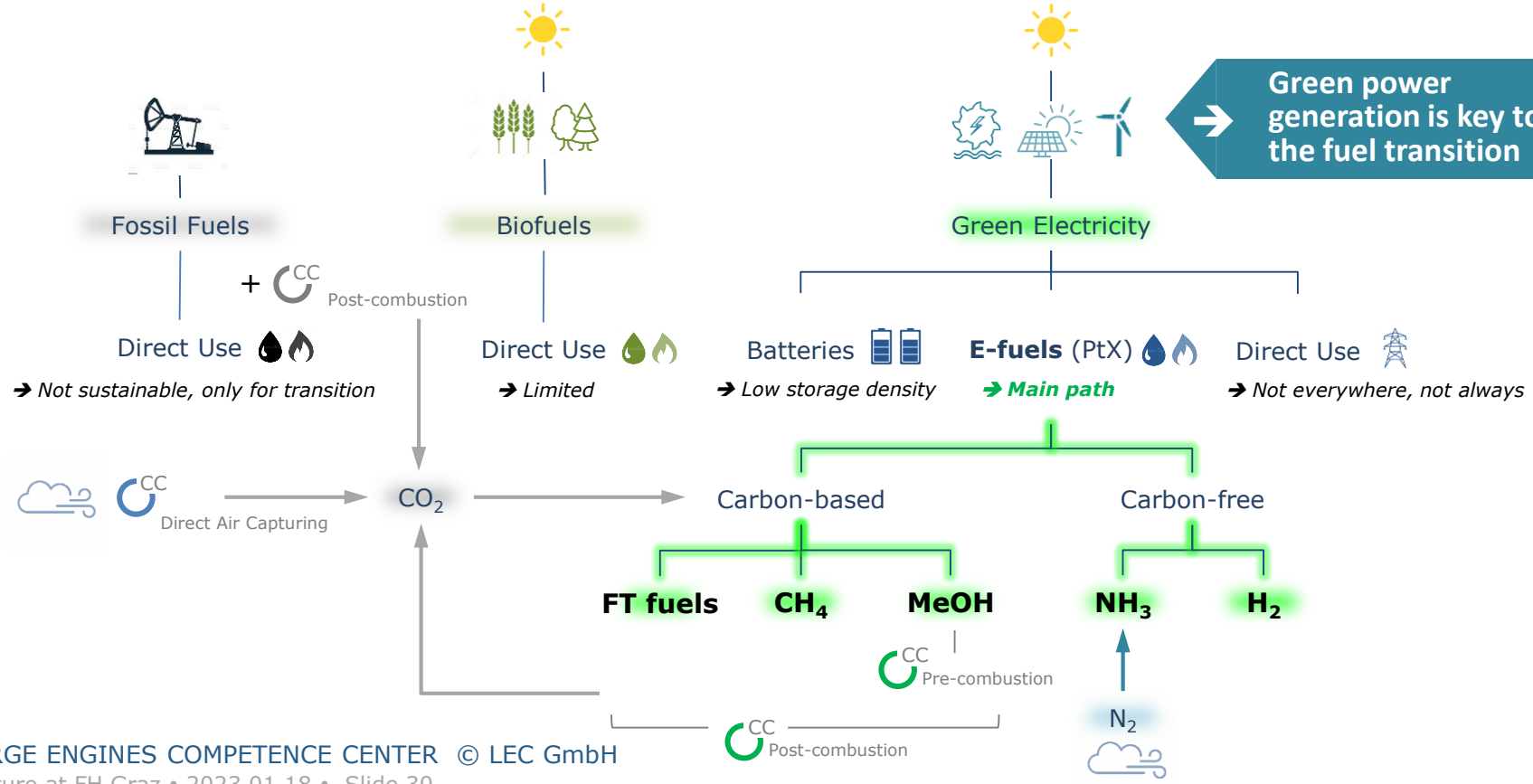


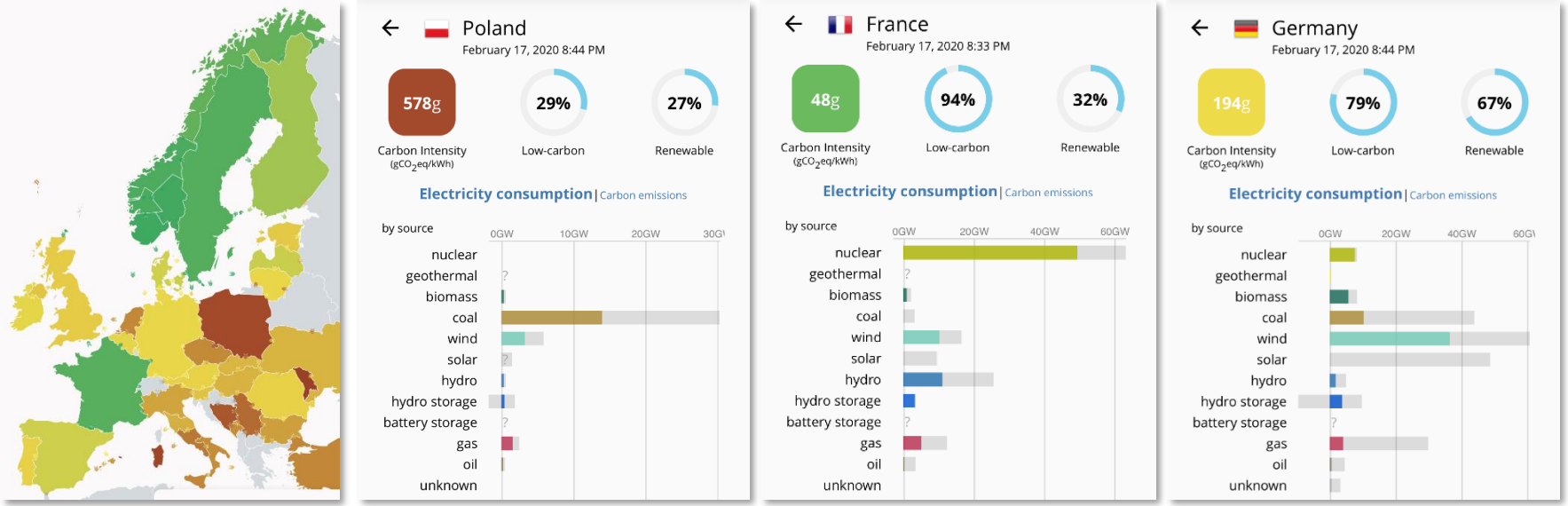



The project has received funding from the European Union's **Horizon 2020** research and innovation program under grant agreement **No 768945**

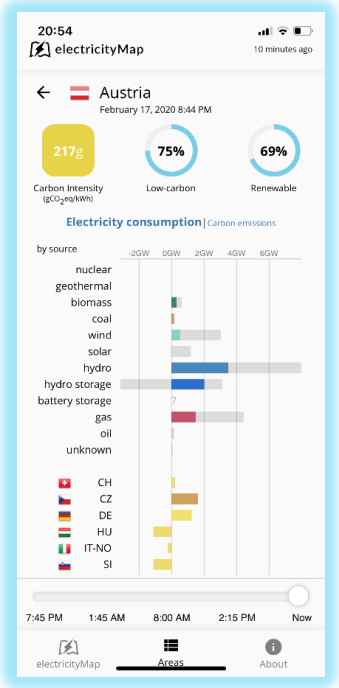
# Pathways to Green Transportation



# Power Generation Europe (www.electricitymap.org)

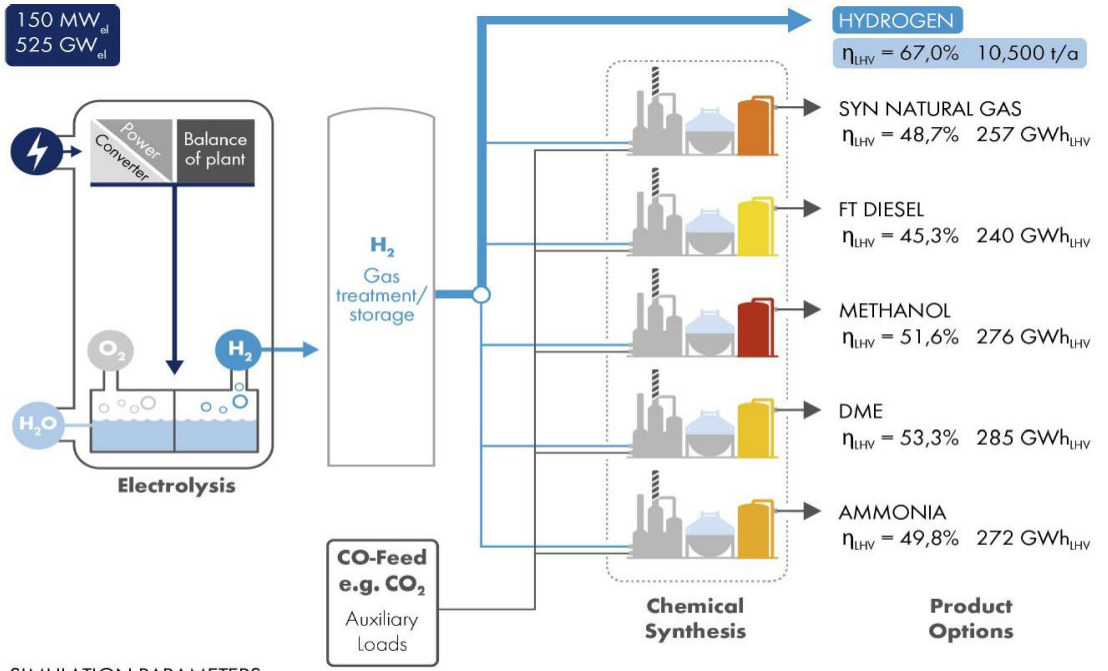


# Power Generation Austria (www.electricitymap.org)




**Mission2030** – Die Klima- und Energiestrategie der österreichischen Bundesregierung

# Energy Demand

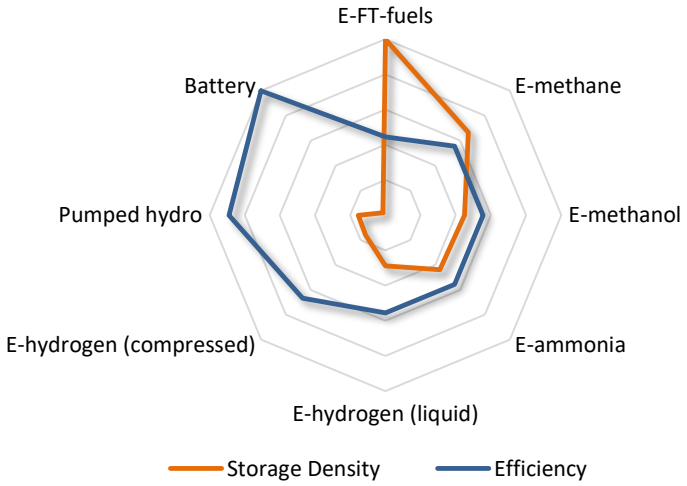


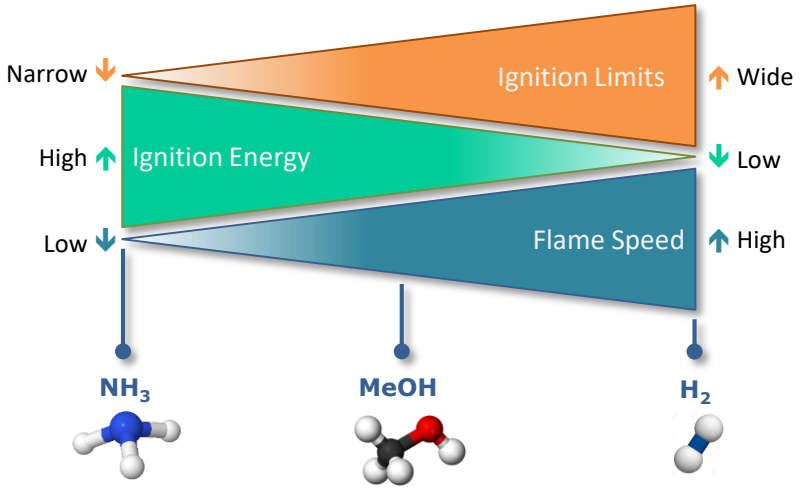

SIMULATION PARAMETERS

Electrolysis efficiency 4.5 kWh/Nm³ (average during operation). $H_2$ throughput: 150 MW electrolysis scale, 3500 EOH. $H_2$ loss: 1%. Auxiliary power consumption dependent on synthesis. Synthesis efficiency dependent on synthesis (thermodynamic limit as reference)

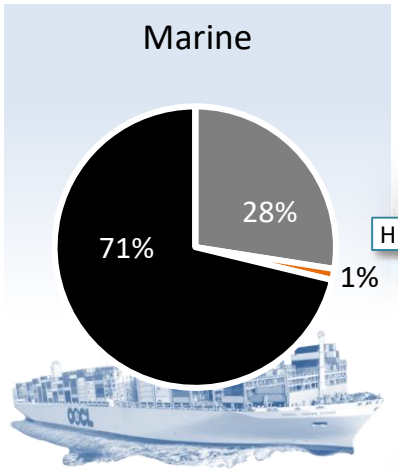
Source:Siemens Corporate Technology, Alexander Tremel: ATZ Automotive Konference, Baden Baden Feb. 2017.

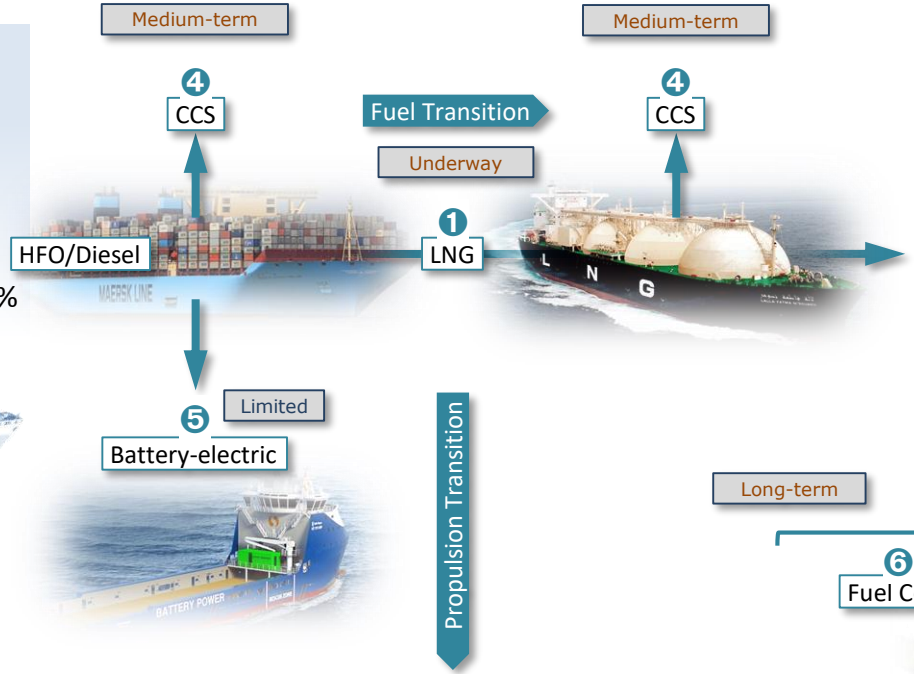
# Green Fuels | Technology Challenges



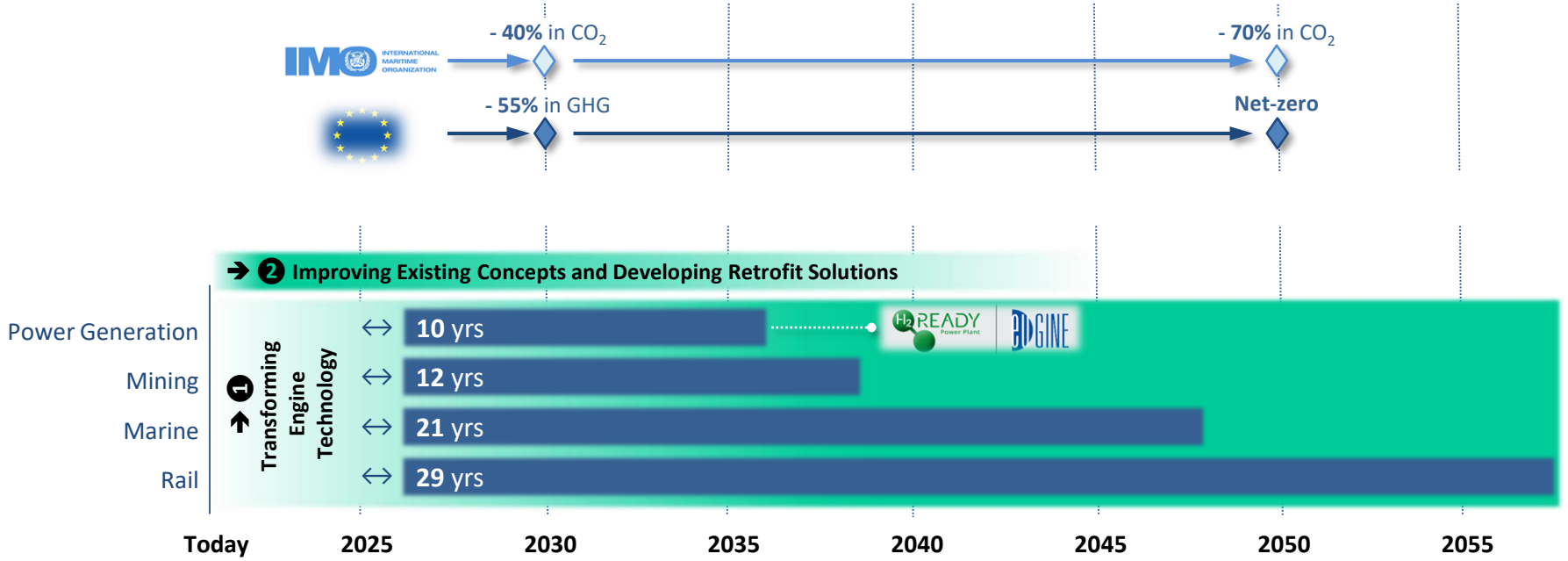



# Towards Green Shipping



# General Approach






Average Lifespan or Time to Major Overhaul of Engine

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➔ GHG reduction potential
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➔ Pathways to green transportation
➔ Power plant of the future
➔ E-fuels for large engine applications

4

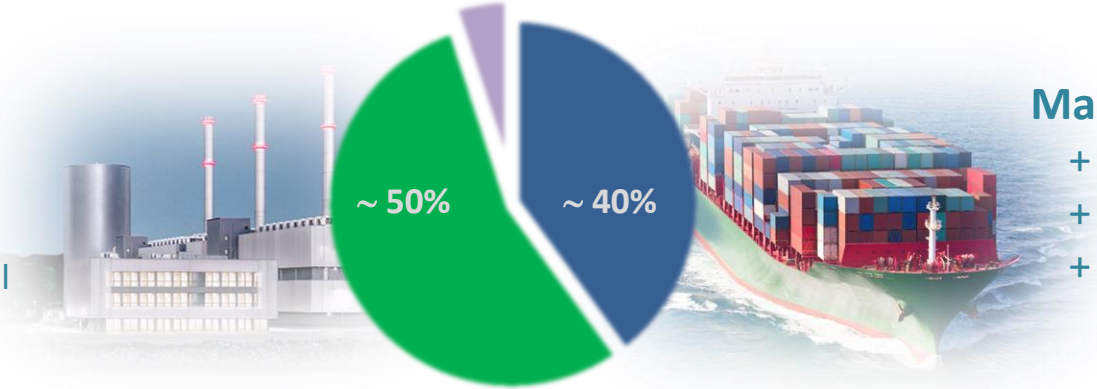
## Summary

➔ Future role of large engines

# Die Rolle der Großmotoren

## Energieerzeugung

+ Effizient
+ Hochdynamisch
+ Modular und flexibel




## Marine

+ Effizient
+ Hohe Reichweiten
+ Robust, zuverlässig und langlebig

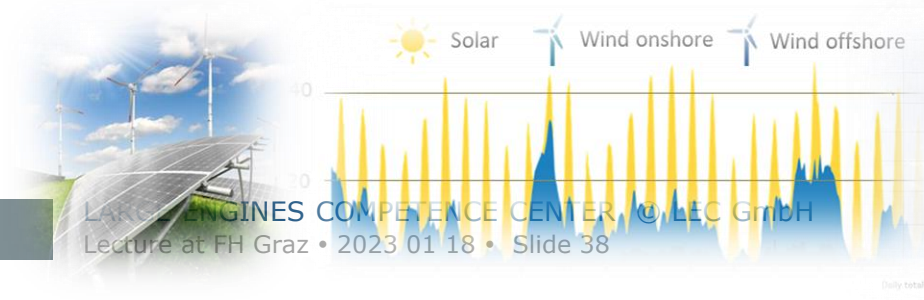
## Beiträge auf dem Weg zur Klimaneutralität

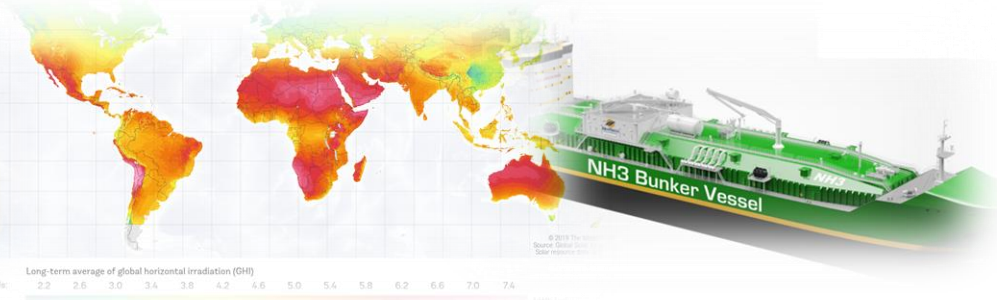
Back-up Power und Regelenergie

Saisonale Energiespeicherung

Import/Transport von erneuerbarer Energie

Defossilisierung des Antriebs



# Summary

- The **transition to green fuels** is key to near-zero emission concepts for transportation.
- The climate-neutral **Power Plant of the Future** will significantly contribute to grid stabilization and thus **pave the way for the energy transition**.
- Extensive research, global collaboration, and **fast launching of large-scale projects** is critical to the transformation process.

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# Danke für Ihre Aufmerksamkeit!



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