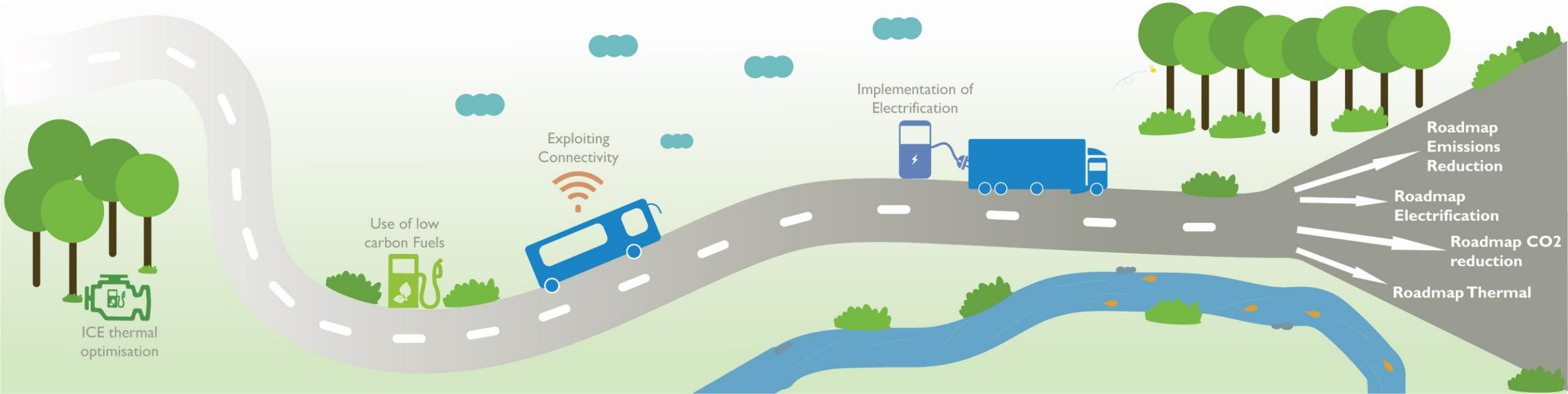
LONG RUN

Development of efficient and environmentally friendly LONG distance poweRtrain for heavy dUty trucks aNd coaches



Facts & Figures

- Start date: 1 January 2020
- Duration: 42 Months
- Total budget: 33.0 M€
- EC funding: 24.9 M€
- EC contract number: 874972

The project consortium consists of 30 partners from 13 EU countries

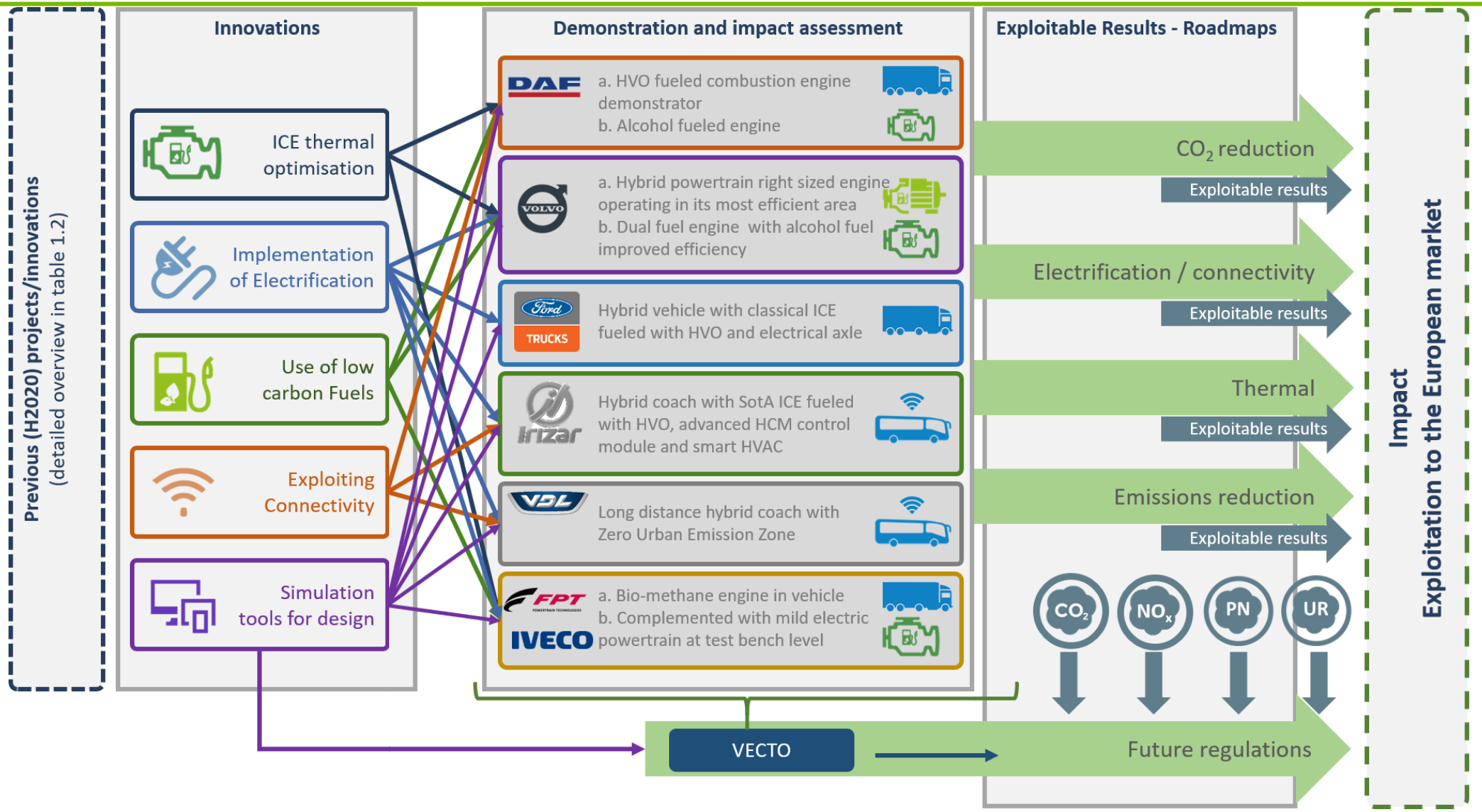
Website: www.H2020-longrun.eu

Reduce impact on environment

Objectives

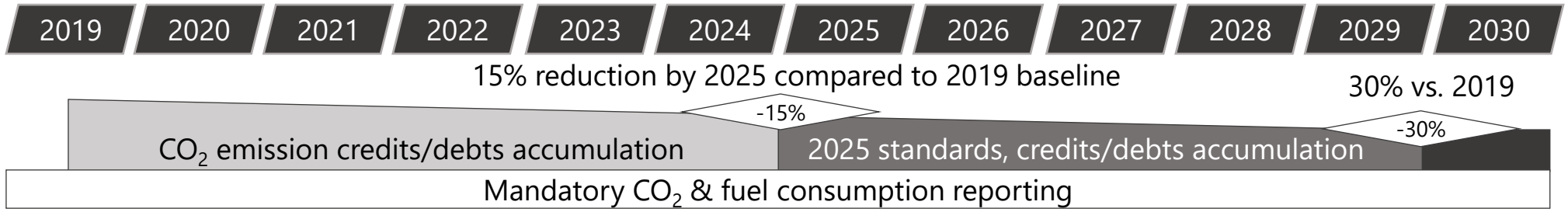
- **Objective 1:** To achieve over **10% energy saving** (tank to wheel (TtW)), excluding effects of plug-in hybrids) and correspondent CO2 reduction
- **Objective 2:** Realization of robust **ICE engine technology for use of future fuels** (HVO, dual fuel mixtures), to achieve a major (>90%) CO_2 reduction well to wheel
- **Objective 3:** To achieve an internal combustion **engine performance which reaches a 50%** target in terms of peak thermal **efficiency**
- **Objective 4**: **Aftertreatment systems integrated into hybrid powertrains** with advanced engines to achieve e.g. **reduction** of **NOx, CO** and **hydrocarbons** in an **extended environmental conditions**
- **Objective 5**: To achieve a multiscale backward/forward **simulation framework to support the design and development of efficient powertrains, including hybrids**
- **Objective 6**: To **demonstrate the optimal combination of *technologies*** by validation on engine test rigs/ test track/on road with the realization of **demonstrator** engine, drivelines and vehicles with the key innovations implemented.

Project structure and roadmaps



Political impact

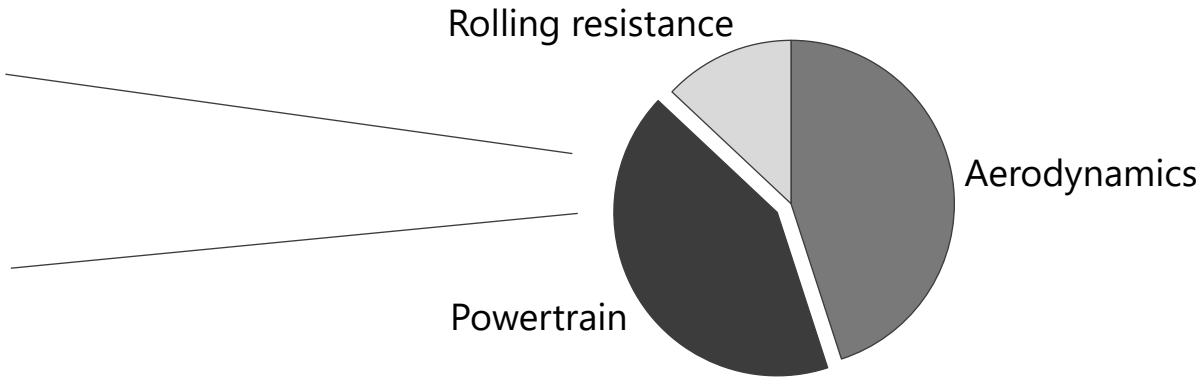
EU



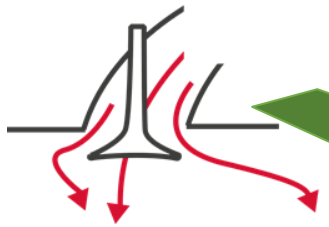
Vehicle & powertrain optimizations mandatory

ICE identified as <u>main</u> contributor

- Implementation of new technologies & further engine optimizations required



Identified pathways

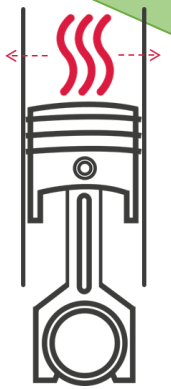


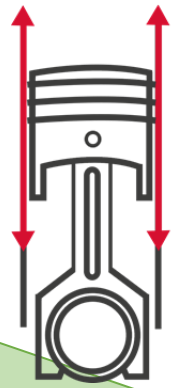
Gas exchange

- TC technology
- EGR operation

Heat transfer

- Insulation
- Fast mixture formation



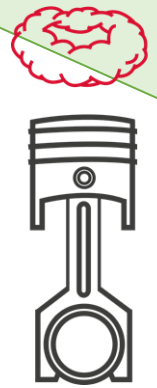


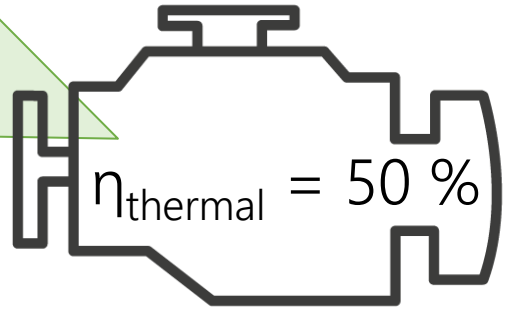
Engine friction

- Auxiliaries
- Piston side forces
- Low viscosity oil

Combustion

- Compression ratio
- High cylinder peak pressure
- High injection flow rate
- Alternative fuels

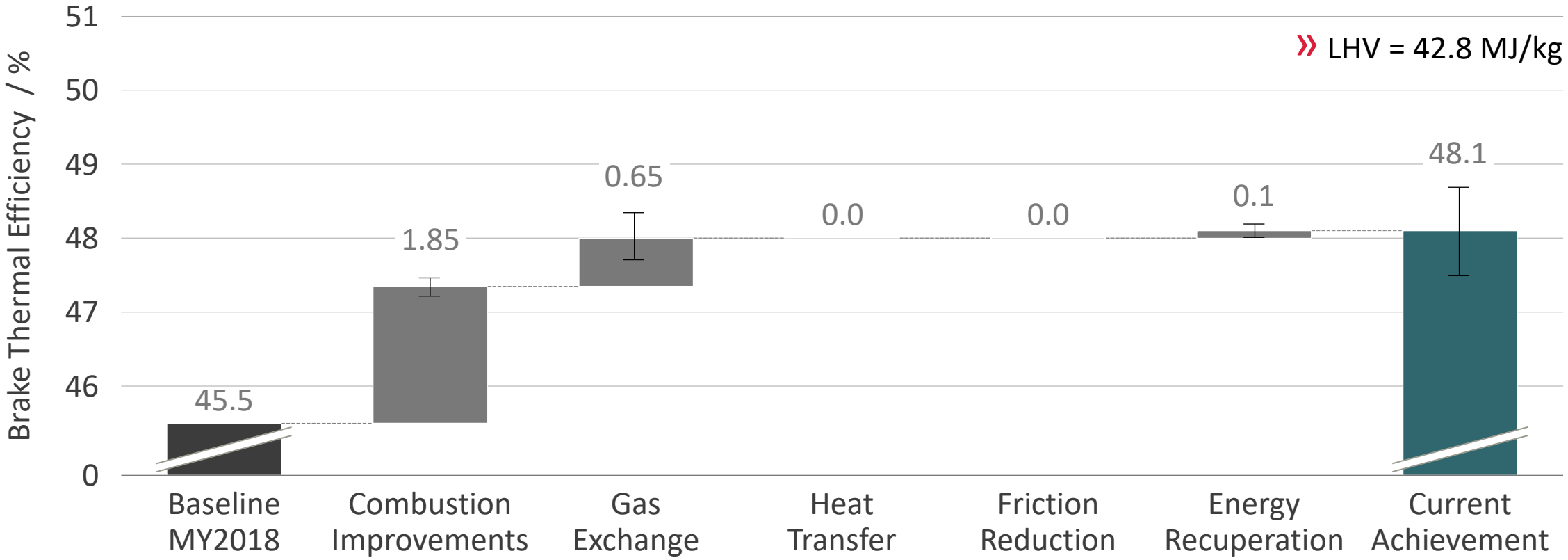




CI diesel ICE improvements Summary

» STATUS M24

Best efficiency point
n = 1200 min^{-1}, ~75 % of full load, $BSNO_X$ = 8-10 g/kWh



UCC 2

CI – Combustion improvements
Compression ration & peak cyl. pressure

DESCRIPTION

- Increased compression ratio (CR) enhances efficiency of thermodynamic combustion process as long as peak cylinder pressure (PCP) is not limited
- By limited PCP capability the higher peak cylinder pressure must be compensated by retarded beginning of injection
- Increased peak firing pressure helps to avoid fuel consumption penalties

ADVANTAGES

- Increased compression ratio to increase efficiency

RISKS / CHALLENGES

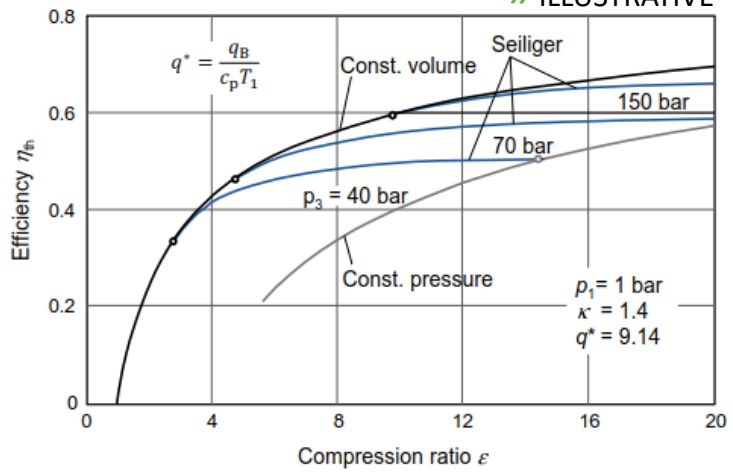
- Higher thermal and mech. stress require more durable engine components
- Smaller piston bowl volume require adaption of injector tech. to keep good mixture formation
- Increased NO_X emissions have to be compensated with improved EATS

ASSESSMENT

BTE impact	Around 1.7 %-point BTE improvements
Invest	Moderate invest expected
Maturity 2025-2030	Medium/high maturity level

Impact: low — medium — high

» ILLUSTRATIVE



UCC 2

CI – Combustion improvements
Fuel injection system

DESCRIPTION

- Modern HD diesel engines use common rail systems, systems with up to 2,700 bar pressure are state-of-the-art, whereas 3,000 bar is under development
- “Leakage free” injectors increase injection pressure with affecting fuel consumption positive
- Higher pressure breaks the trade-off between good air utilization at low engine speeds and high engine output power
- Strong benefits by high pressure only in combination with EGR

ADVANTAGES

- Reduced PM emission
- Enables further optimization of PM/NO_X trade off (only with applied EGR concept)
- Enables good mixture formation for high CR concepts

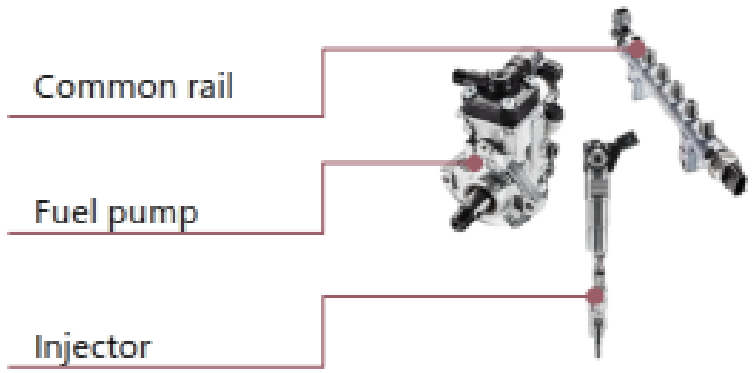
RISKS / CHALLENGES

- Lower reliability due to the increased stress caused by high pressure
- Increase of frictional losses
- Higher costs (improved injectors / components required)

ASSESSMENT

BTE impact	Around 0.5 %-point BTE improvements by better air utilization
Invest	Moderate invest expected
Maturity 2025-2030	Medium/high maturity level, ready for series production

Impact: low — medium — high



Source: Denso

UCC 2

CI – Combustion improvements Alternative fuels – HVO

DESCRIPTION

- Hydrotreated Vegetable Oil (HVO) is a transparent paraffinic and a most-promising alternative to diesel fuel
- Feedstock and industrial processes availability
- Increased low heating value and more reactive ignitability enables > 2 % fuel economy benefit compared to diesel
- HVO is a drop-in capable fuel
  - Fulfills EN 15940 regulation and calibration changes not required

ADVANTAGES

- Drop-in capability
- Significant lower PM emission due to absent of aromatics
- Excellent ignitability also at cold start due to high Cetane number
- > 90 % WtW CO_2 reduction

RISKS / CHALLENGES

- Phase out of HVO made from high indirect land use change from 2022 due to EU RED II

ASSESSMENT

BTE impact	Max. 0.3 %-point BTE improvements by better combustion behavior
Invest	Low invest
Maturity 2025-2030	Already released for series application

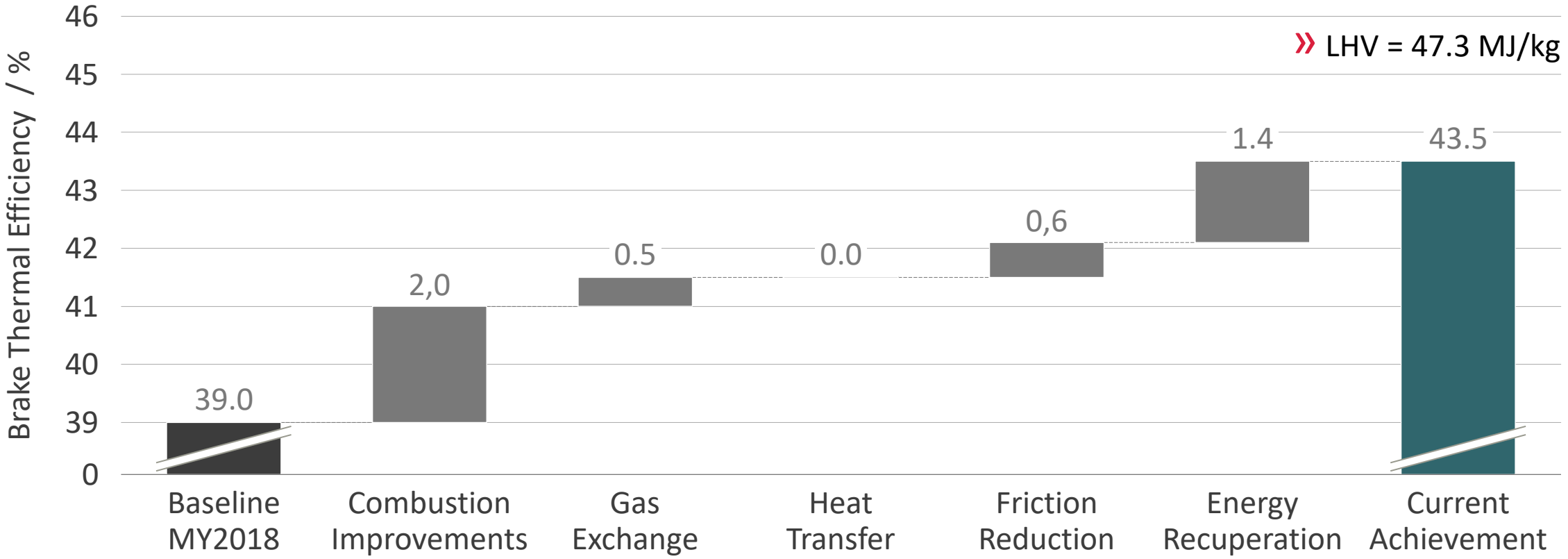
Impact: low — medium — high

Source: Neste

SI natural gas ICE improvements Summary

» STATUS M24

Full load efficiency @ n = 1100 min^{-1}



UCC 2

SI – Combustion improvements Application of high CR & EGR

DESCRIPTION

- Increased compression ratio enhances efficiency of thermodynamic combustion process as long as knock tendency is not present
- Application of EGR suppresses knock tendency without retarding spark timing at high engine loads
- In part load operation, EGR allows to de-throttle the engine operation

ADVANTAGES

- Increased compression ratio to increase efficiency
- Fuel consumption benefits due to de-throttling of the engine

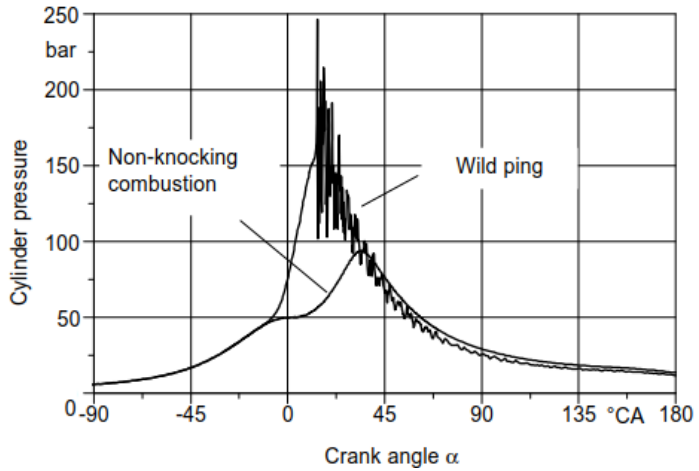
RISKS / CHALLENGES

- Increased combustion temperatures enhance knock tendency
- Components of EGR path have to be durable for high exhaust temperatures at full load
- Implementation of swirl charge motion

ASSESSMENT

BTE impact	Around 2.0 %-point BTE improvements
Invest	Moderate invest expected
Maturity 2025-2030	Medium/high maturity level

Impact: low medium high



UCC 2

SI – Gas Exchange Intake Miller

DESCRIPTION

- Miller cycle increases ratio between expansion and compression
- Miller reduced combustion knock tendency due to reduced temperature at the end of compression and of combustion process
- Late IVC supports swirl formation for EGR compatibility
- Potential cylinder filling losses in part load can be balanced with increased boosting pressures

ADVANTAGES

- Potential to increase the compression ratio without increasing combustion process temperature that lowers knock tendencies
- Increased EGR compatibility

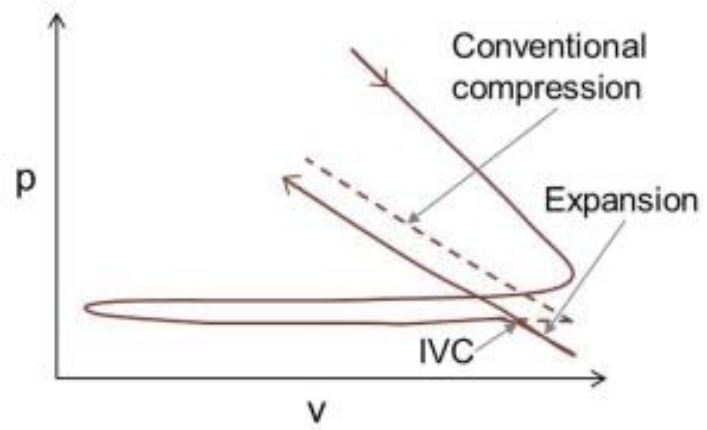
RISKS / CHALLENGES

- High degree of boosting required to compensate for less cylinder filling
- Lower NO_X reduction efficiency compared to EGR

ASSESSMENT

BTE impact	Around 0.2 %-point
Invest	Moderate invest expected
Maturity 2025-2030	High maturity level, series production

Impact: low — medium — high



Outlook – Next 6 months

1 DAF development

- Single cylinder engine
  - Multi pulse injection
  - Intake Miller timings
  - Exhaust port insulations
  - HVO
- Multi cylinder engine
  - High efficiency eTurbo

2 VOLVO development

- Validation of high efficiency combustion on single cylinder engine
- Initial multi cylinder engine investigations

3 FPTi development

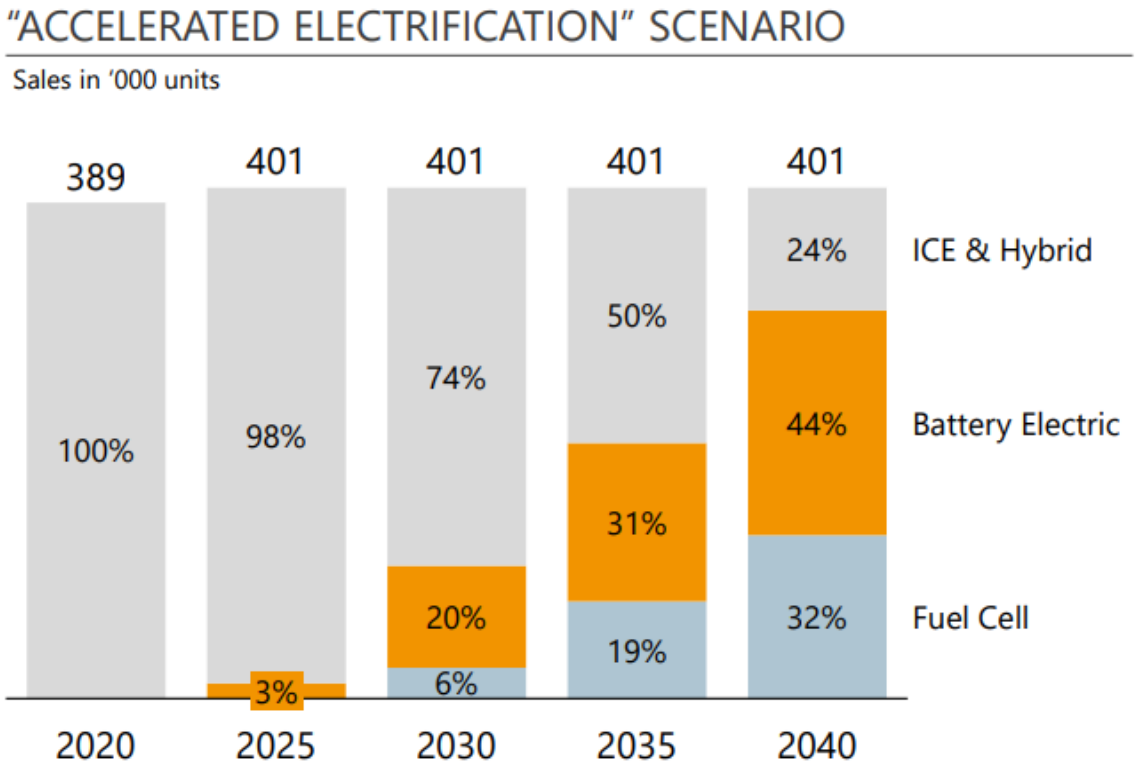
- Validation of Swumble™ combustion concept on single cylinder engine
- Initial analysis of SI pre-chamber technology on thermal efficiency
- Initial analysis of energy recovery system e.g. eTurbo, WHR

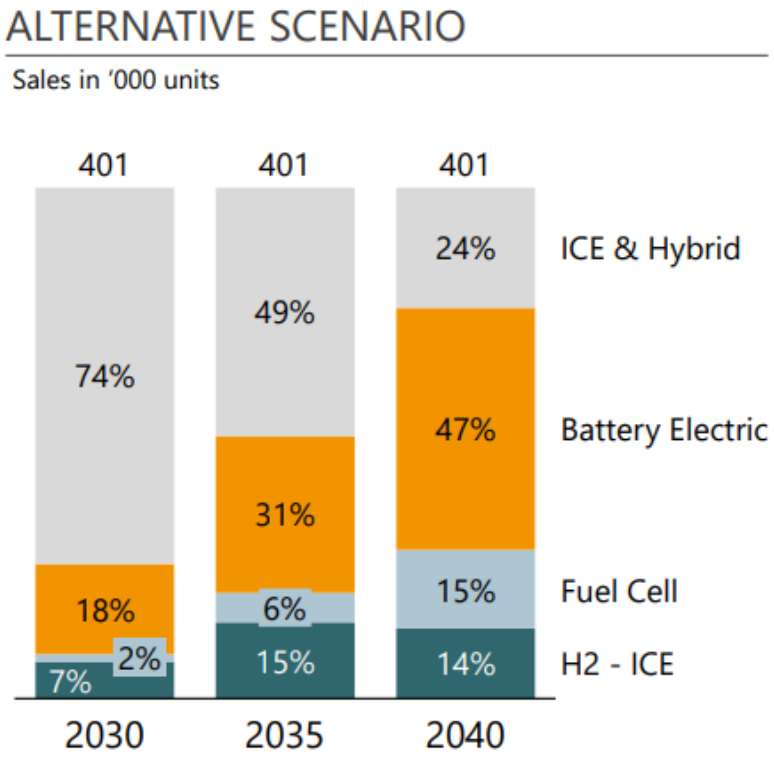
4 Coatings

- Further investigation of combustion chamber insulations on single cylinder engine
  - Thermal piston coating
  - Thermal flame deck coating

Still high share of ICE powered powertrain in 2030

- Sales forecast scenarios for medium- and heavy-duty trucks in Europe





Source: Why internal combustion engines and fuel cells will both play a role in a future hydrogen society, Engine congress Baden Baden, FEV Consulting GmbH

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LONG RUN

Looking forward to an interesting discussion

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