Liebherr's approach to Hydrogen based ICE

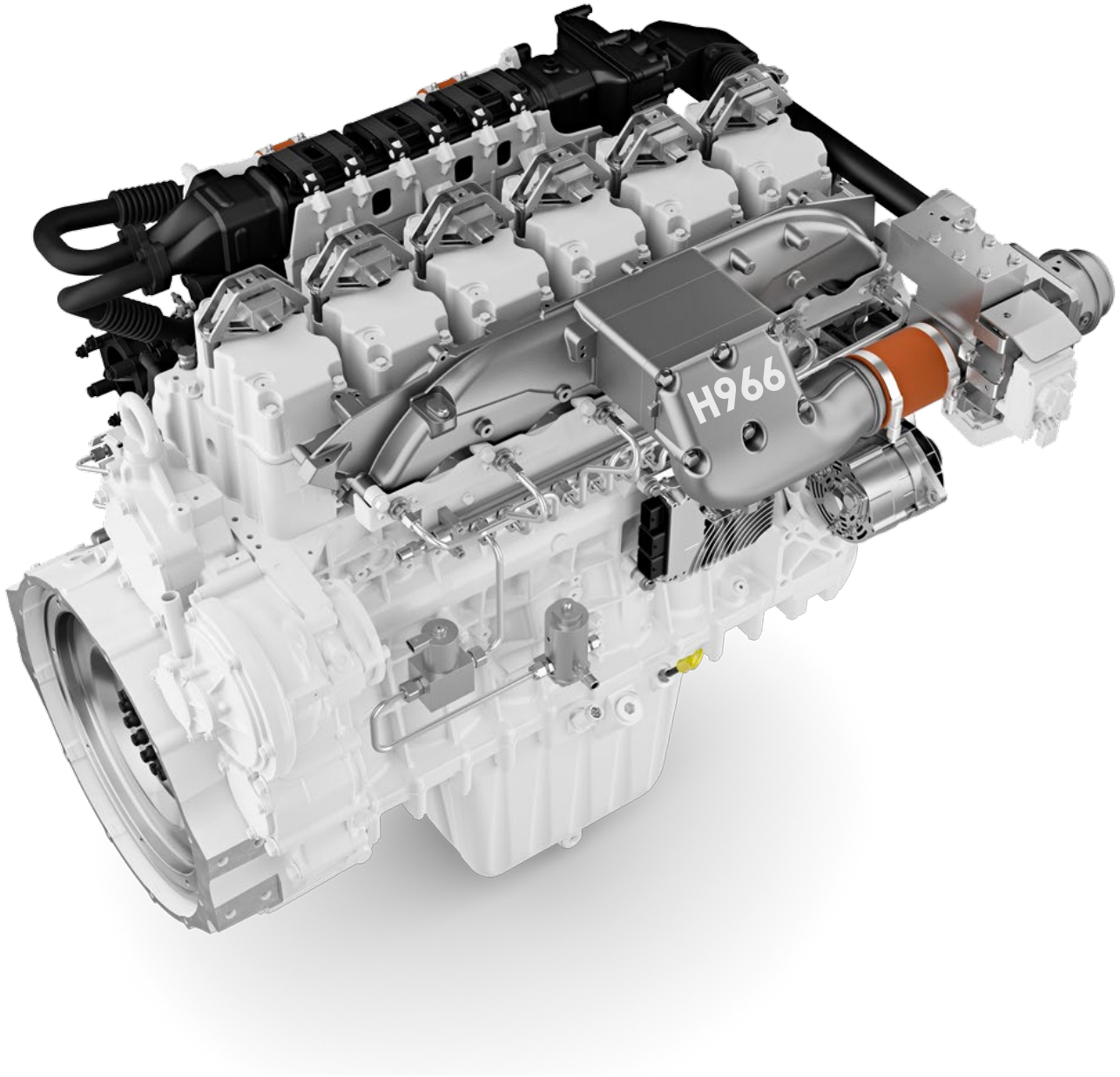
Paul Mercurio

Diesel Progress Summit

September 25, 2023

LIEBHERR

Components

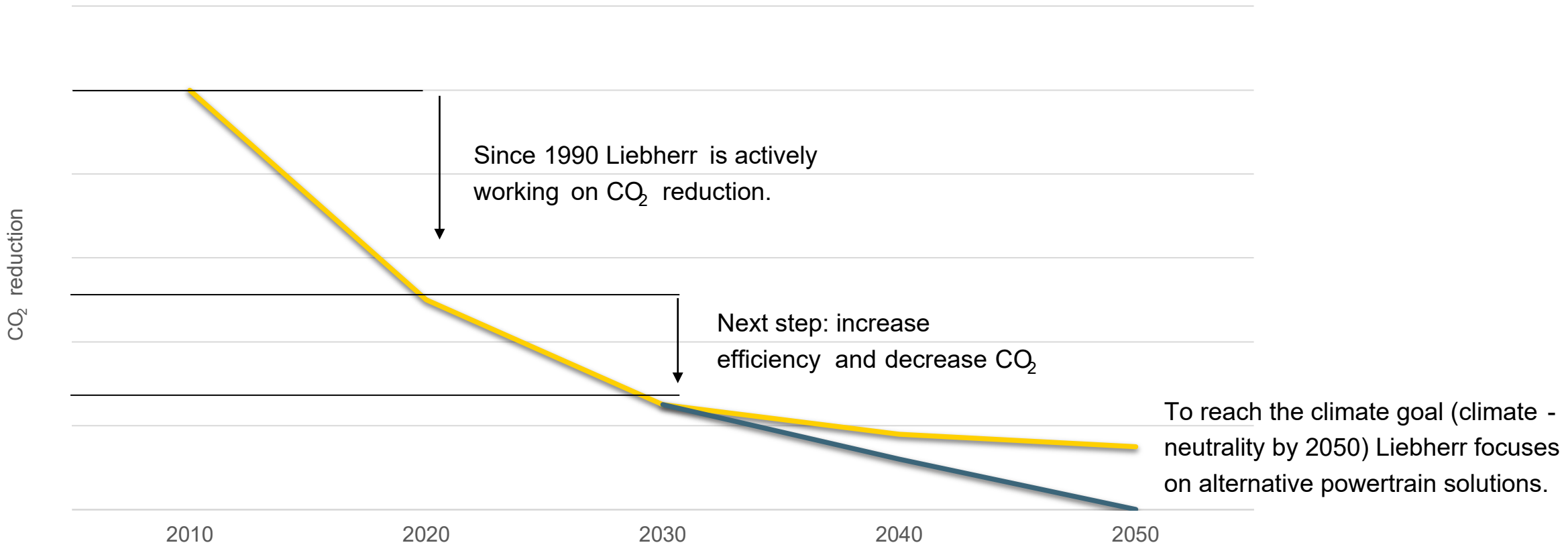


Agenda

1. Countdown to zero
2. Progression of future powertrains
3. Reduced emission technology
4. Summary & conclusion

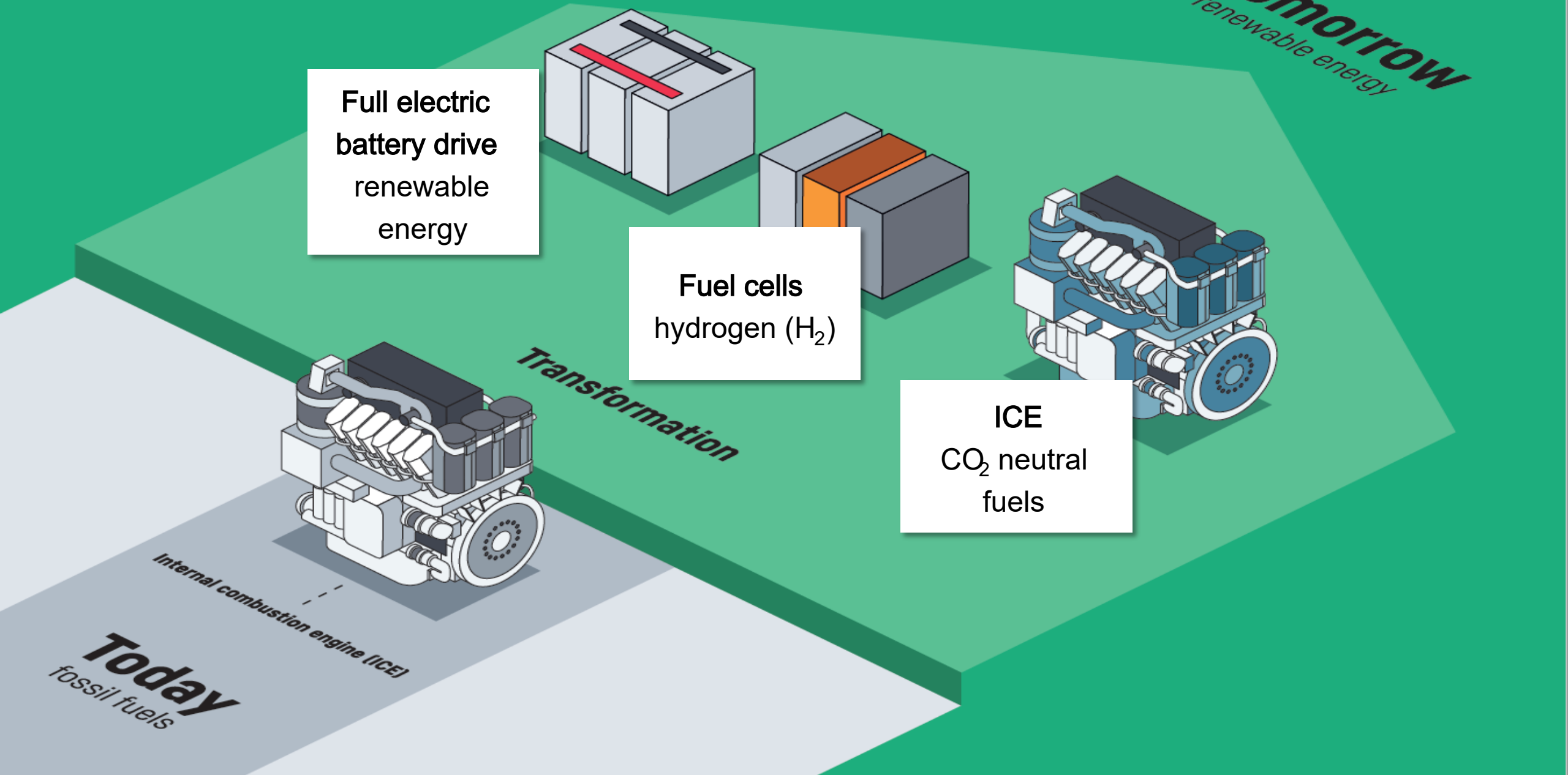
Countdown to zero

We have done a lot but still must do more



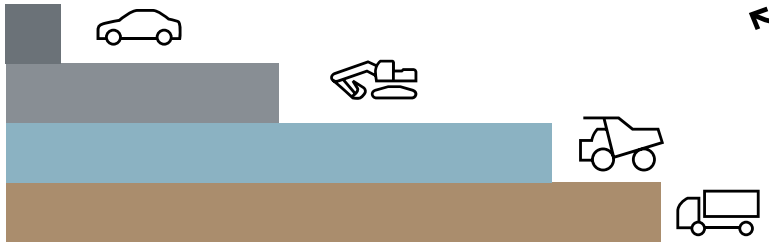
LIEBHERR

Progression of future powertrains

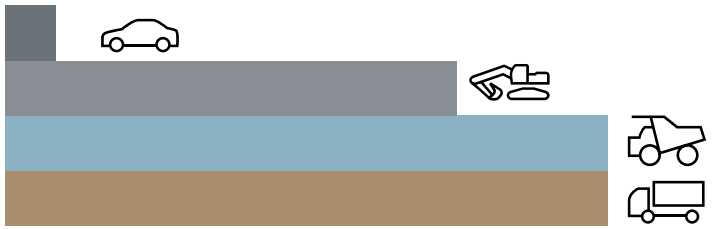


Different applications require different solutions

Energy/Day

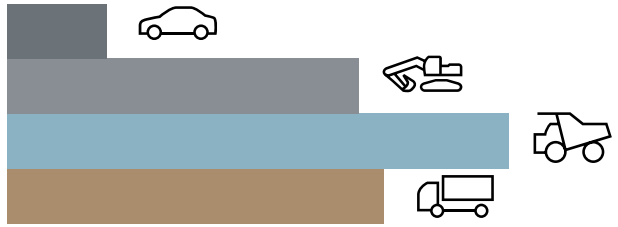


Powertrain/Life



Hours/Year

Duty factor



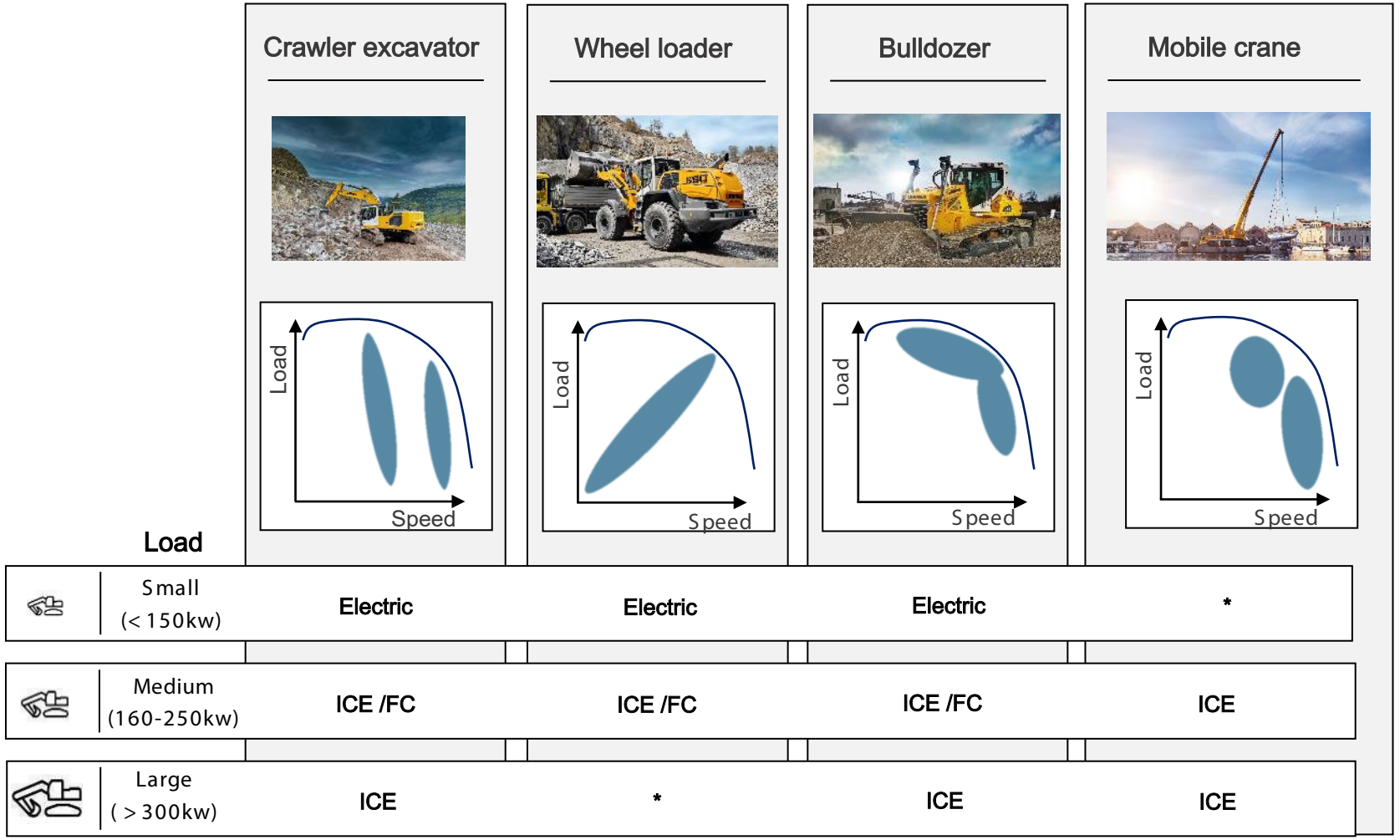
Requirements of heavy duty applications

- High energy usage
- Longer powertrain life
- Long running hours
- Higher duty factor

LIEBHERR

Progression of future powertrains

Load/power requirements and solutions



* no Liebherr application existing

LIEBHERR

Progression of future powertrains

Managing challenging conditions

Off-highway vehicles and machines

— Tough operating environment

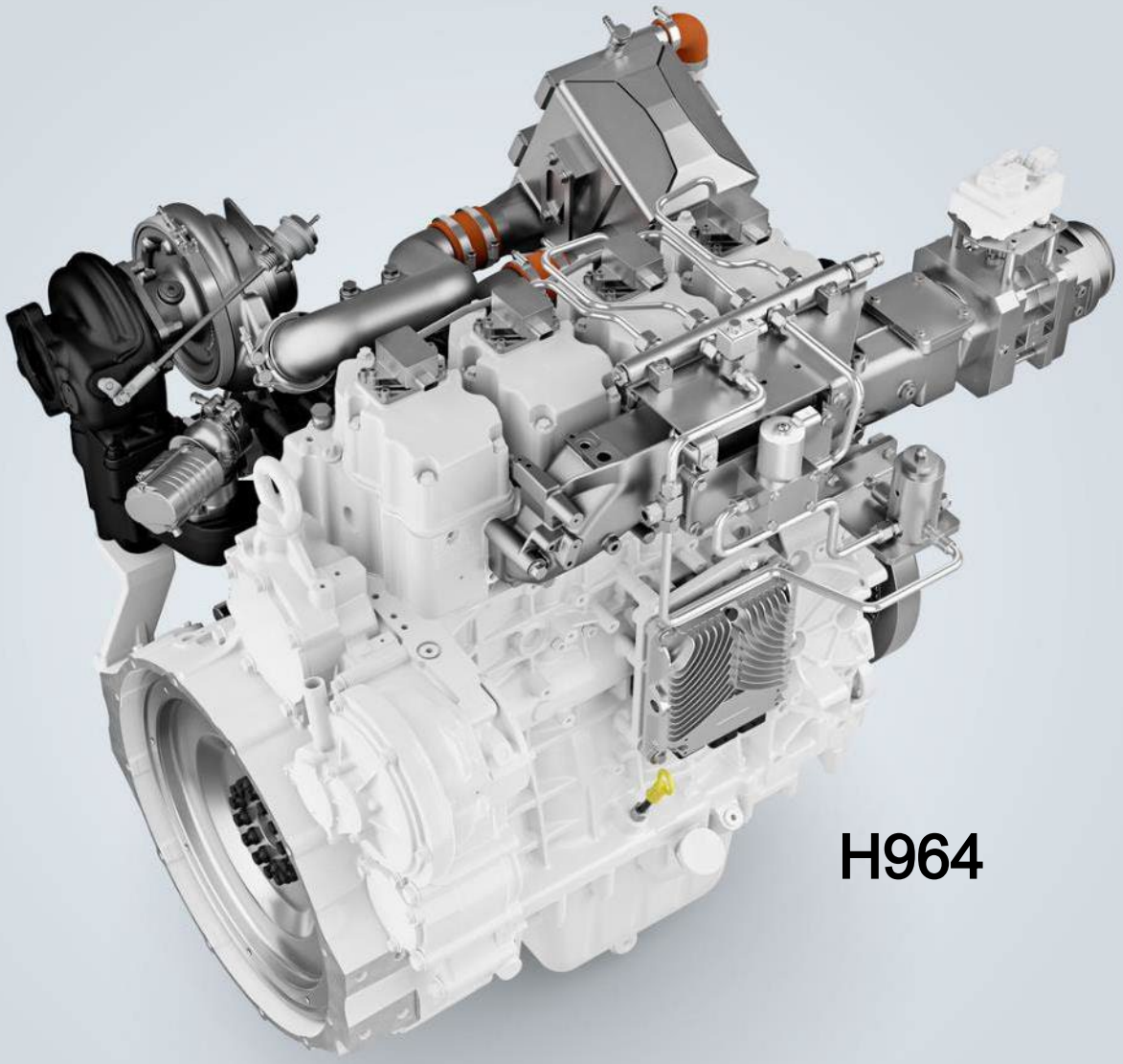
— Exposure to dirt, dust & temperature extremes

— On-site fueling and maintenance

— Lower airflow – no ram air cooling

— 3-shift, continuous operation

In these extreme, but common, conditions for off-highway machines, a battery-electric only solution may not fulfill the demands of a mid- & heavy-duty applications where an ICE is more capable.



Future progression of powertrains

Hydrogen ICE a perfect fit and a way forward

— Favorable cost-related alternative to diesel

— Fulfillment of zero CO_2 in all operation conditions

— Builds on existing ICE supply-chains, after-market and technical training

— Target: provide productivity comparable to diesel

LIEBHERR

Reduced emission technology

Key technologies for low emission ICEs

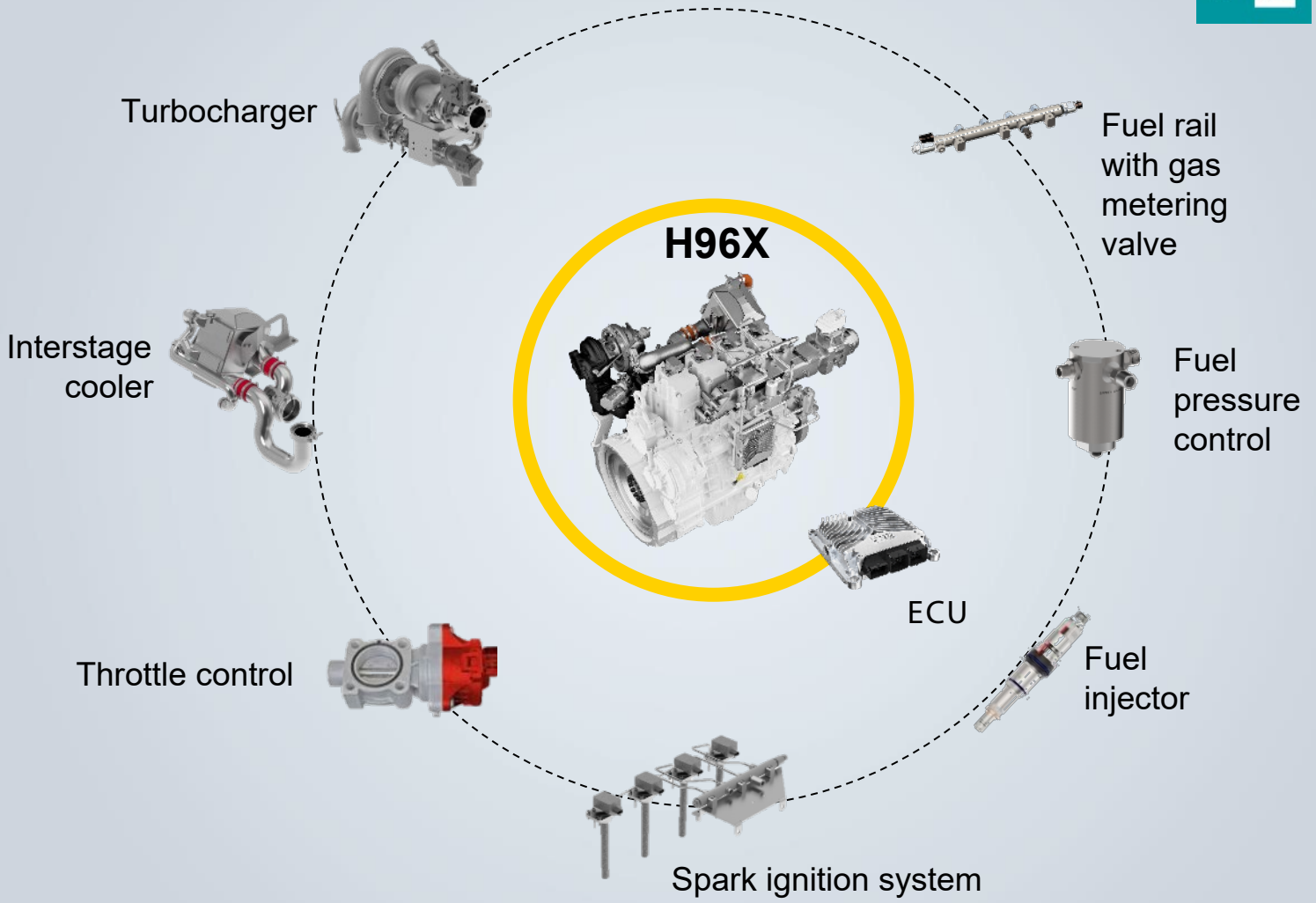
Main development targets

—High level of parts commonality with diesel ICEs

—Power density similar to diesel engines

—Efficiency > 40%

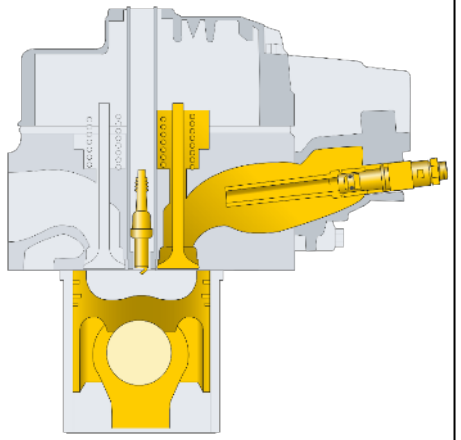
—Lifetime and maintenance intervals similar to diesel ICE



H_2 ICE fuel injection concepts

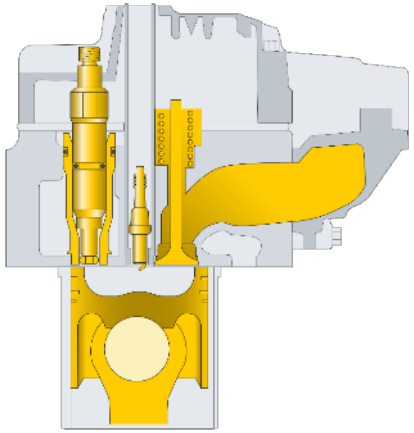
Port fuel injection (PFI) ≤ 15 bar

- 20 - 30% lower power density vs. diesel engines
- Good mixture homogenization
- Lower efforts for FIE application → shorter time to market



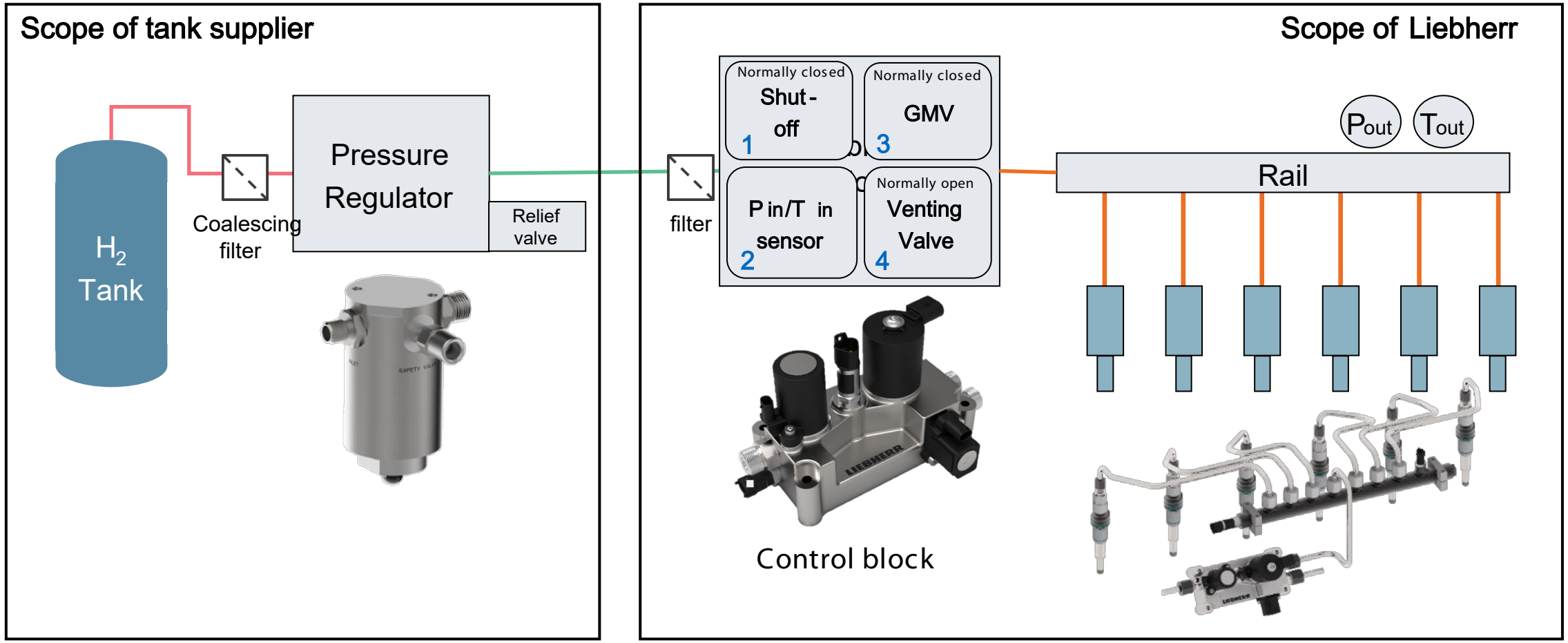
Direct injection (DI) ≤ 30 bar

- Target: power density similar to today's diesel engines
- Challenge in mixture homogenization
- Higher efforts for FIE application → longer time to market



Both solutions offer unique advantages.
Liebherr develops H2 fuel injection solutions for DI and PFI engines.

H_2 injection system layout for DI / PFI



Liebherr control block enables, at engine level, one component control & safety system

LIEBHERR

Reduced emission technology

The road to Liebherr H_2 engines on market

2020

idea

2022

LH prototype excavator R9XX H_2 with H966 engine @Bauma 2022.

Liebherr won the Innovation award in the category climate protection.

2025- future

1st Hydrogen ICE application – Wheel loader

Summary and conclusion

Open technology approach: Liebherr develops climate-friendly powertrains for future with applications incl. **FC and ICE, alternative fuels.**

ICE with alternative fuels (e.g., hydrogen) offer **advantages,** especially **for off-road applications** .

Liebherr believes the ICE remains a viable solution supporting future heavy-duty applications.

The concern is not the combustion engine itself, but the fuel that is burned.

Thank you.

LIEBHERR