Liebherr-Component‘s road to zero

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Dr. Ingo Wintruff

Diesel Progress Summit
Chicago, September 26, 2022

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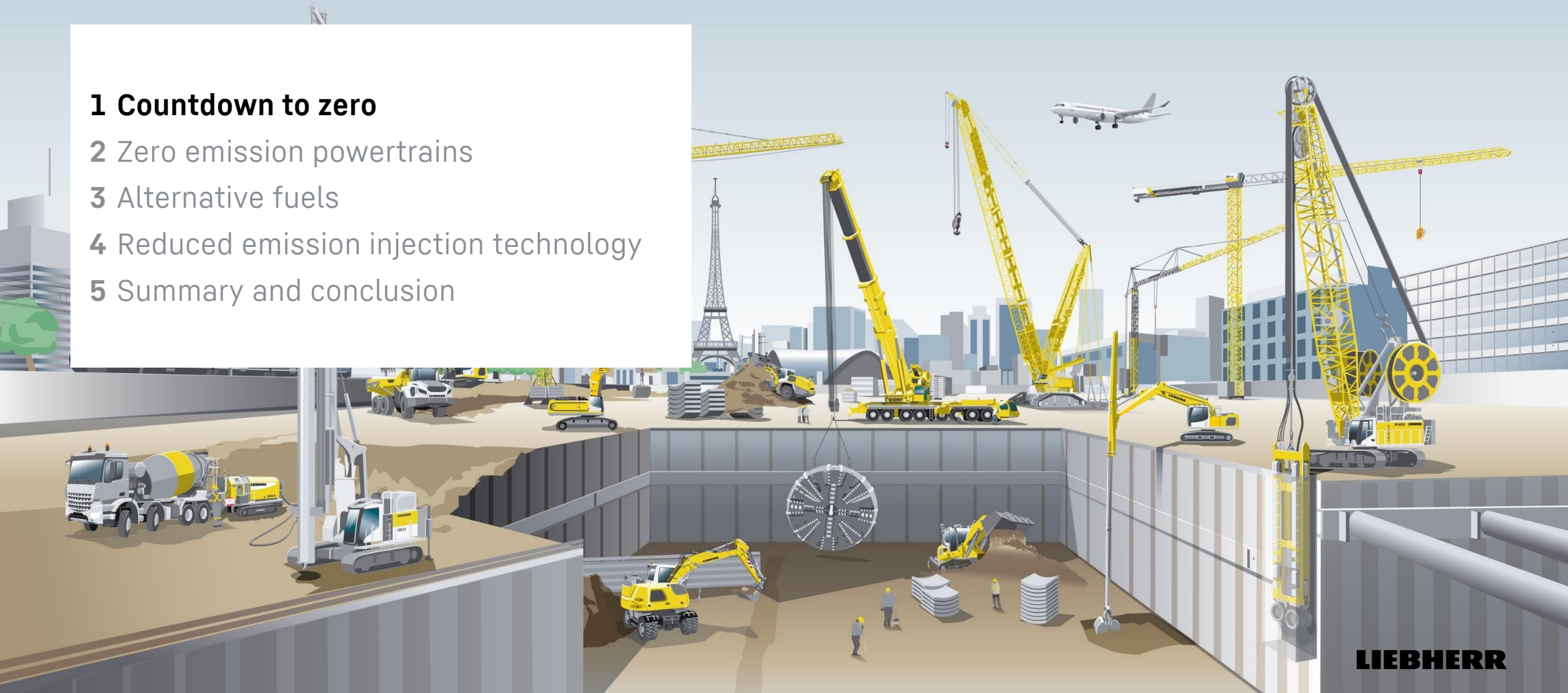
Liebherr Components AG

Liebherr-Component‘s road to zero



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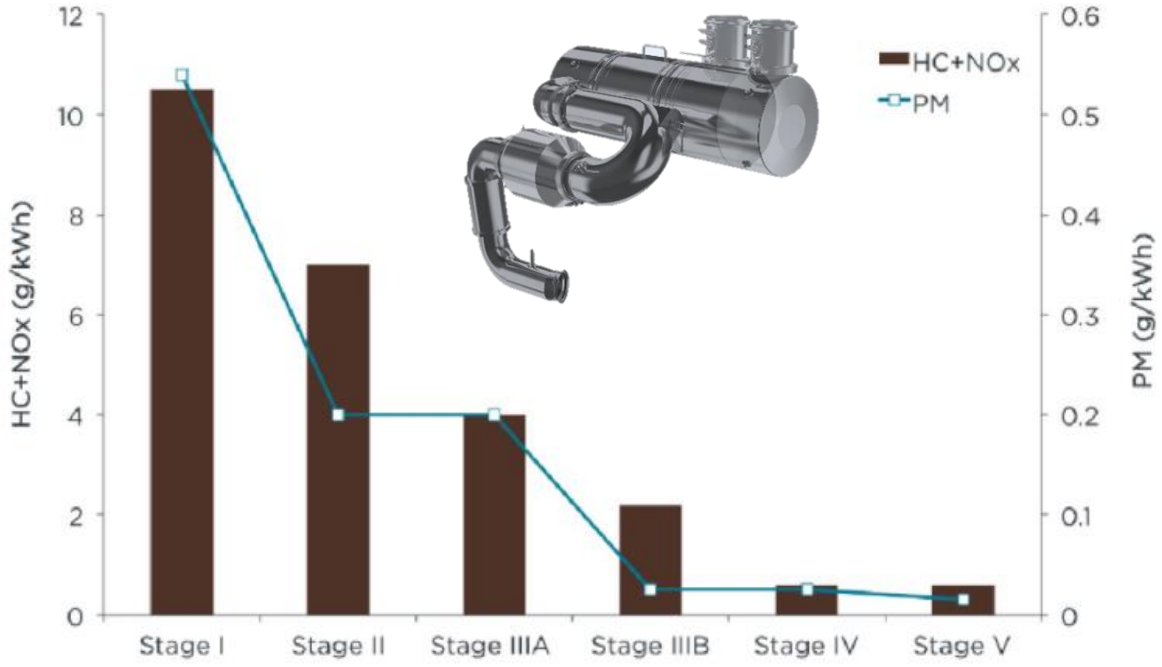
We have done a lot – but not enough…

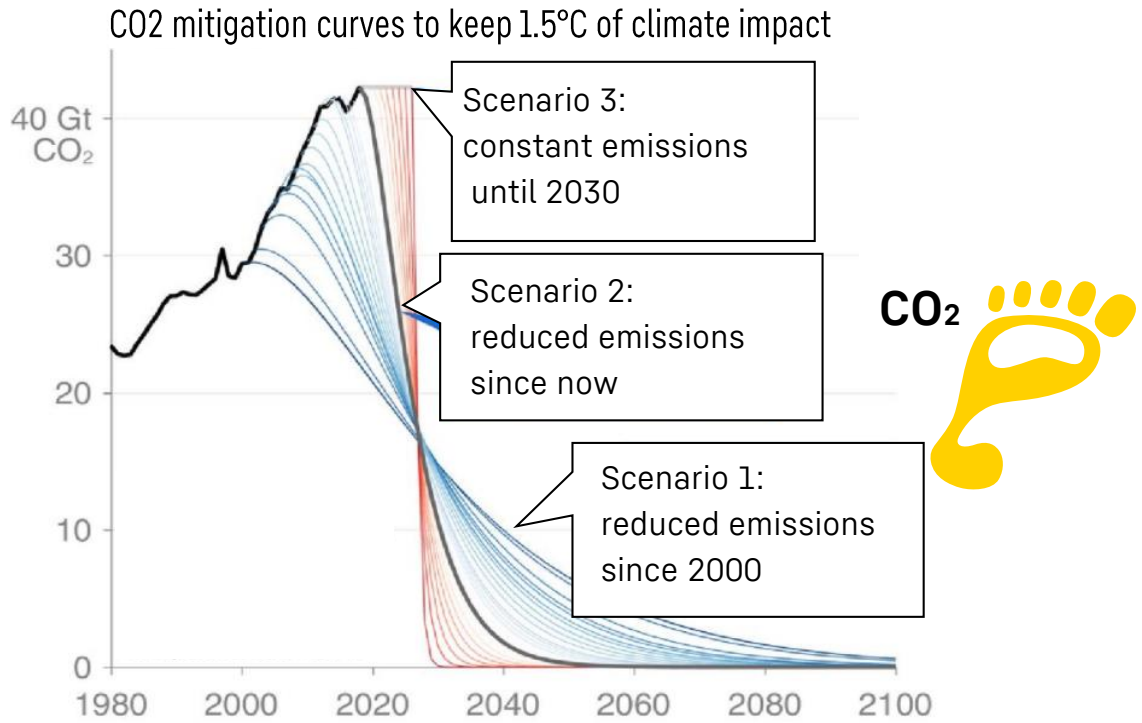
1999-2020



Source: Mark Preston Aragonès, Bellona Europa, Green NRMM – Virtual Conference, 07/08.10.2021

„Classic“ pollutant heavily reduced in the last two decades!

2020-2050



„CO_2 Budget“ to limit climate impact almost exhausted!

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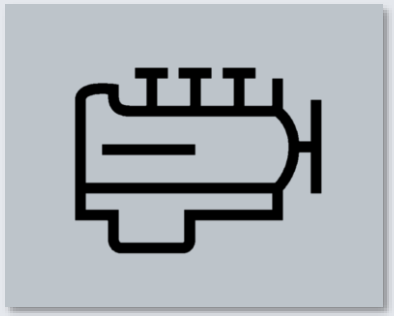
Zero emission is a „multiple choice“ approach

Today

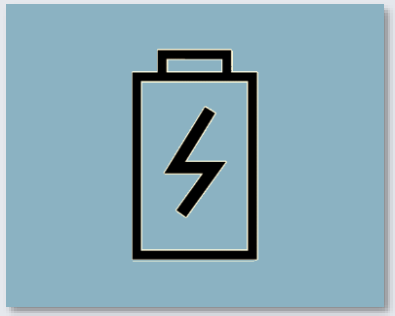
Internal combustion engine (ICE)
fossil fuels



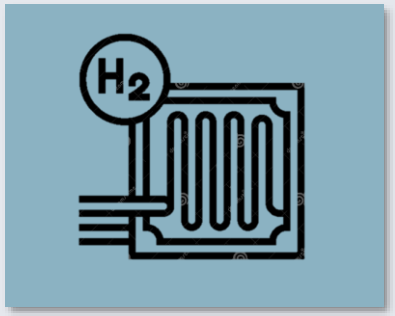
Transformation

Tomorrow

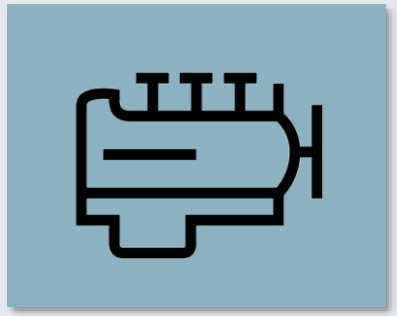
Full electric battery drive
renewable energy



Fuel cells
„green“ hydrogen (H_2)



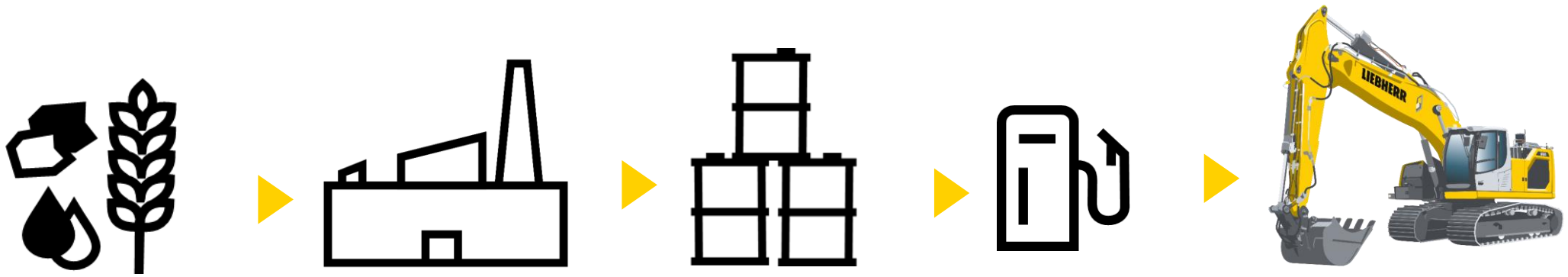
Internal combustion engine (ICE)
CO_2 neutral fuels



Future powertrains have to be „zero emission“ in a well- to wheel –approach.

Well to wheel: fuel life cycle assessment of CO_2 emissions

Feedstock + production + storage & transport + distribution + operation



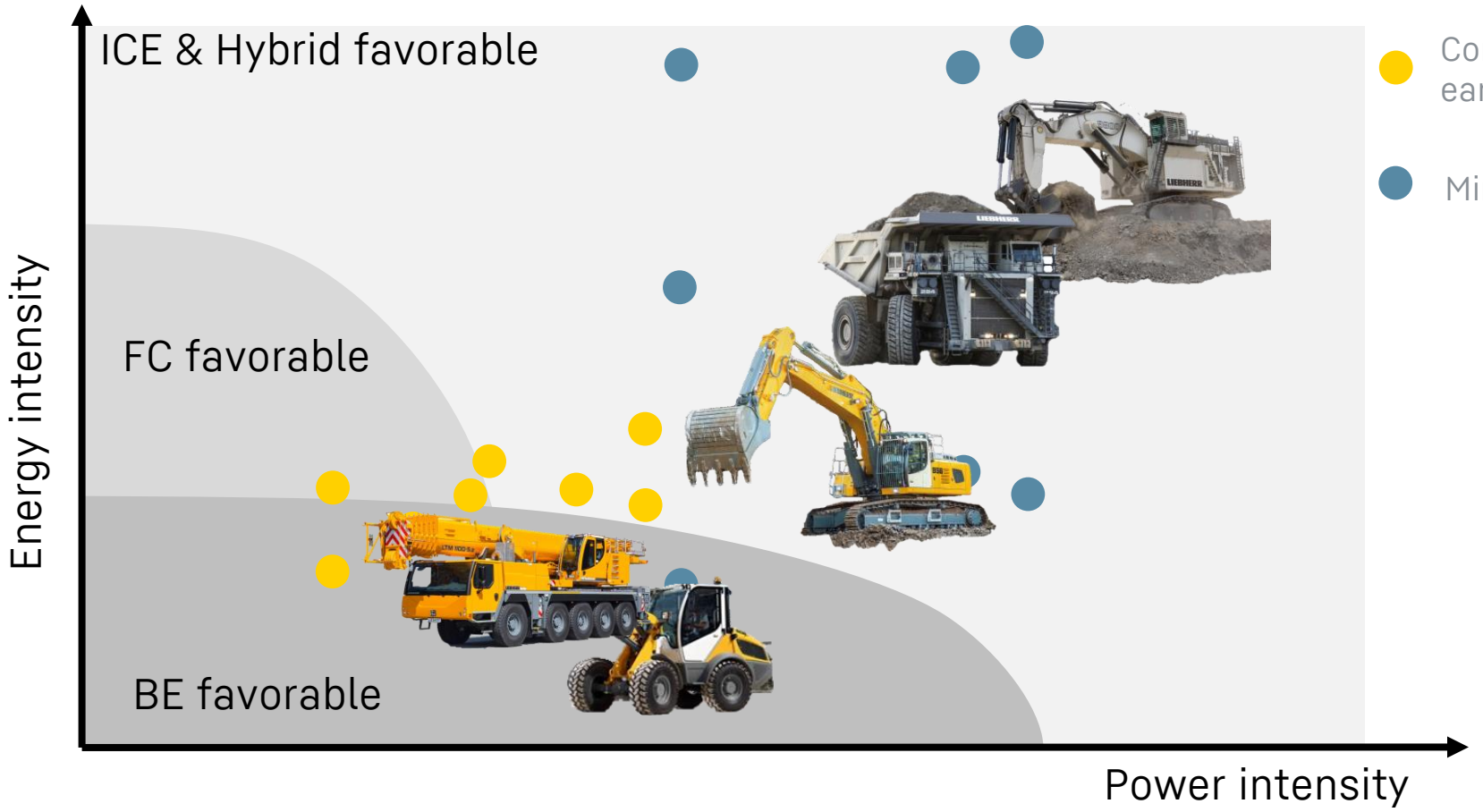
Energy carrier

CO_2 emissions

Tank to wheel

Well to wheel

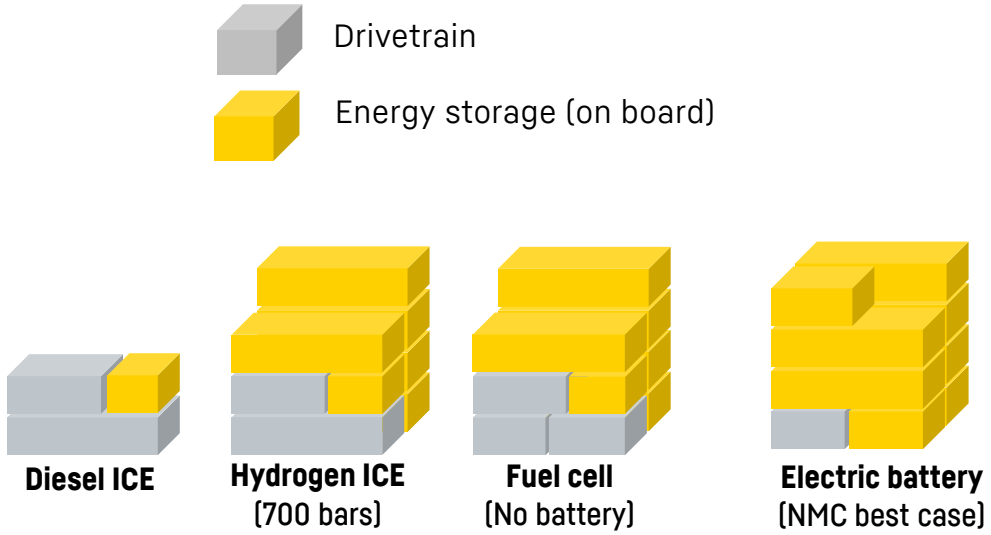
Different requirements create different solutions



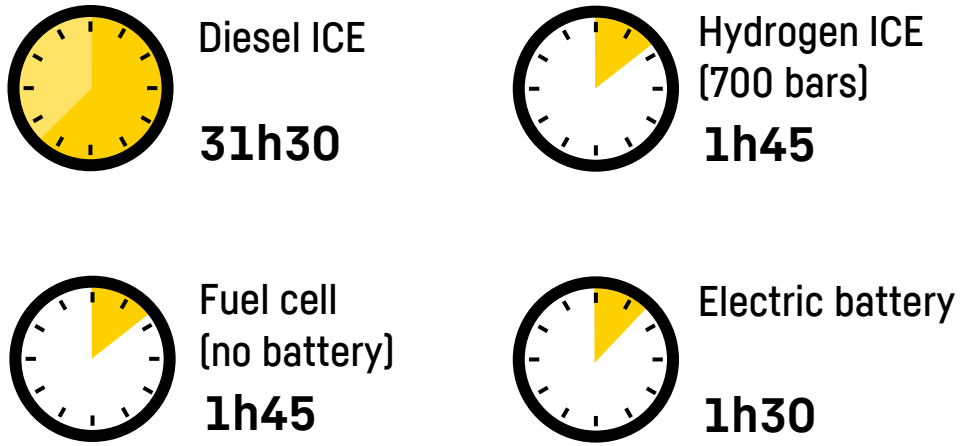
Zero to near emission combustion engine will be one of the future powertrain solutions.

What makes the diesel unique?

L 550 Xpower



Current diesel powertrains are very compact.
The integration of a new technology requires a much larger volume.



When energy storage volume can not be increased, operating time (until re-fueling) has to decrease.

What makes the combustion engine unique?

Challenges for fuel cells

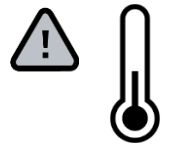
Challenges for battery electric

Challenges for H_2 combustion engines

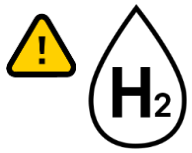
Humidity

Altitude

Thermal management



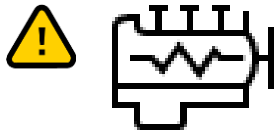
Fuel sensitivity



Dust

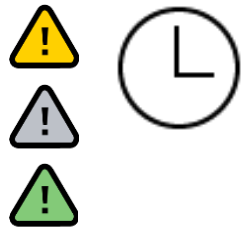
Shock & vibration

Transient operation



Costs

Operation time



Combustion engines have significant advantages under harsh conditions.

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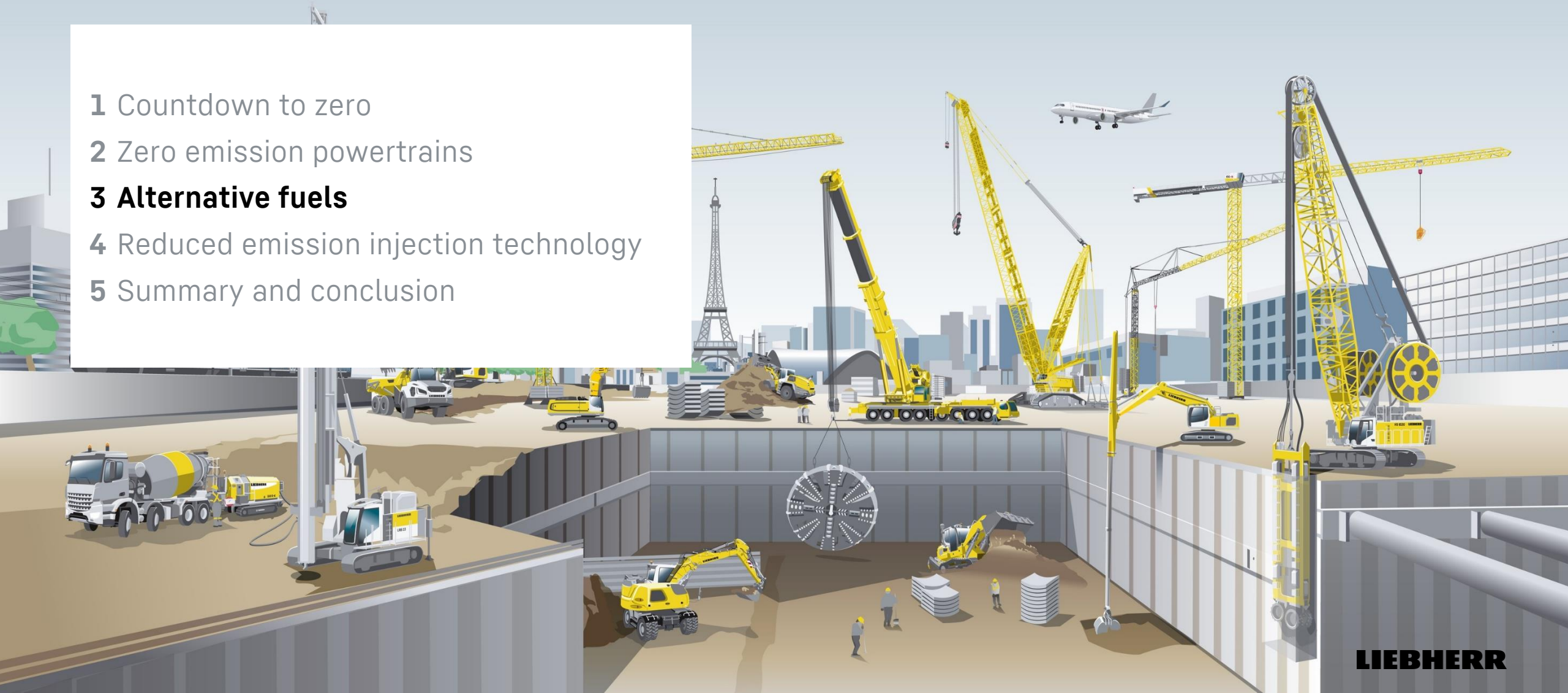

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Roadmap of alternative fuels

Diesel

BioFuels

Synthetic fuels

Hydrogen

H_2

Ammonia

NH_3

Methanol

CH_3OH

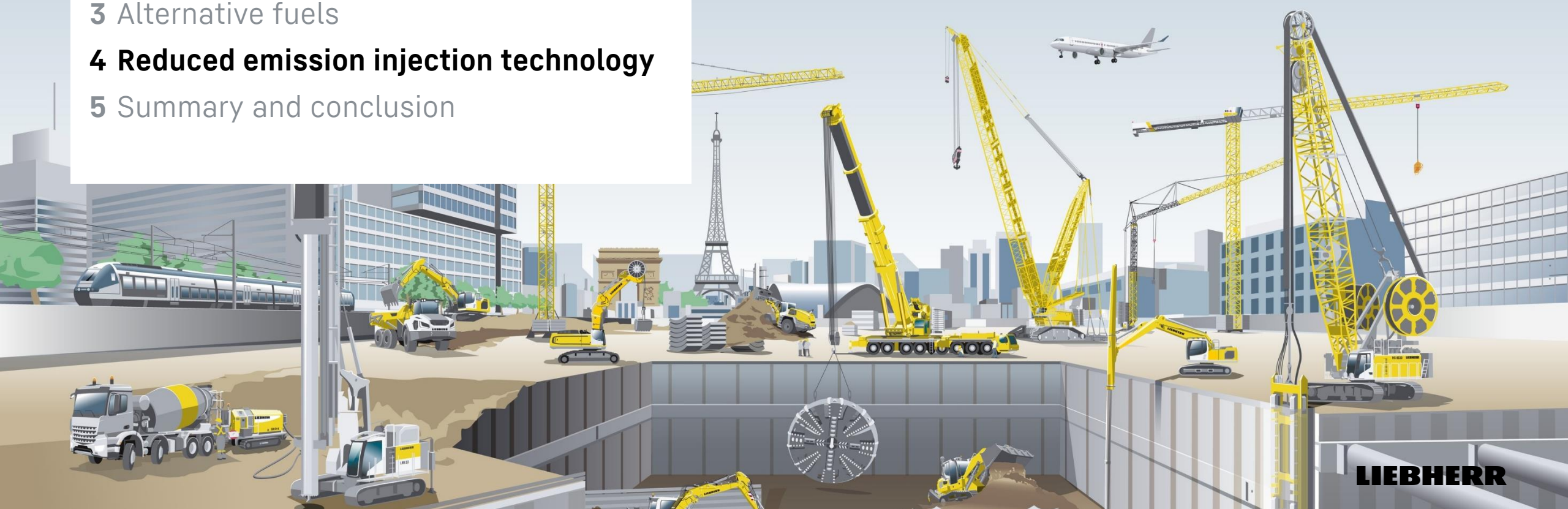
HVO & GTL

EN 15940

Liebherr benefits from its **experience and knowledge** in ICE development.

A modular diesel platform is the basis to **evolve** operation with alternative fuels.

Liebherr-Component‘s road to zero



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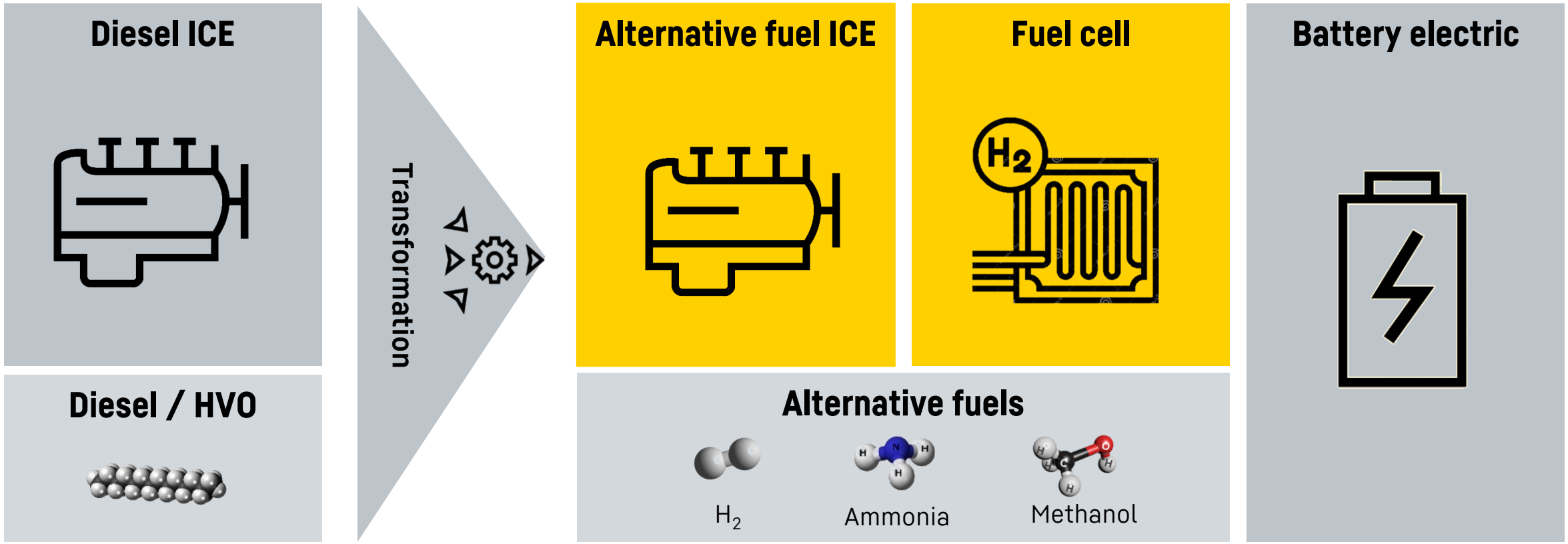
Reduced emission injection technology

Liebherr's field of actions

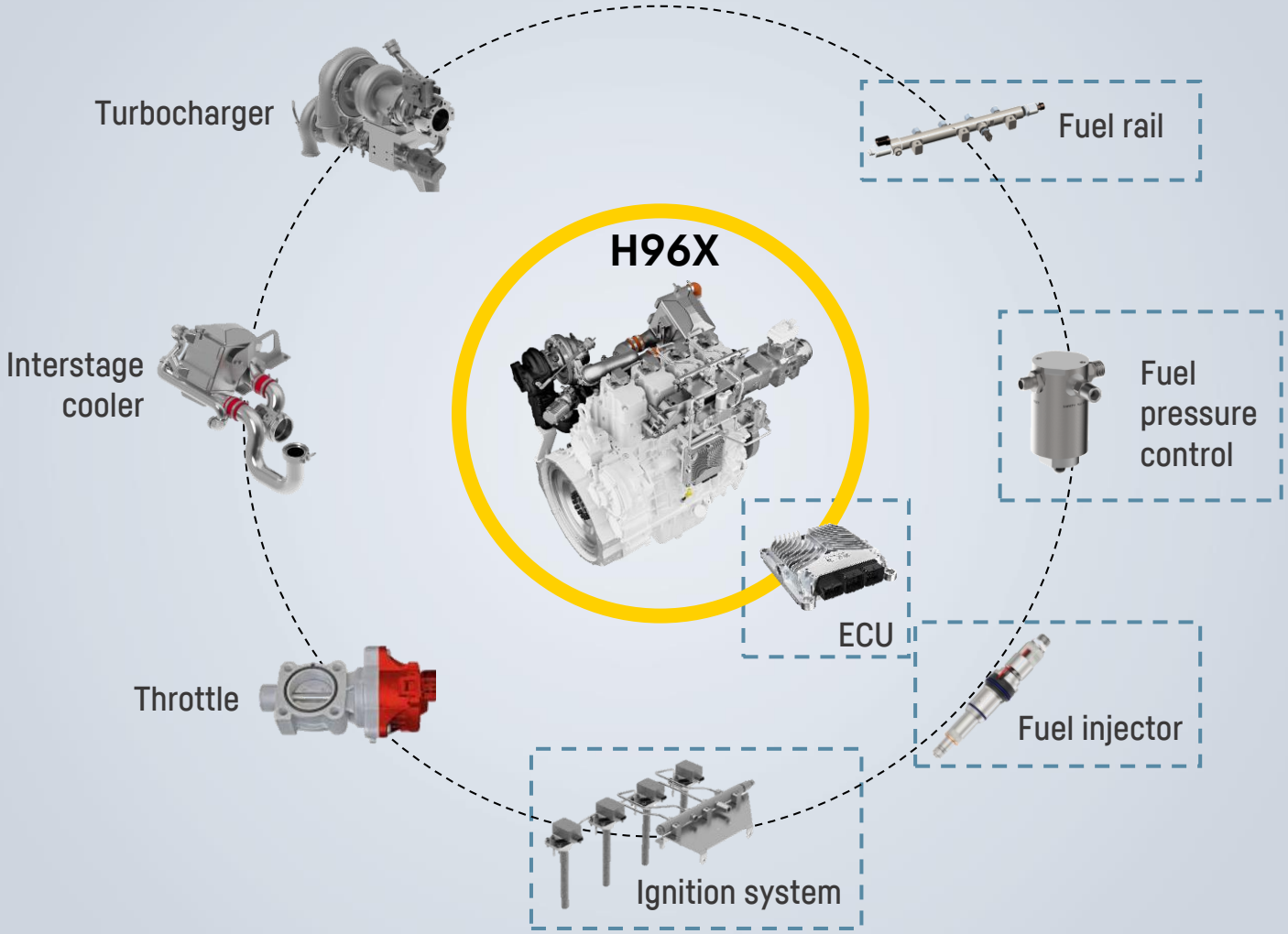


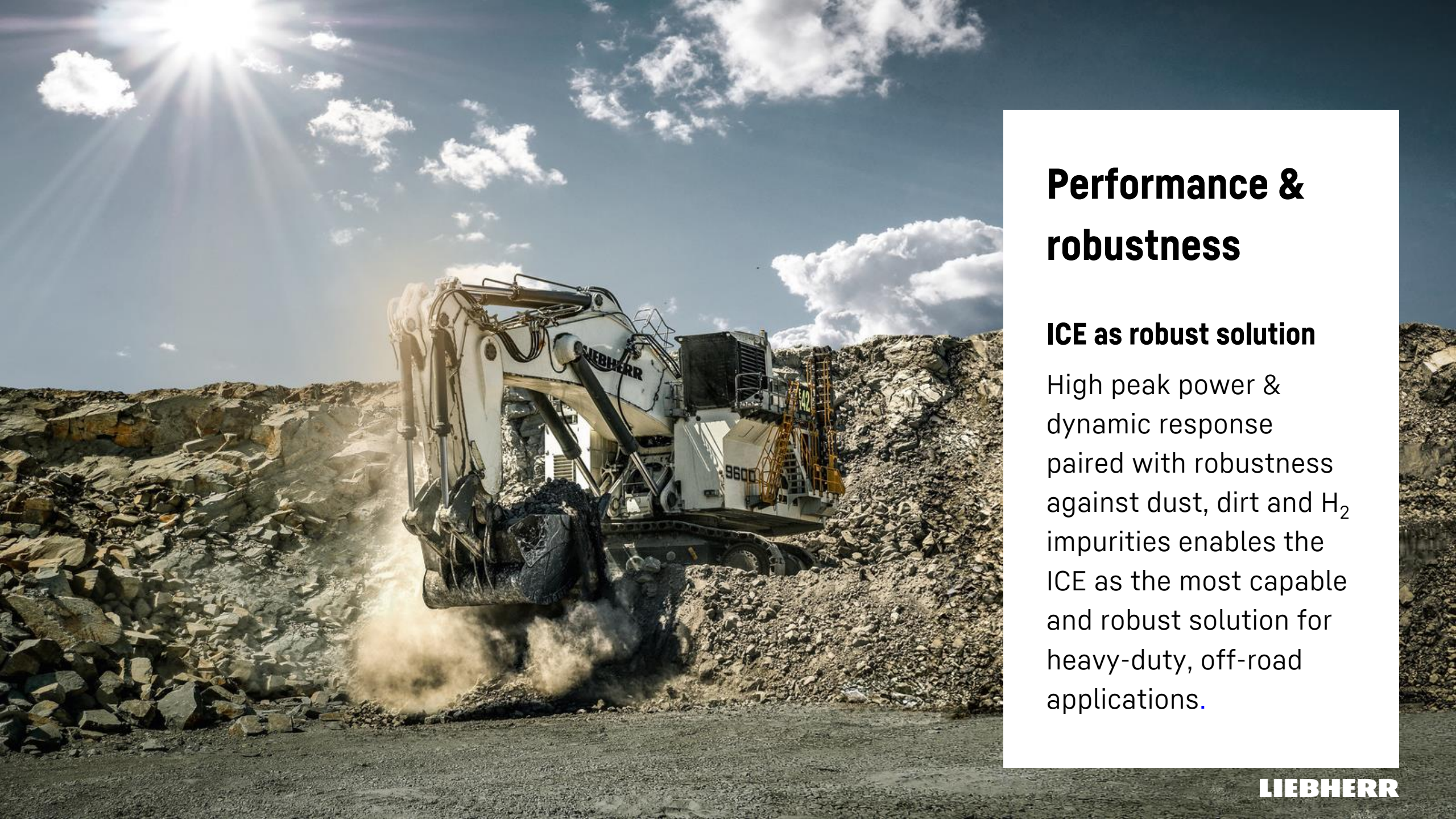
Liebherr-Components product segment mainly focuses on ICE and fuel cell solutions.

Key technologies for „zero“ ICEs

Main development targets

- High parts commonality
- Power density similar to diesel engines
- Efficiency > 40%
- Lifetime and maintenance intervals similar to diesel engine
- Biggest influence and highest complexity → fuel system





Performance & robustness

ICE as robust solution

High peak power & dynamic response paired with robustness against dust, dirt and H_2 impurities enables the ICE as the most capable and robust solution for heavy-duty, off-road applications.

Integration & cost

ICE as existing solution

requires only minor adaption of the vehicle concepts and enables hydrogen powertrains in high variety of low volume applications.

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Time to market

ICE as first enabler

for zero GHG emission powertrain solutions in heavy-duty, off-road and special vehicle applications with high variety of different applications

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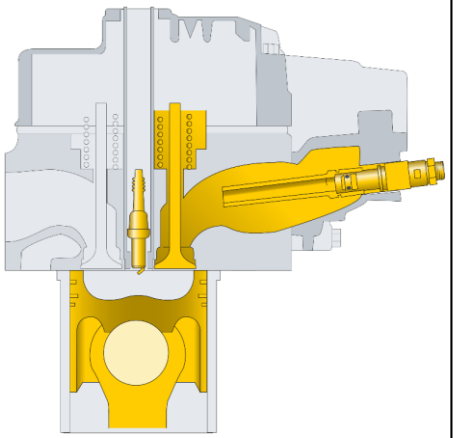
Reduced emission injection technology

H_2 ICE fuel injection concepts

Port fuel injection (PFI) ≤ 15 bar

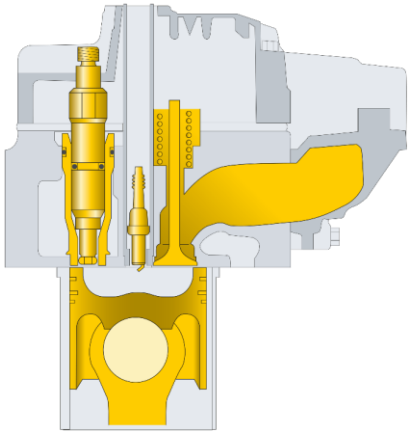
- 20 - 30% lower power density vs. diesel engines
- Good mixture homogenization → low NO_x
- Low efforts for FIE → short time to market



vs.

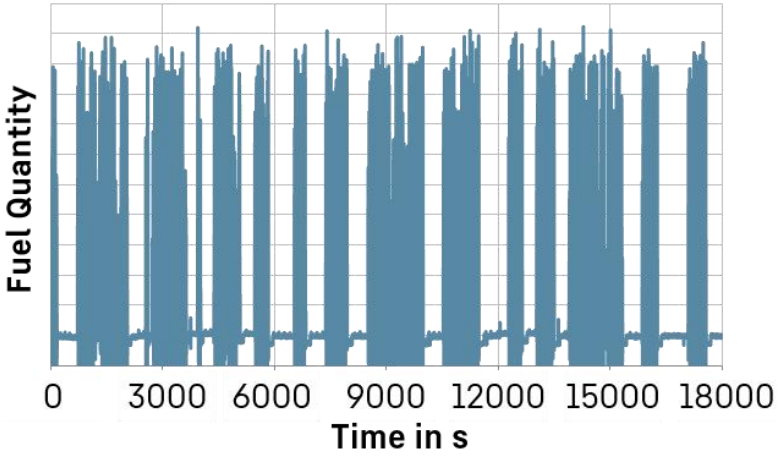
Direct injection (DI) ≤ 60 bar

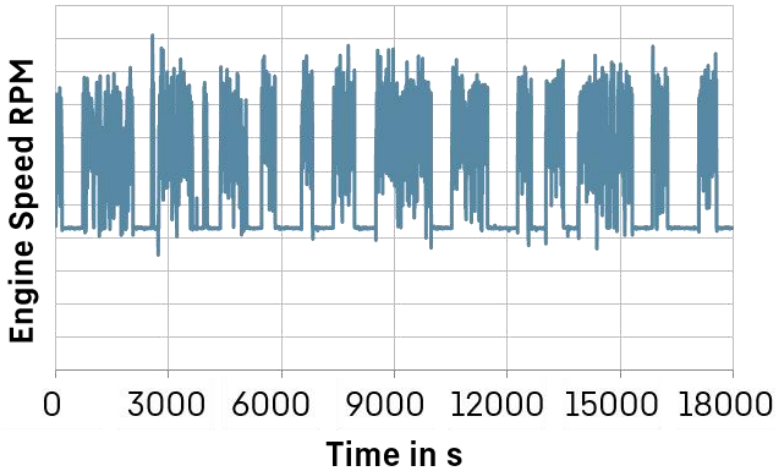
- Power density similar to today's diesel engines
- Worse mixture homogenization → higher NO_x
- High efforts for FIE → longer time to market

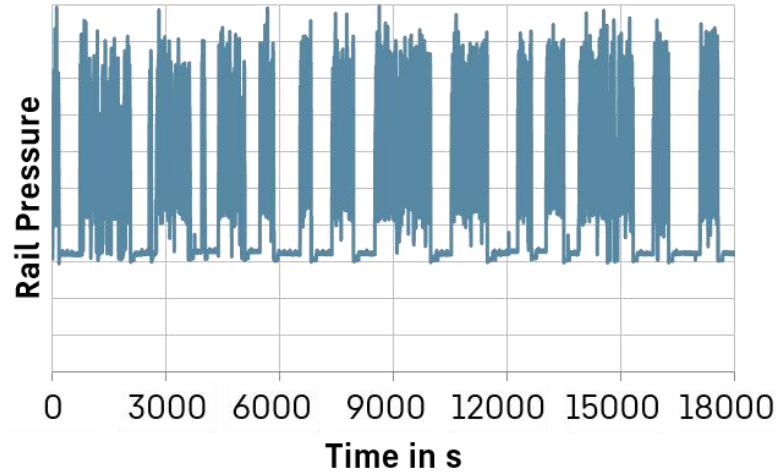


Both solutions offer unique advantages.
Liebherr develops fuel injection solutions for DI and PFI for H_2 ICE.

Wheel loader load profile as reference for H_2 system



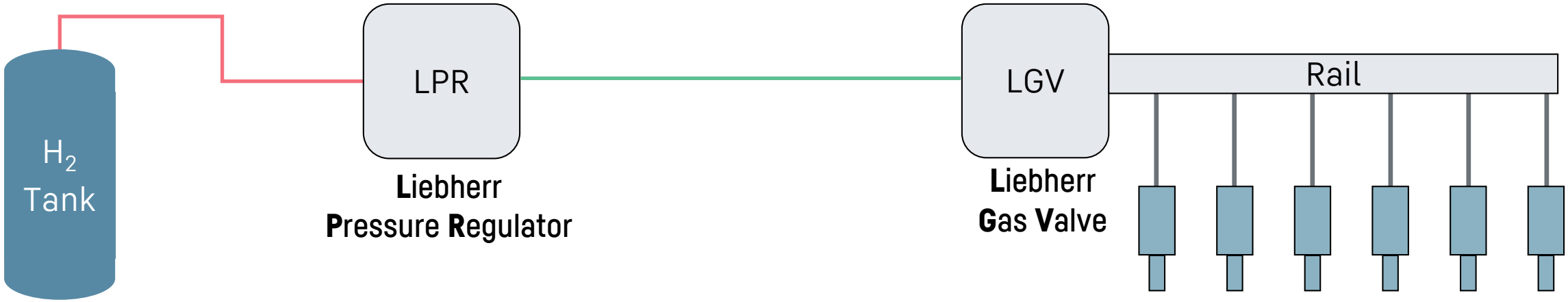


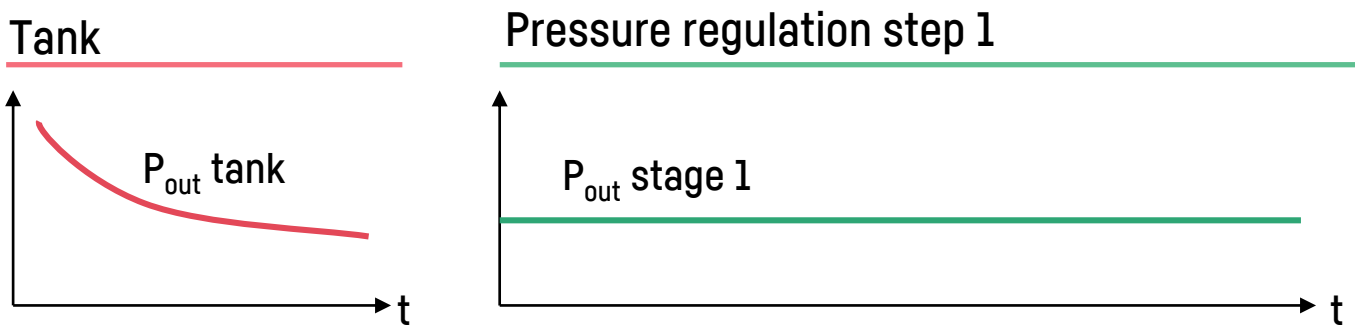


- very dynamic application
- mainly operated in idle lower speeds
- minimal full load operation
- high frequent load steps between idle and full load

→ **need for dynamic fuel system**

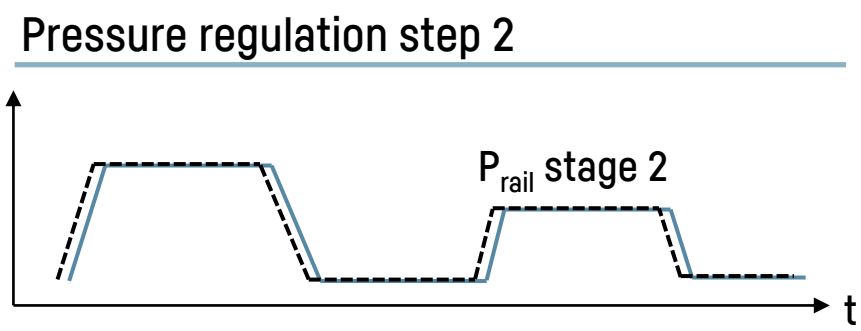
Highly dynamic & precise pressure regulation





Variable tank pressure (t) based on filling level

Pressure regulator supplies constant nominal system pressure



Gas valve controls dynamic pressure profile acc. to engine load profile (speed & load)

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Is there a future for internal combustion engines?

> **The concern is not the combustion engine, but the fuel that is burned!**

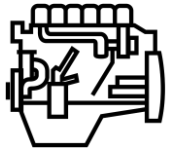
The once pronounced dead, ICE, lives on…..

Combustion engines

… have unbeatable advantages under harsh conditions.

Combustion engines

… become favorable for higher energy and power densities.



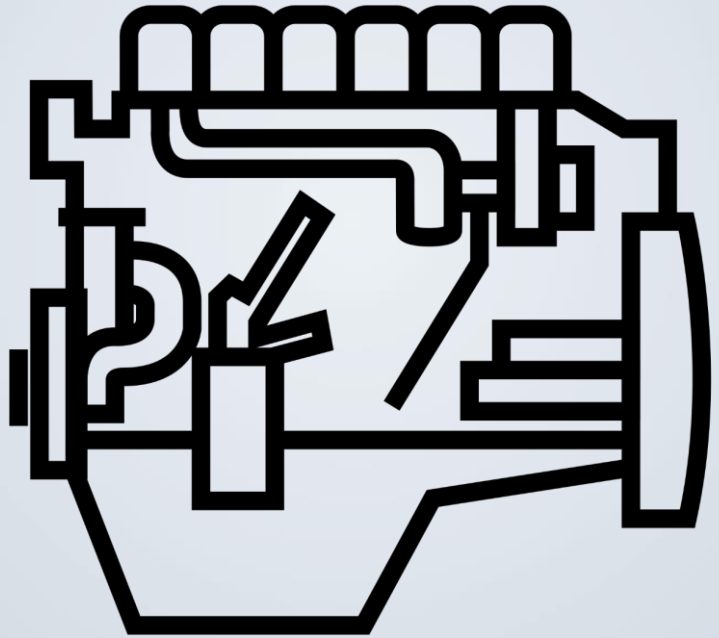
Combustion engine technology

… has been optimized over centuries and is very mature.

Injection technology

… for hydrogen is already available.

Liebherr is convinced that combustion engines will remain a viable and essential solution to support future heavy-duty applications.



Thank you.