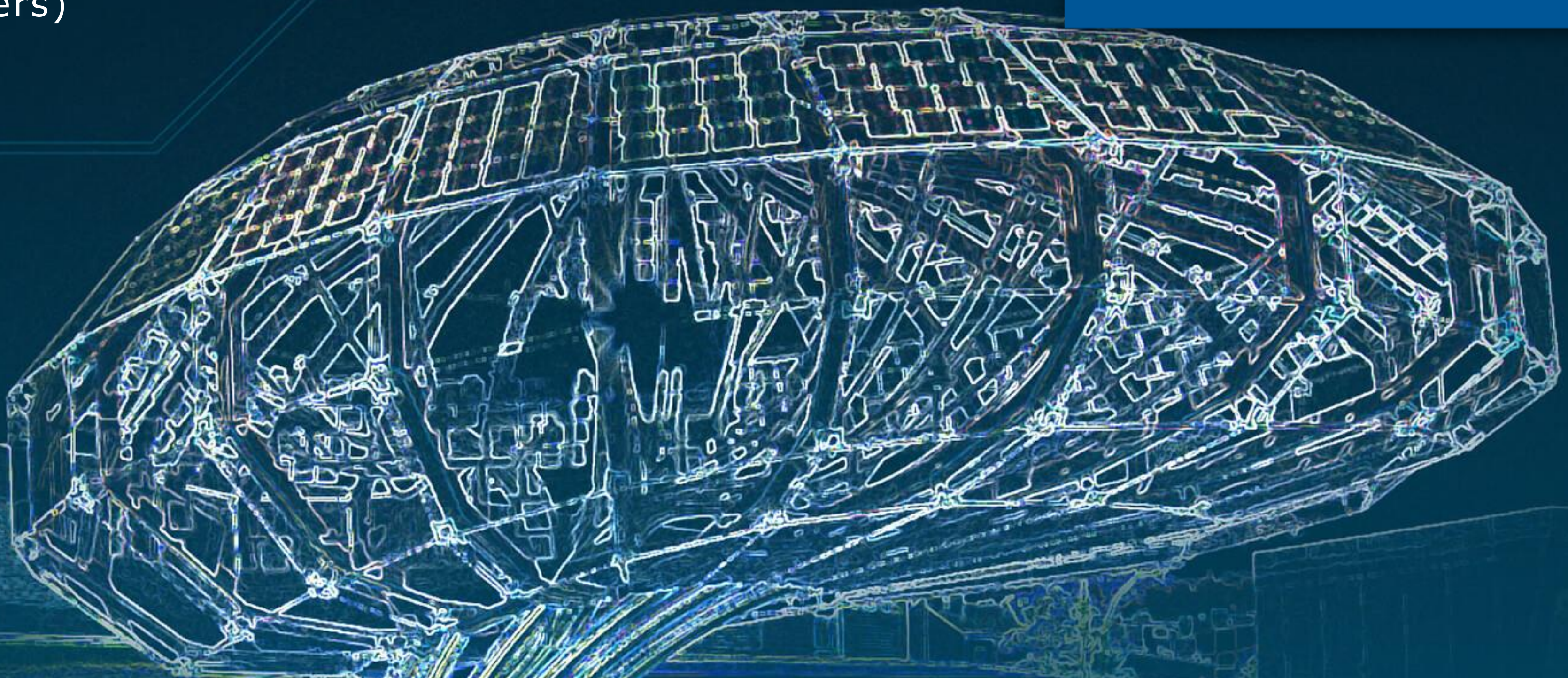
AVL List GmbH (Headquarters)



Requirements of CV on future energy carriers

Joint symposium Waseda University
May 20, 2019

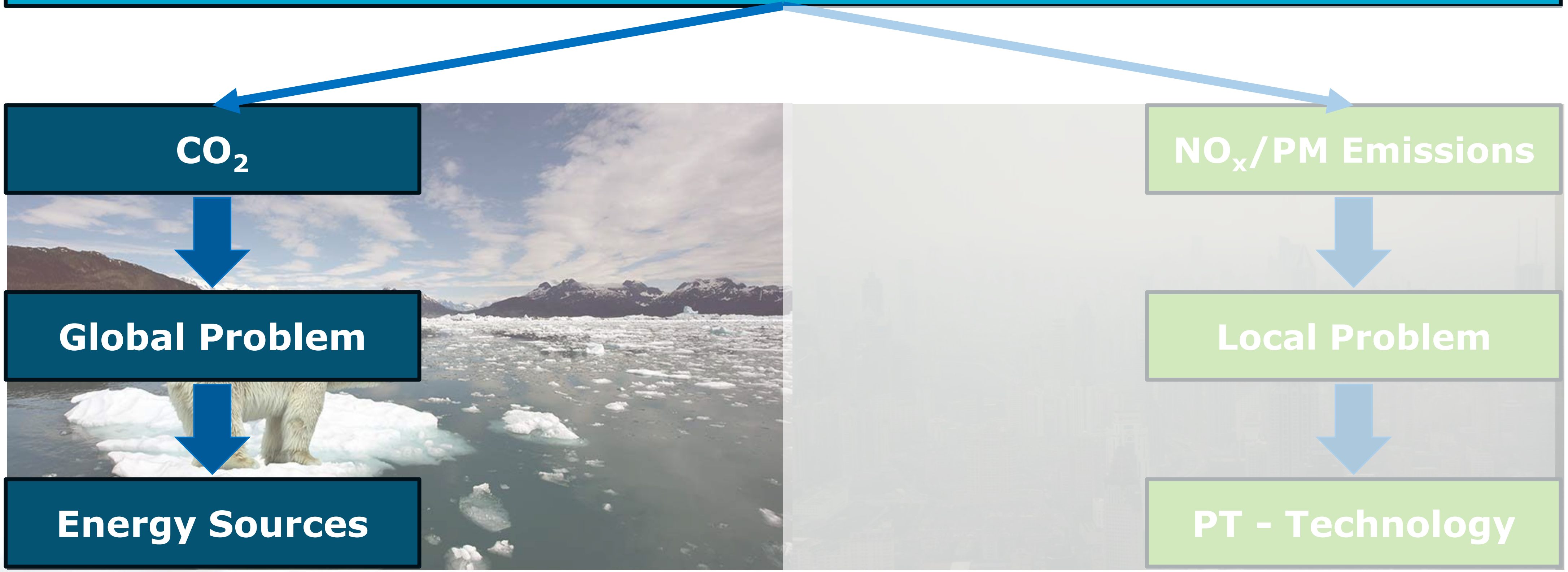
Content

Requirements of CV on future energy carriers

- Sustainable Transportation and Classification of emission
- Contribution of commercial transport on CO_2 emission
- CO_2 legislation
- Typical transportation tasks
- Technical solution
- Technology for lowest emission
- Conclusion

Requirements of CV on future energy carriers
Classification of emissions

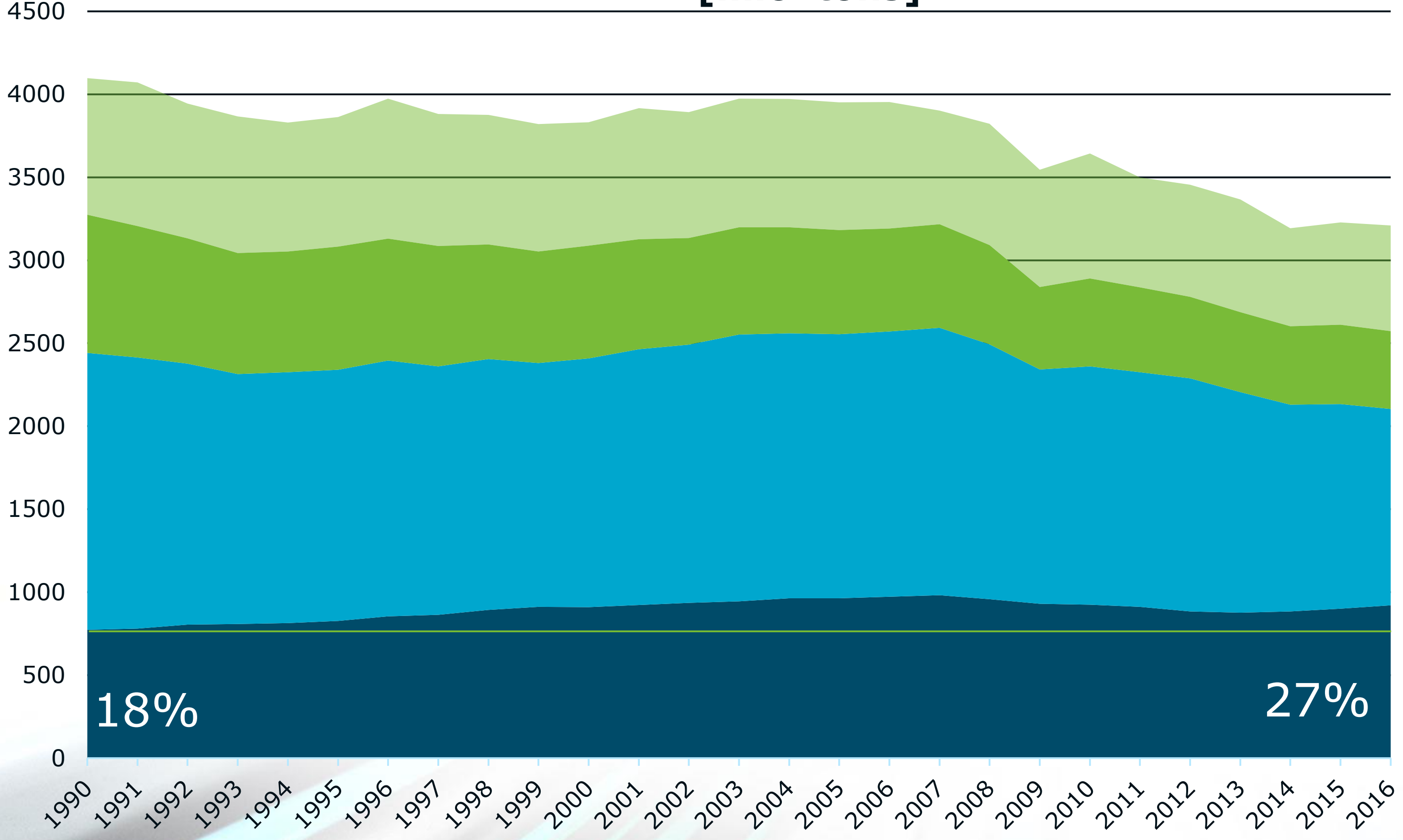
Problem of global CO_2 Emissions and local NO_x/PM… emissions



We need an economical and commercial solution in the next 10 years

Requirements of CV on future energy carriers
Development annual of CO_2 Emissions EU28

EU28 annual CO_2 emission, Fuel combustion
[mio. tons]



Source: European Environmental Agency

Since 1990:

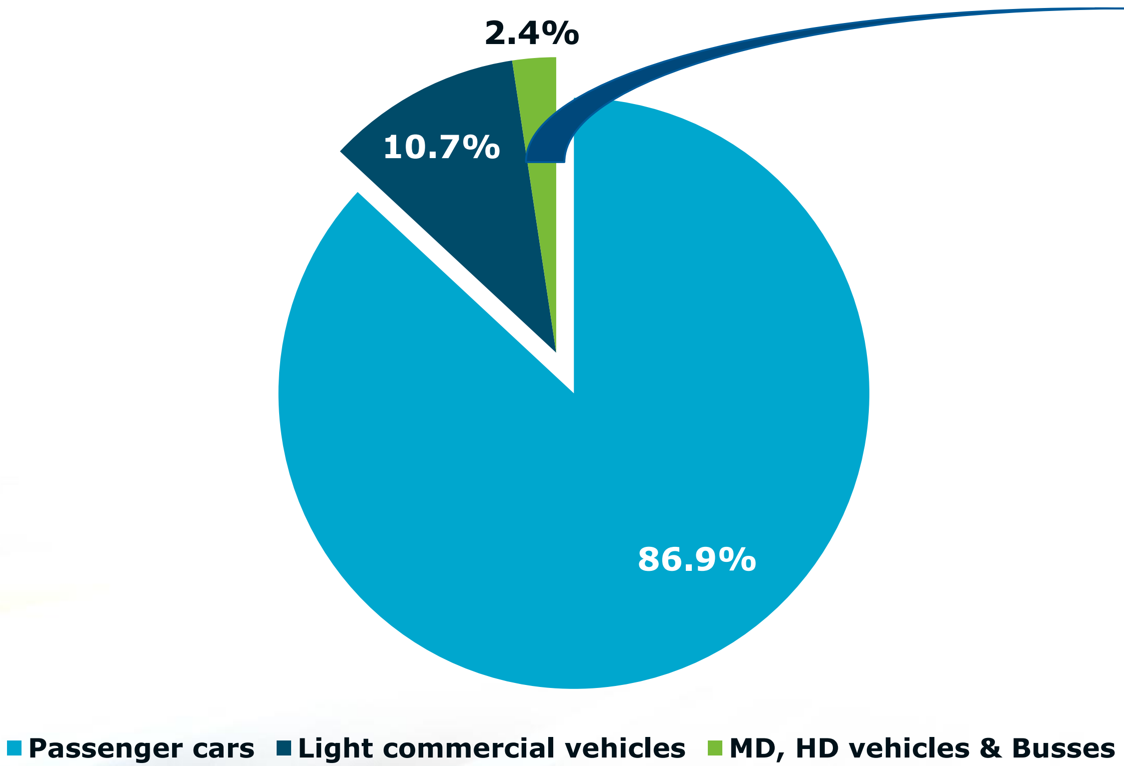
Total CO_2 Emissions decreased by 22%

In the meanwhile CO_2 emissions for transportation increased by 20 %

27% of Europe's CO_2 emissions from Transportation

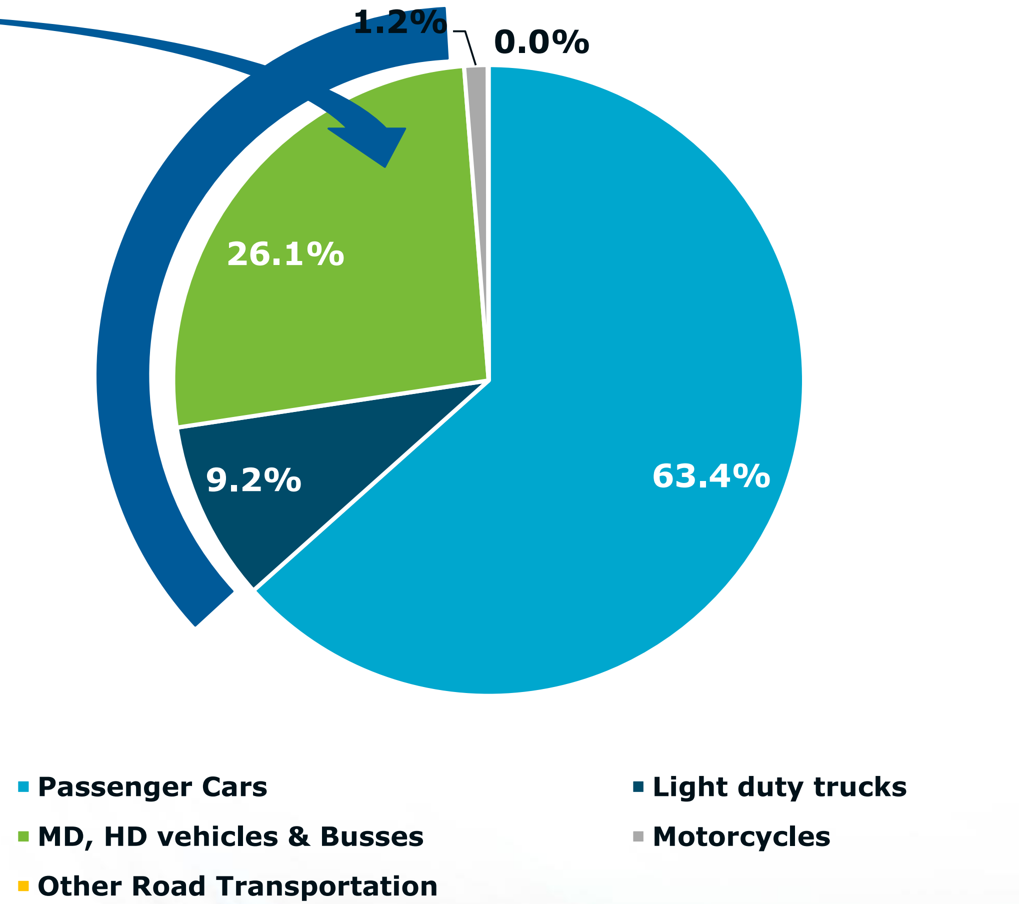
Requirements of CV on future energy carriers
Contribution of goods transport on CO_2 Emissions EU28

Modular split EU28 vehicle fleet [%]



Source: ACEA

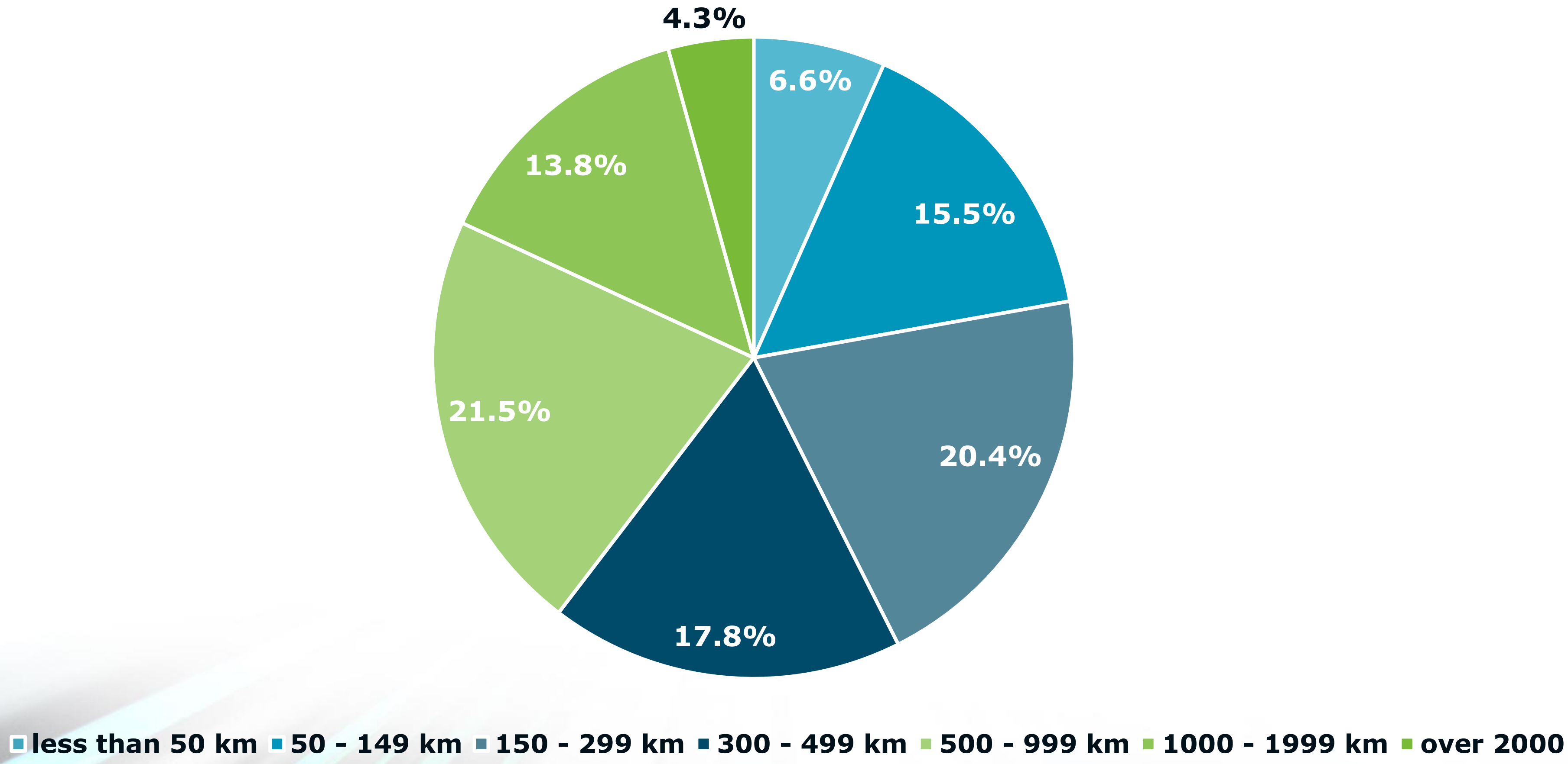
Modal split road transport CO_2 emission [%]



13 % of entire vehicle fleet responsible for 35 % of CO_2 emissions

Requirements of CV on future energy carriers Distributor transport vs. long/line haulage

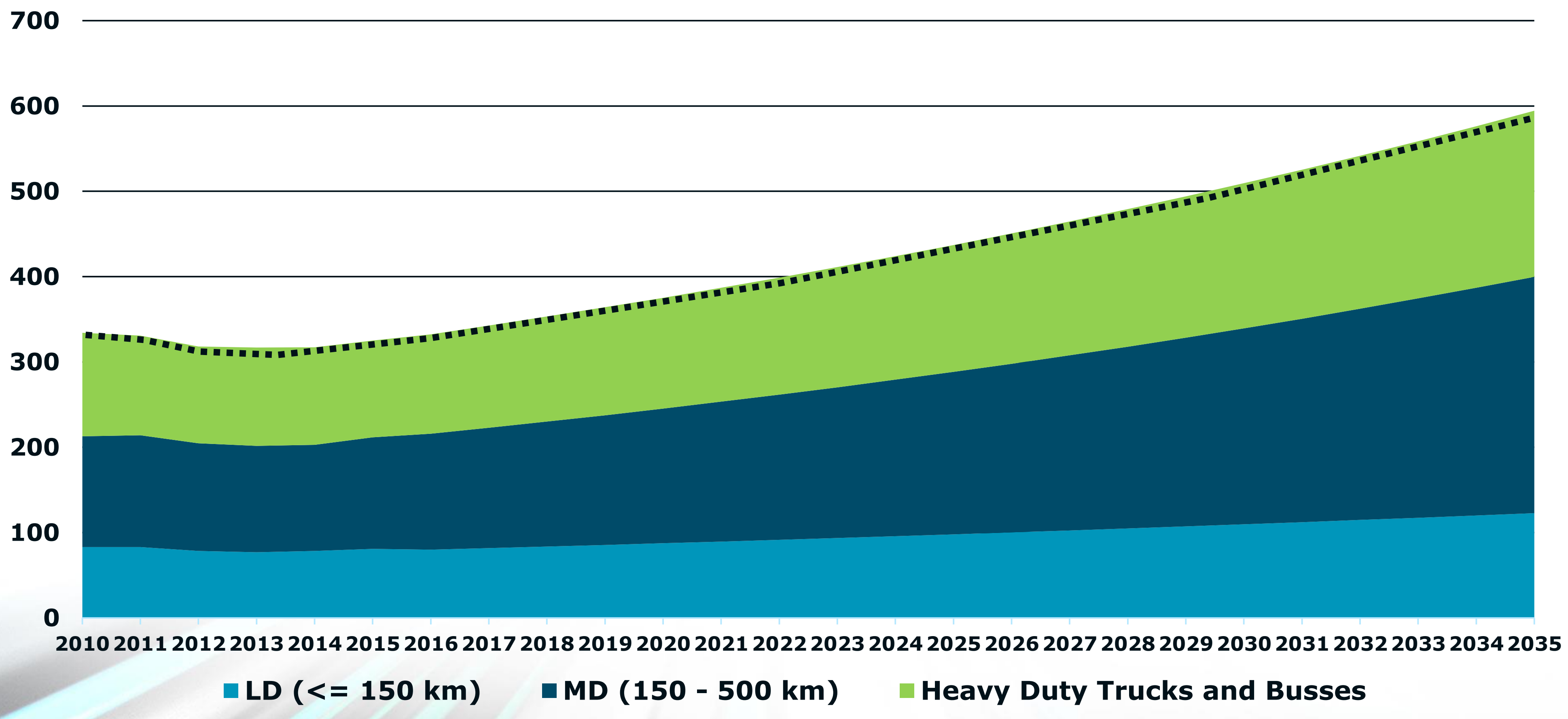
Goods transport distance EU28 [t-km]



23 % local, 38 % mid range distribution and 39% long haulage transport

Requirements of CV on future energy carriers
Future transport scenario EU28

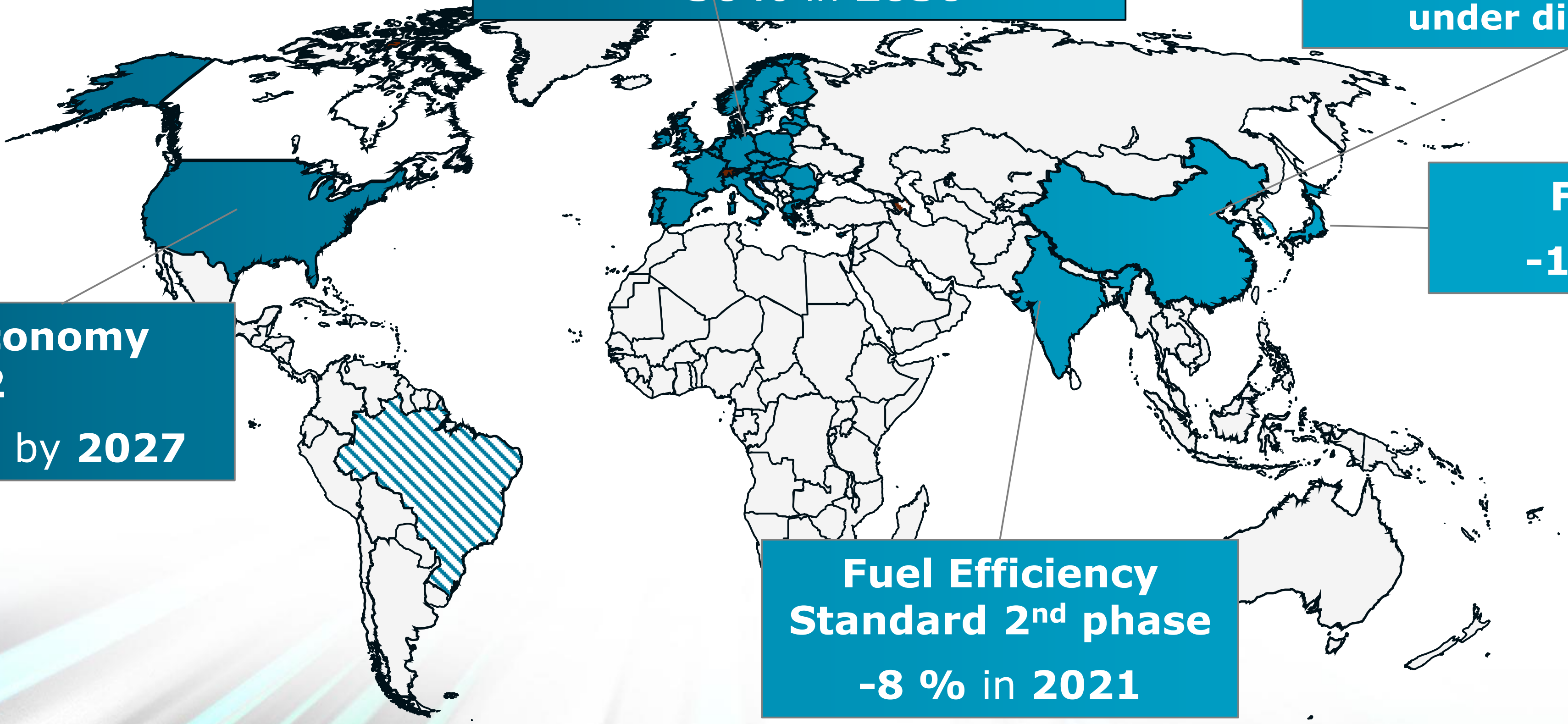
Probable future road transport CO_2 scenario
[mio. tons]



35 % increase in road transport caused CO_2 emissions expected between 2020 and 2030

Requirements of CV on future energy carriers
Worldwide fleet CO_2 trends

→ Consequences for engine & vehicle



Provisional agreement EU parliament & council

-15% in **2025**
-30% in **2030**

Fuel consumption limitation stage 4

Introduction 2025

Method and targets under discussion

FES Phase 2

-13 % in 2025

GHG & Fuel Economy Phase 2

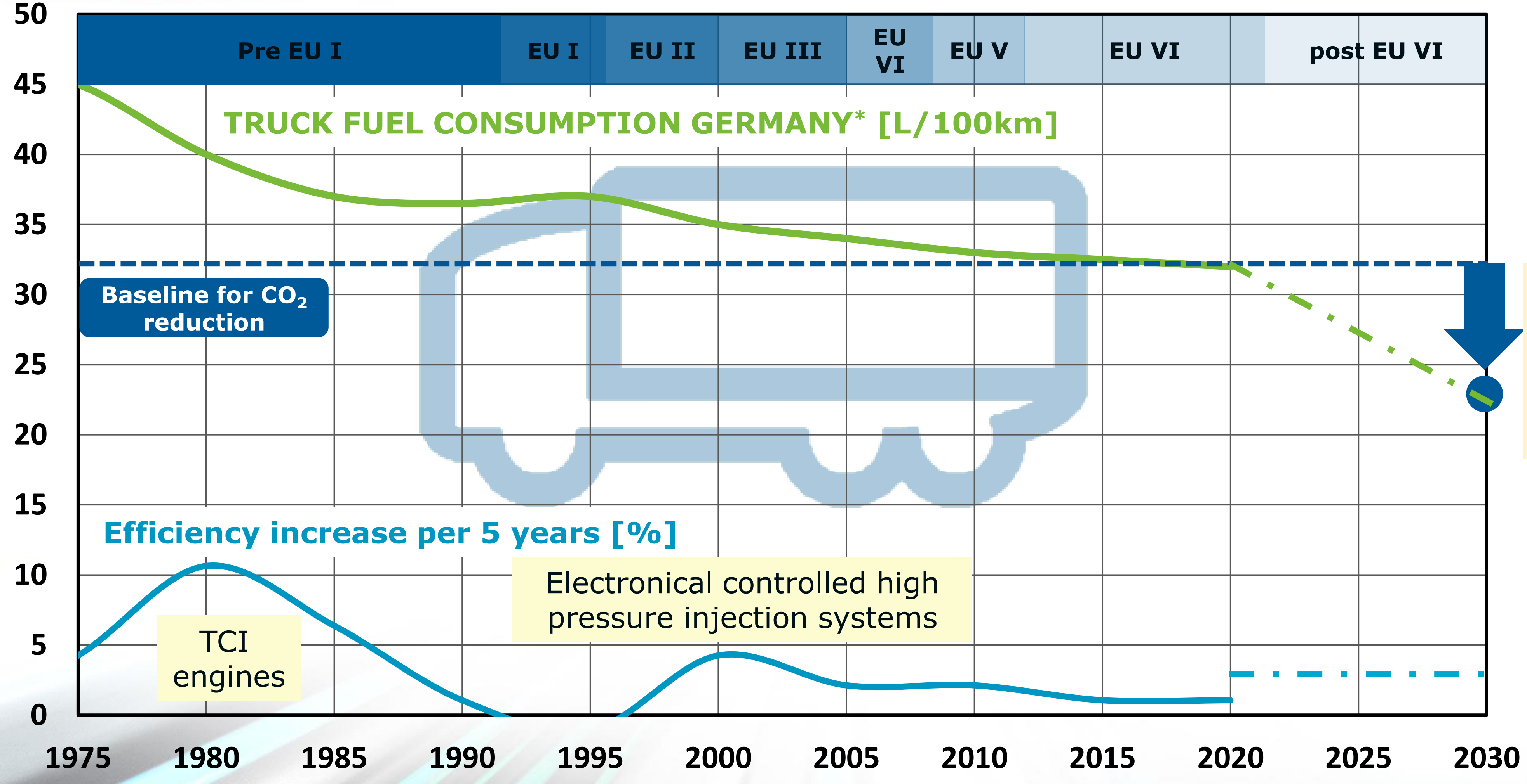
-25% expected by **2027**

Fuel Efficiency Standard 2nd phase

-8 % in **2021**

Global trends towards 15% / 30% CO_2 reduction by 2025 / 2030

Requirements of CV on future energy carrie
Impact of EU CO_2 fleet standards



In the next 10 years there are 3% annually required

*Source Lastauto Omnibus 4/2014

Past 20 years average annual efficiency increase ~ 1,5% was achieved

USA EPA CO2 and Fuel Consumption

Phase 1 and Phase 2 – Engine Standards

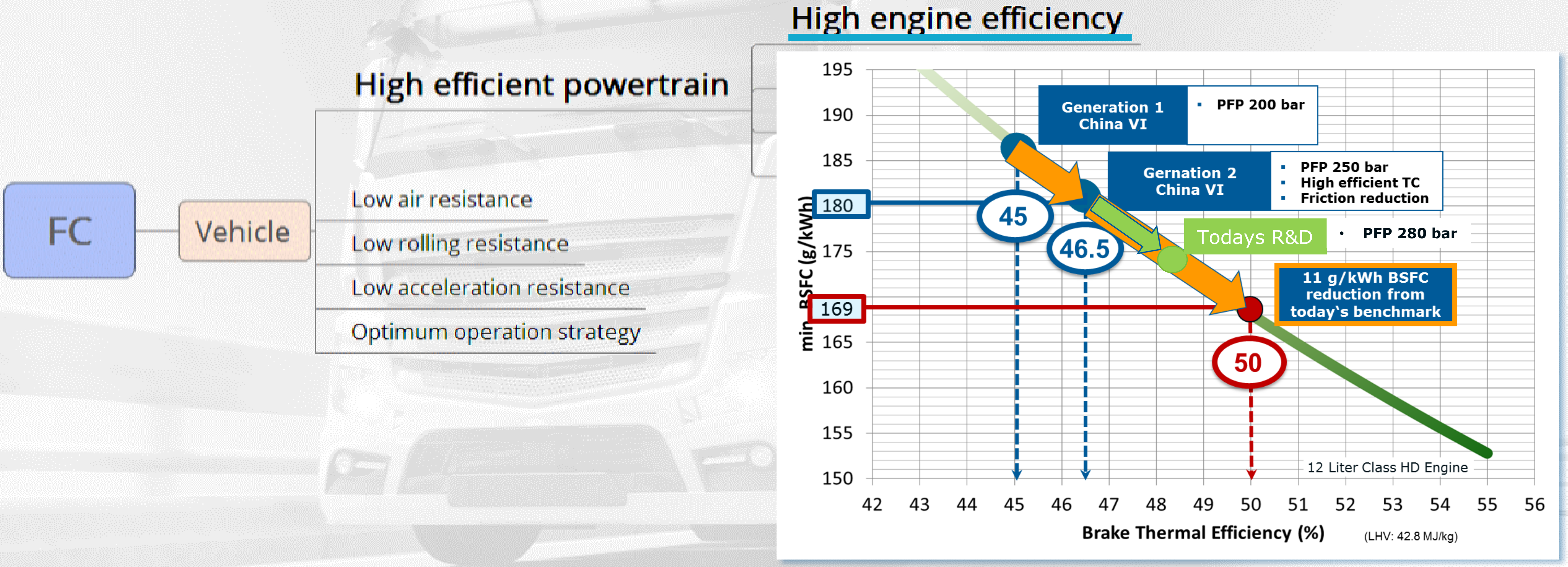
	MY		~BSFC Minimum g/kWh	BSFC in RMC g/kWh	Heavy Heavy Duty - Tractor
($g\ CO_2$/ hp-hr)	2014-		189	199	475
	2017-	-3%	182	193 ^{190}	460 ^{455}
	2021-	-5%	178	187	447
	2024-	-6%	173	183	436
	2027-		169	181	432

BTE ~ 50%

Test cycles: RMC (tractor engines), transient duty cycle (other engines); certification as tractor and vocational engine: both duty cycles.
Reweighting of RMC modes for Phase 2.
CH_4: 0.10 g/hp-hr (transient duty cycle)
N_2O: 0.10 g/hp-hr (transient duty cycle)
LHD: use in Class 2b-5 vehicle, MHD: Class 6-7, HHD: Class 8

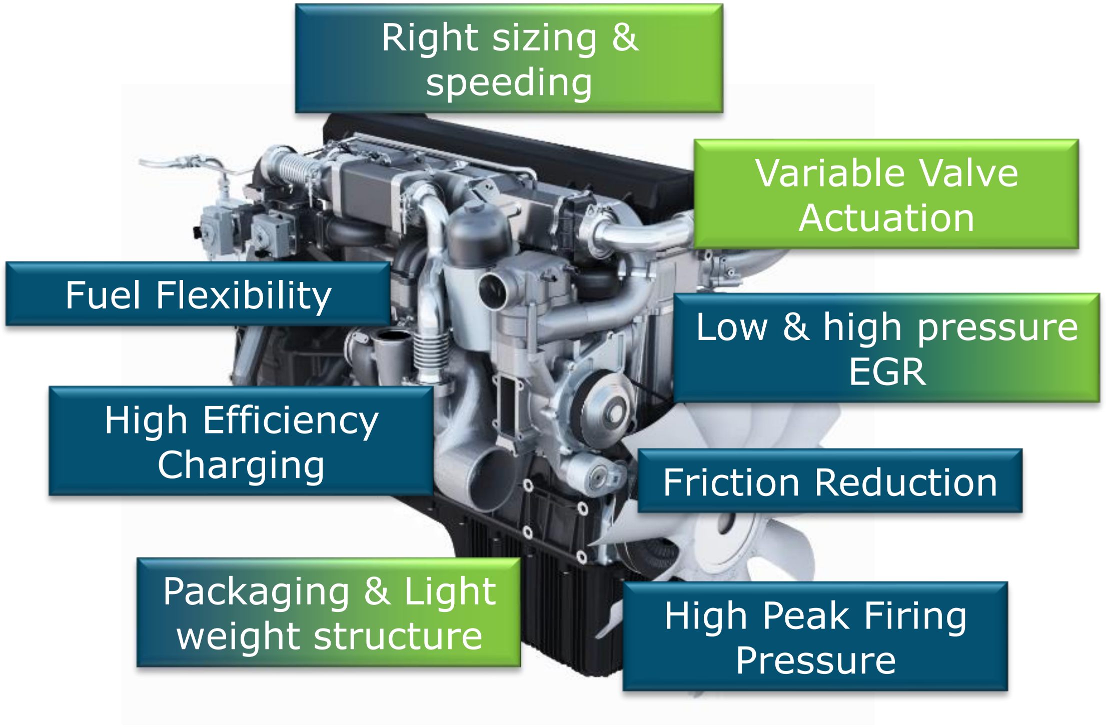
BTE above 50%
Definition of BTE relevant parameters

A further BTE increase above 50% means a BSFC reduction of ~ 11 g/KWh



Requirements of CV on future energy carriers
Future ICE technologies

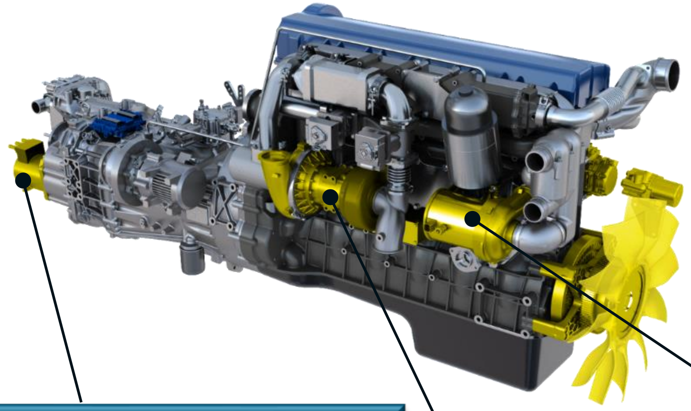
- **ICE remains dominant main propulsion for future HD powertrains**
- **Next generation ICE will require significant upgrades:**
  - Increase of thermal efficiency
  - Reduction of losses
  - Flexibility / Tailoring
- **~ 33 % of the vehicle CO_2 reduction via the ICE**
- **Vehicles on the market in 3-5 years**



CO_2 Emission

FC improvement potential next generation engines 3-5 %

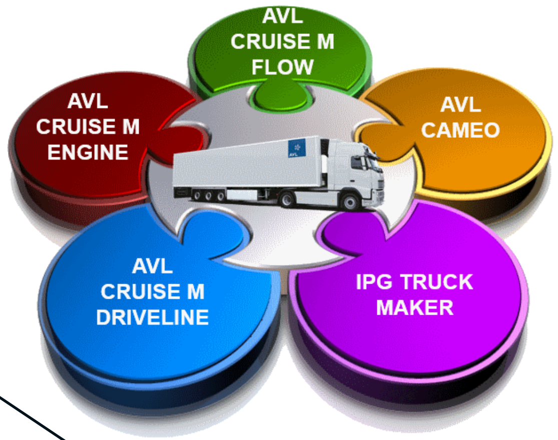
Requirements of CV on future energy carriers
48V Mild Hybrid

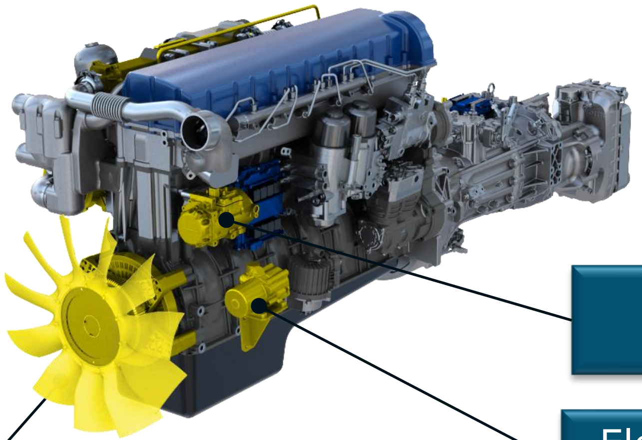


48V Motor/Generator

Electrical Assisted Turbo

Electric Driven Coolant Pump





WHR

Electric Driven A/C Compressor

Electro Hydraulic Power Steering

Electric/Hybrid Fan

System features and customer benefits

- 48V bordnet combined with 24V/12V bordnet
- Smart, partly electrified, auxiliaries
- Advanced control architecture including predictive control
- System simulation platform for evaluation of best system architecture
- Fully integrated in vehicle system

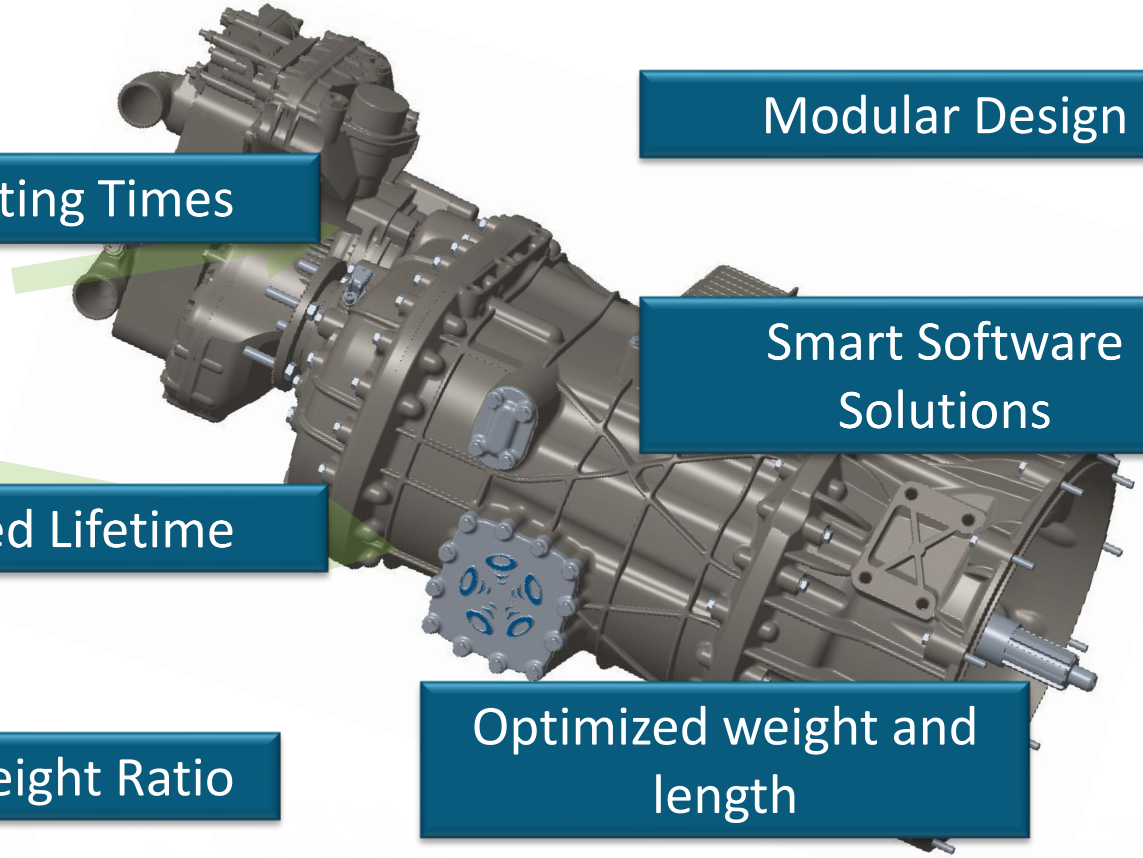
FC improvement potential 48V Mild hybrid technology 2 – 3 % (with WHR 4 – 6 %)

Requirements of CV on future energy carriers
Integrated AMT solutions for the CO_2 challenge

Advanced hardware (bearings, lubrication, minimized friction…)

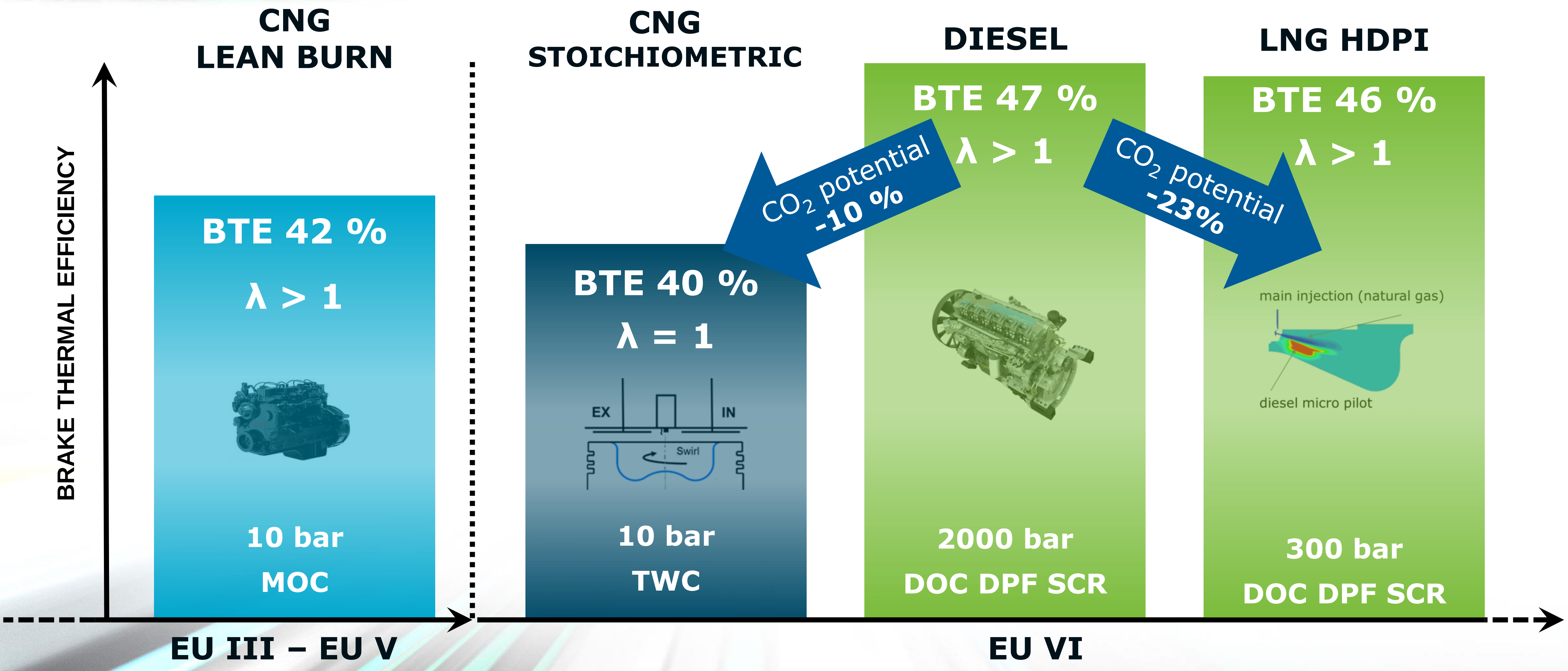
Advanced software technologies

Tailored for down speeded engines



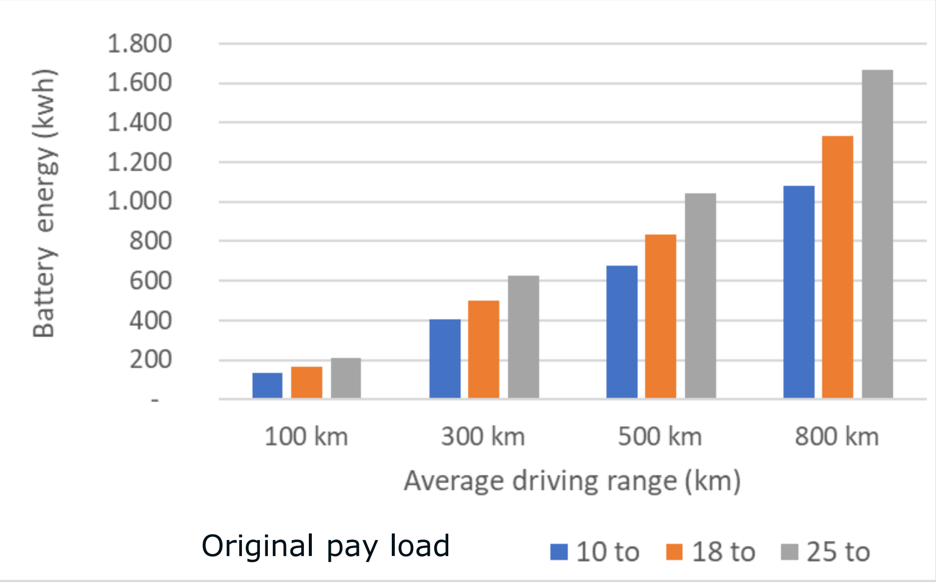
FC improvement potential of advanced AMT technology ~1 %

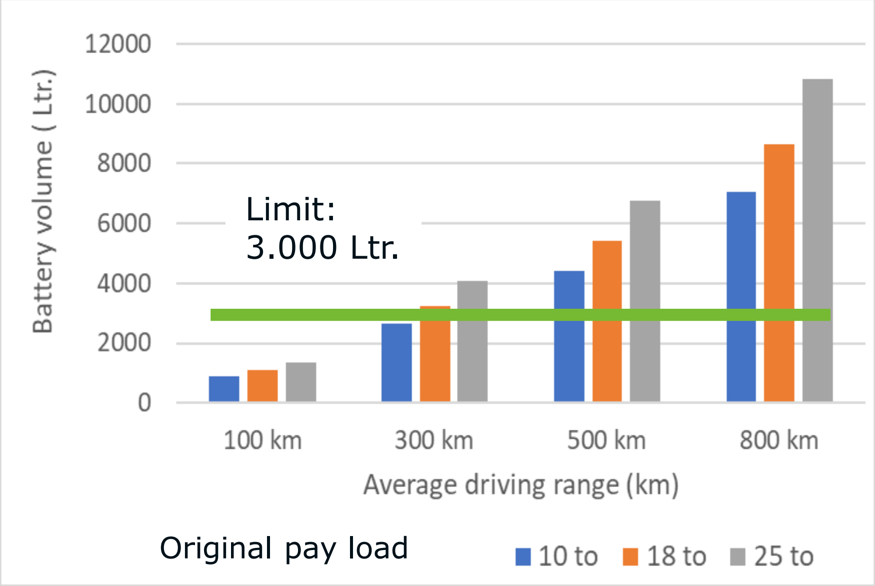
Requirements of CV on future energy carriers
Gas engine technology: Efficiency vs. emission

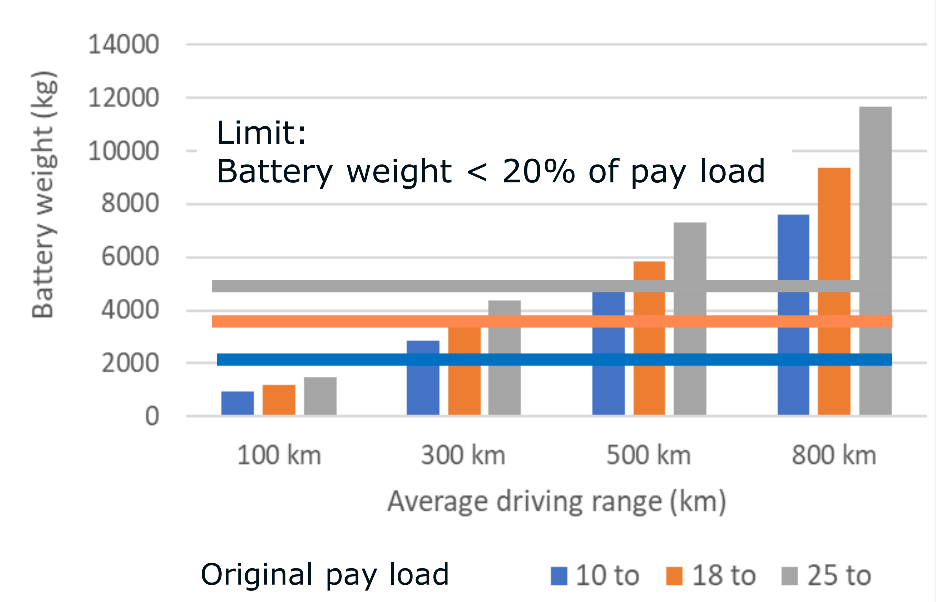


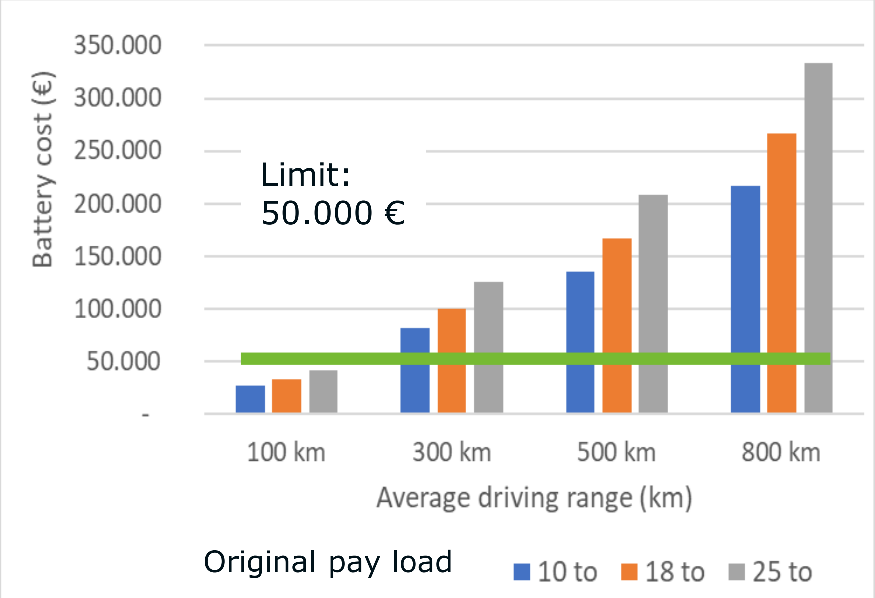
Gas engine technology shows CO_2 reduction potential of up to 23 %

Situation of battery electric vehicle









Conclusion:
A battery electric vehicle is mainly limited by price at a mileage range < 200 km

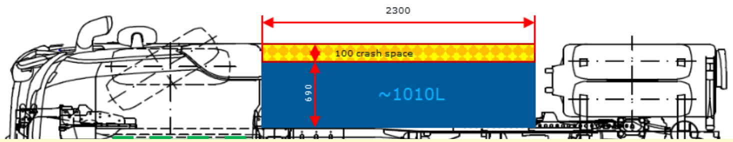
Boundaries:
Battery weight: 7,0 kg / kwh
Battery Volume: 6,5 Ltr / kwh
Battery price: 200 € / kwh

Executive summary – Fuel cell Truck

- Approx. **500km** mileage requires approx. 50kg of H2 to be packaged
  - Packaging behind the cabin
  - **Longest wheelbase** needed
    (to achieve the required 2,04m between tanks and kingpin of the trailer)
  - Not all trailers can be used
    (due to the long wheelbase overall length exceeds legal

- **New task:** Packaging of the tanks and periphery on the side of a truck with a big cabin size.

Shown Model:
- Mercedes-Benz Actros 1863 LS 4x2
- 4000mm wheelbase (longest available wheelbase for tractor)
- GigaSpace Cabin (biggest available cabin)

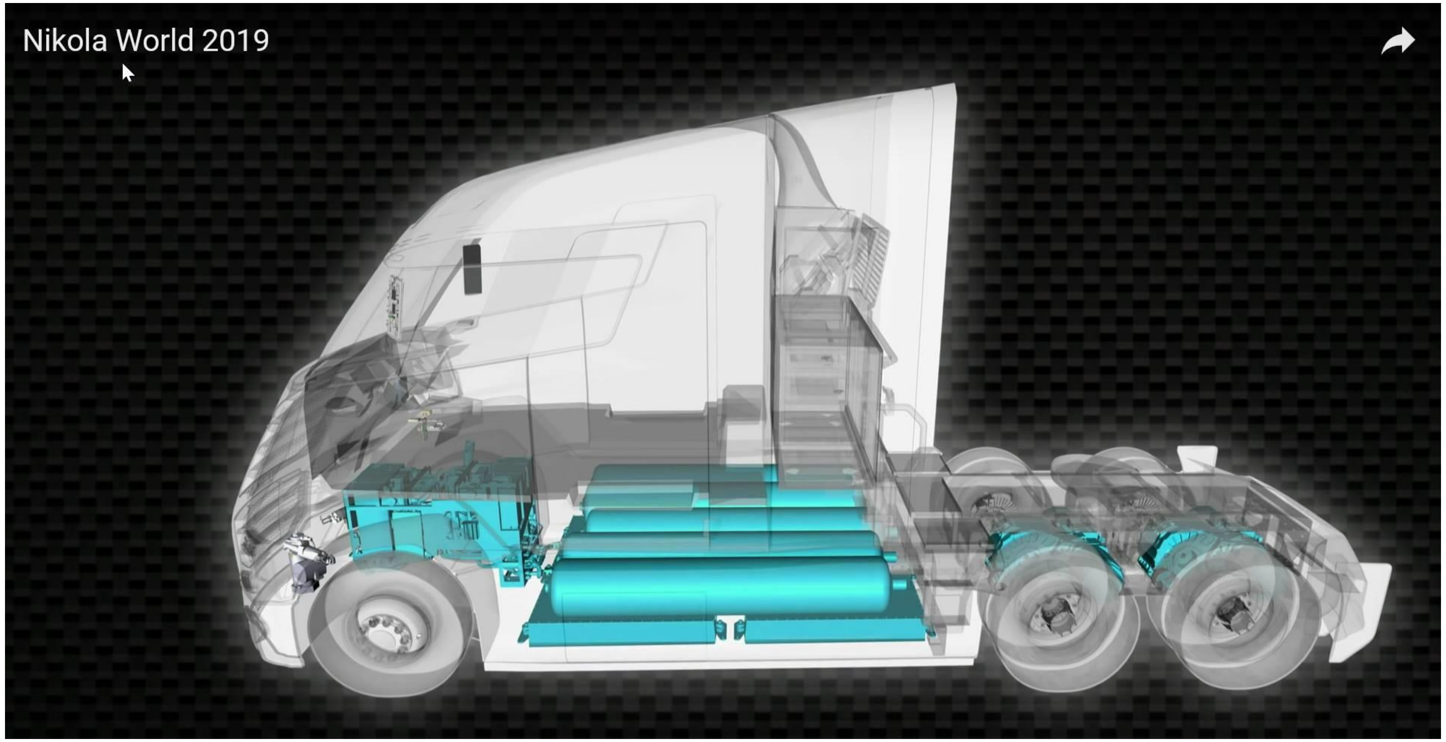


- A fuel cell electric vehicle with todays vehicle concept is mainly limited by the required space of the H_2 storage system to a range max. 500 km

- Packaging of ~50kg of H2 with current European truck dimension legislation, would lead to a smaller cabin or to reduced payload as the cargo volume would be reduced.
- With reduced customer requirements (power, mileage, …) it might be possible to place all necessary components on the side of the truck

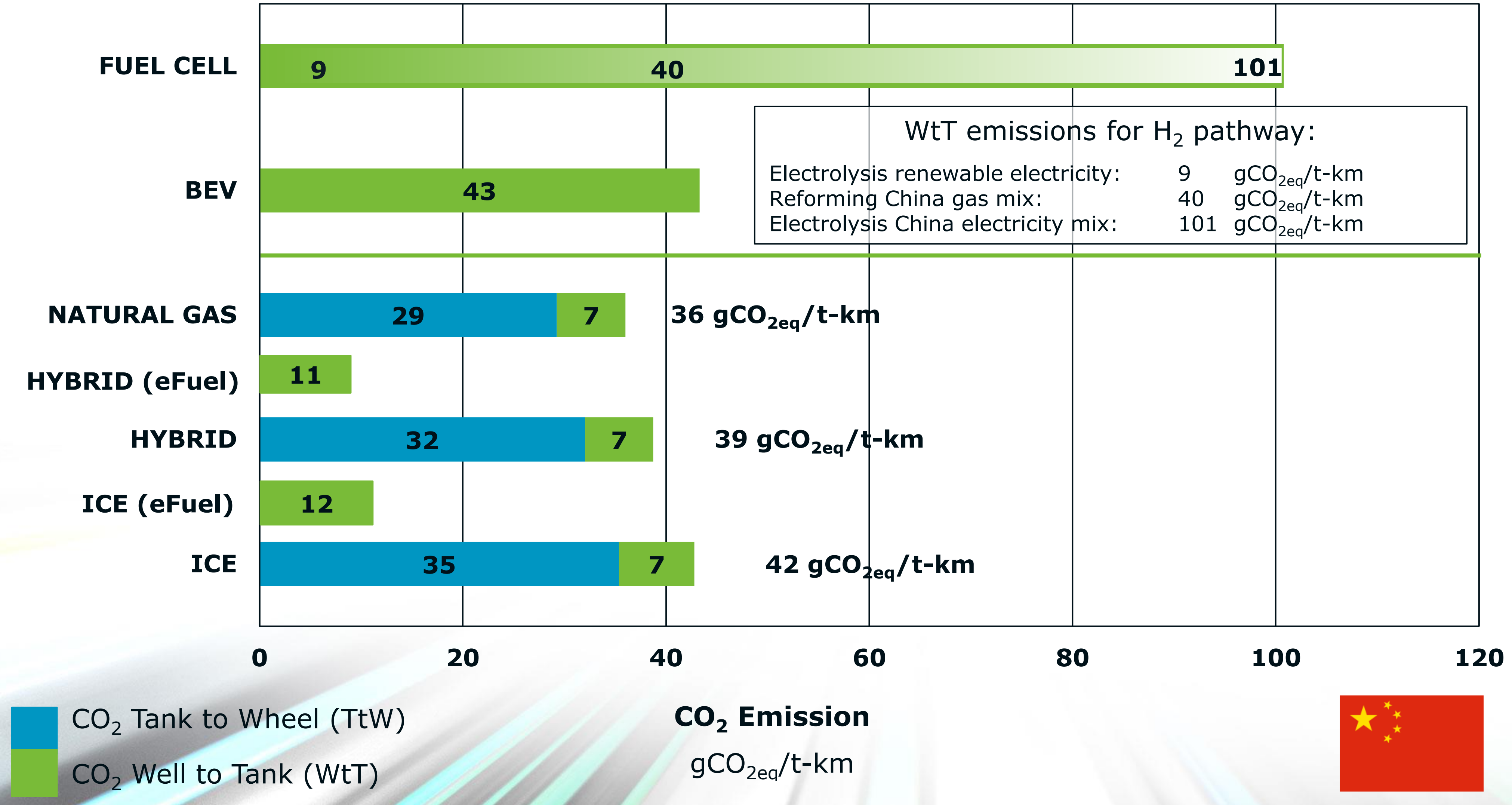
FC Long-haul Tuck

New vehicle concept might be required in order to achieve acceptable transportation distances



Source: https://nikolamotor.com/

Requirements of CV on future energy carriers
Well to wheel Emissions 40t Container carrier - China



CONTAINER CYCLE

30% Highway
30% Rural
10% City
10 % Traffic Jam

FUEL CELL

E-Motor: 300 kW cont.
FC: 122 kW
Battery: 60 kWh

BEV

E-Motor: 300 kW cont.
Battery: 634 kWh

CNG

IL6 11l 260 kW SI
AMT

PARALLEL HYBRID

IL6 8l 200 kW
E-Motor: 80 kW
Battery: 10 kWh

ICE

IL6 11l 285 kW
AMT

Requirements of CV on future energy carriers
Future CO_2 neutral energy sources

AVL

Renewable Energy out of:

Sun Wind Water

Electricity

Direct electrical

H_2 electrical

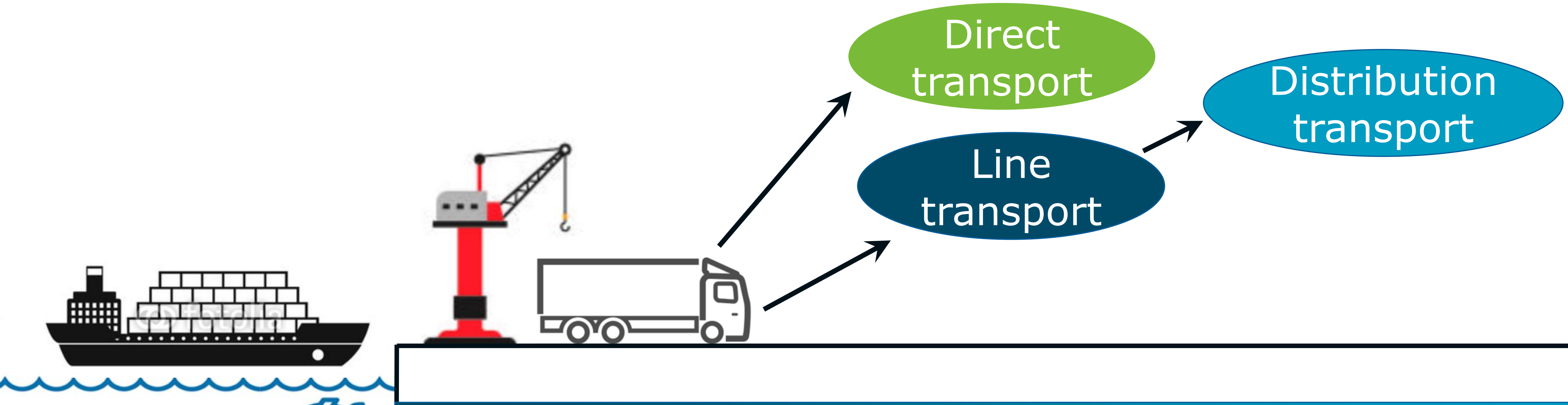
e-Fuel electrical

Battery electrical Vehicle

Fuel cell electrical Vehicle

Zero impact emission e-Fuel vehicle

Requirements of CV on future energy carriers
Types of transport tasks



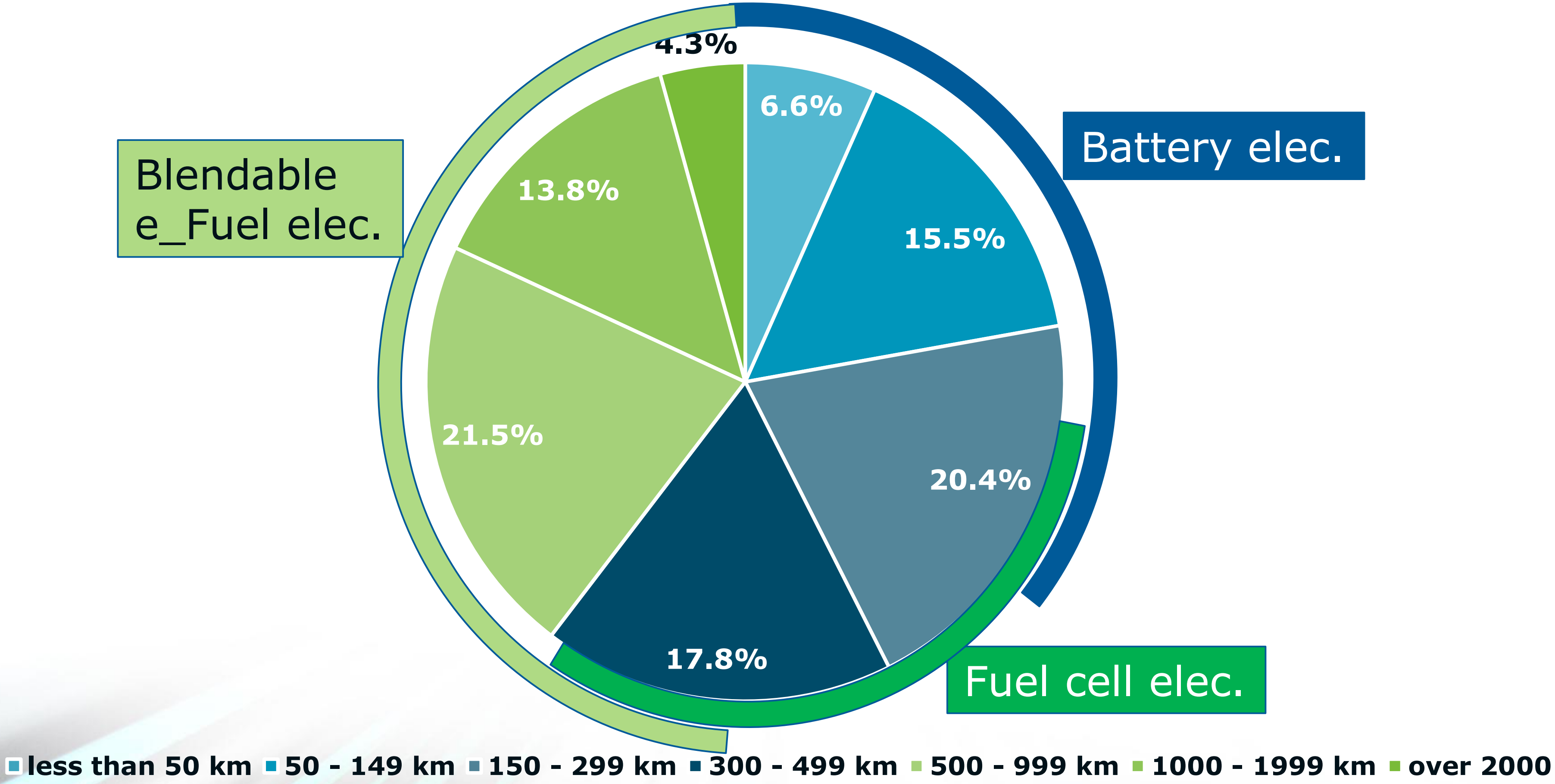
An average day at the Port of Rotterdam:

- **40.000** container unloaded
- **10.000** Trucks needed for road distribution*
- **3.500.000 Km** of direct and line transport

* 53% of road based distribution

Requirements of CV on future energy carriers Distributor transport vs. long/line haulage

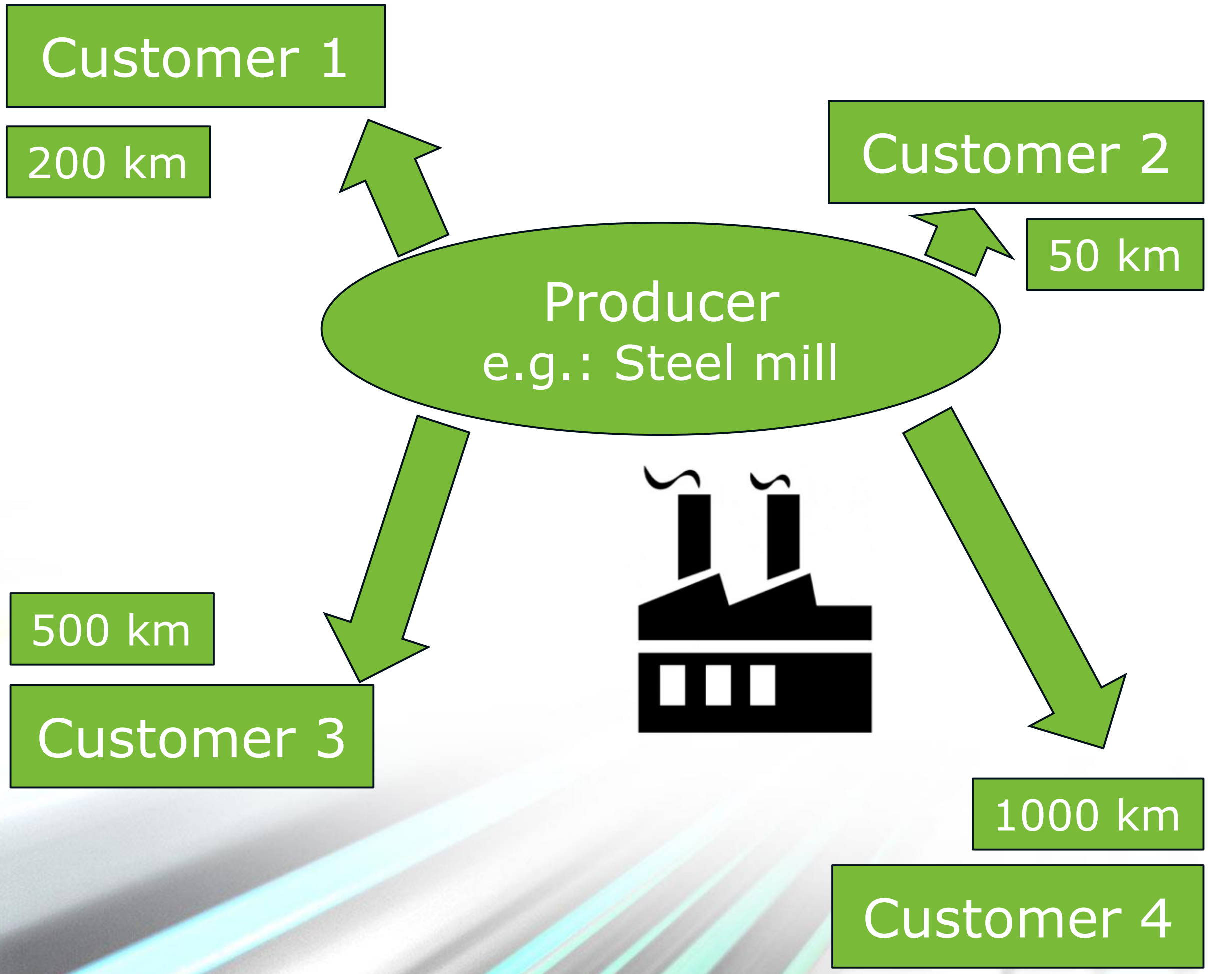
Goods transport distance EU28 [t-km]



23 % local, 38 % mid range distribution and 39% long haulage transport

Requirements of CV on future energy carriers
Direct transport

DIRECT TRANSPORT



- **Same** transportation **task**
- Entirely **different routes**
- **Driving distance limited** by drivers working hours
- **No owned infrastructure** on route
- Net transportation **weight critical**

Solution 2030+

- **Zero impact emission Diesel Hybrid vehicle**
- **e – Fuel Scenario**
  ➔ Availability e-Fuel

- **Fuel cell electric vehicle**
  ➔ H_2 infrastructur
  ➔ Durability fuel cell

Requirements of CV on future energy carriers
Line transport

AVL

Line transport

Producers, consumer goods

↓ Local traffic

Forwarding agency Hub 1
Line traffic

↓ Long distance traffic

Forwarding agency Hub 2
Line traffic

↓ Local traffic

Final customer

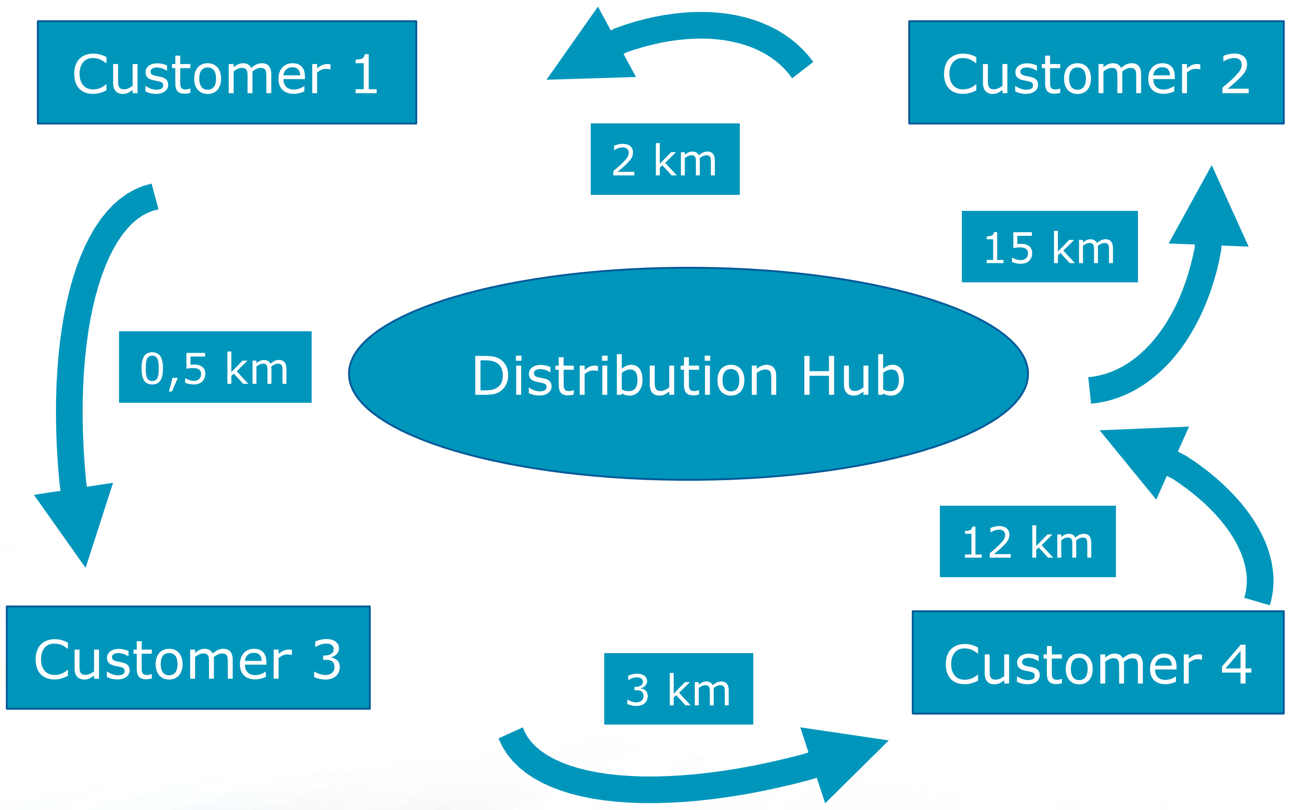
日本通運
NIPPON EXPRESS

- **Similar** transportation **tasks**
- **One** defined **route**
- **Hub to Hub** Transport in **3 shift** operation
- **Own infrastructure** at the hubs
- Net transport **weight non critical**

Solution 2030+

- **Zero impact emission Diesel Hybrid vehicle**
- **e – Fuel Scenario**
  ➔ Availability e-Fuel
- **Fuel cell electric vehicle**
  ➔ Durability fuel cell
- **Batterie electric vehicle**
  ➔ Battery quick exchange system
  ➔ Electricity supply

Requirements of CV on future energy carriers
Distributor transport



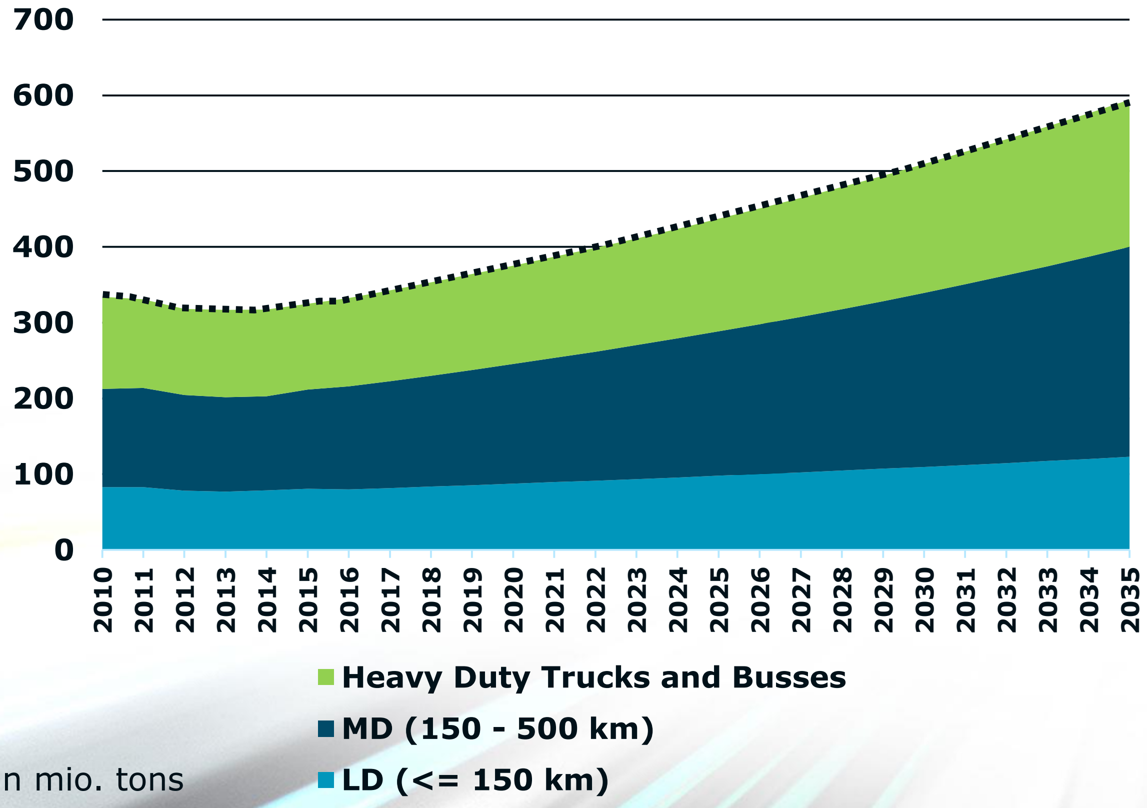
- **Similar** transportation **tasks**
- **Similar route**
- Distribution transport in **1-3 shift operation**
- **Own infrastructure** at the hubs
- Net transport **weight non critical**

Solution 2030+

- **Zero impact emission Diesel Hybrid vehicle**
- **e – Fuel Scenario**
  ➔ Availability e-Fuel
- **Fuel cell electric vehicle**
  ➔ Durability fuel cell
- **Battery electric vehicle**

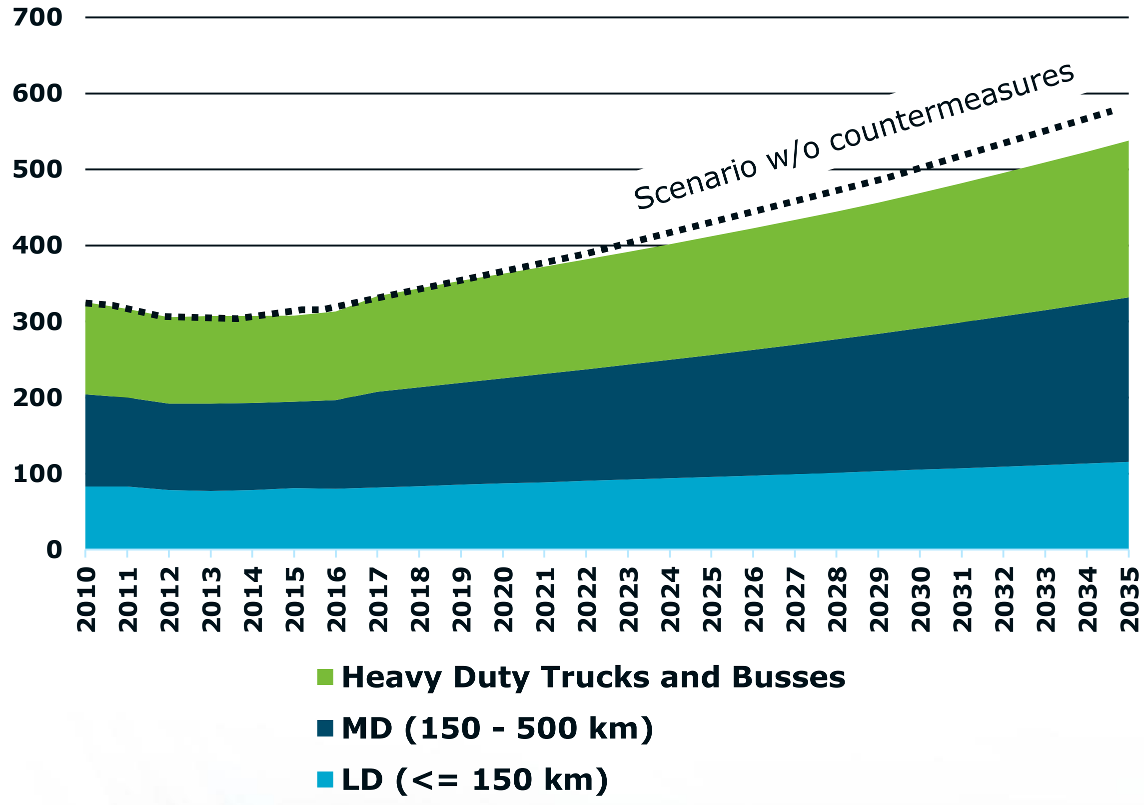
Requirements of CV on future energy carriers
Future transport scenario EU28

Probable future road transport CO_2 scenario*



* in mio. tons

Advanced powertrain & vehicle technology & HDPI*

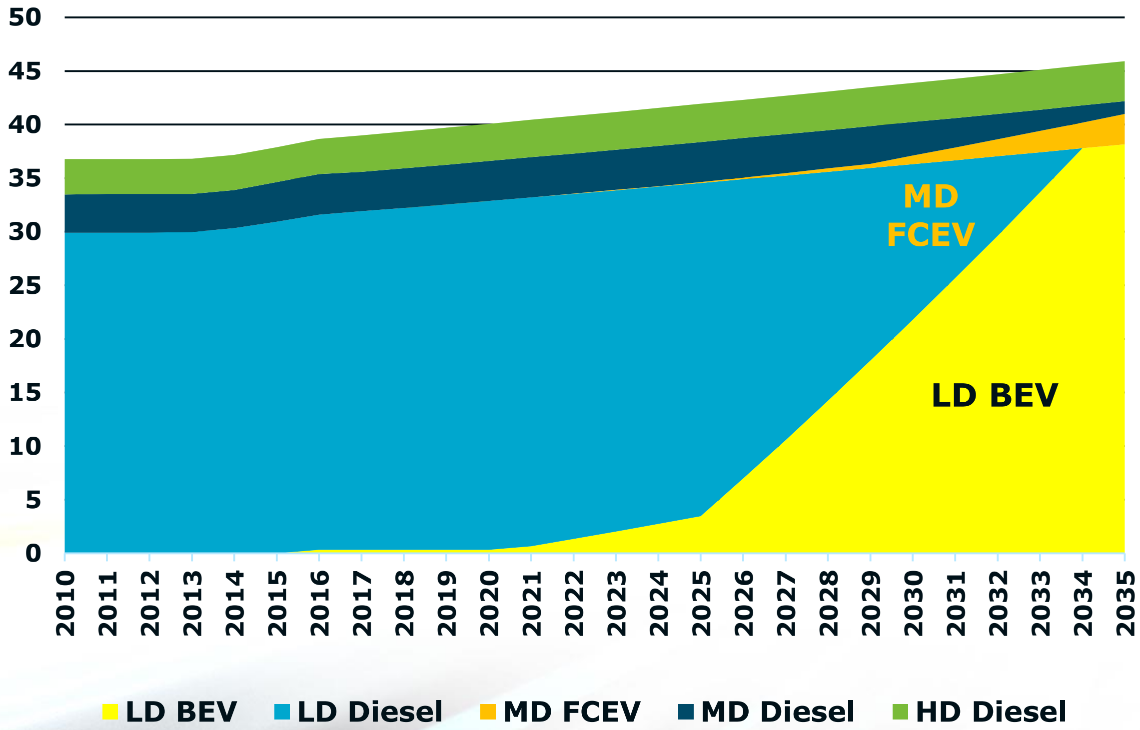


Field renewal with advanced technology vehicles leads to a $C0_2$ reduction of 5 %* by 2030

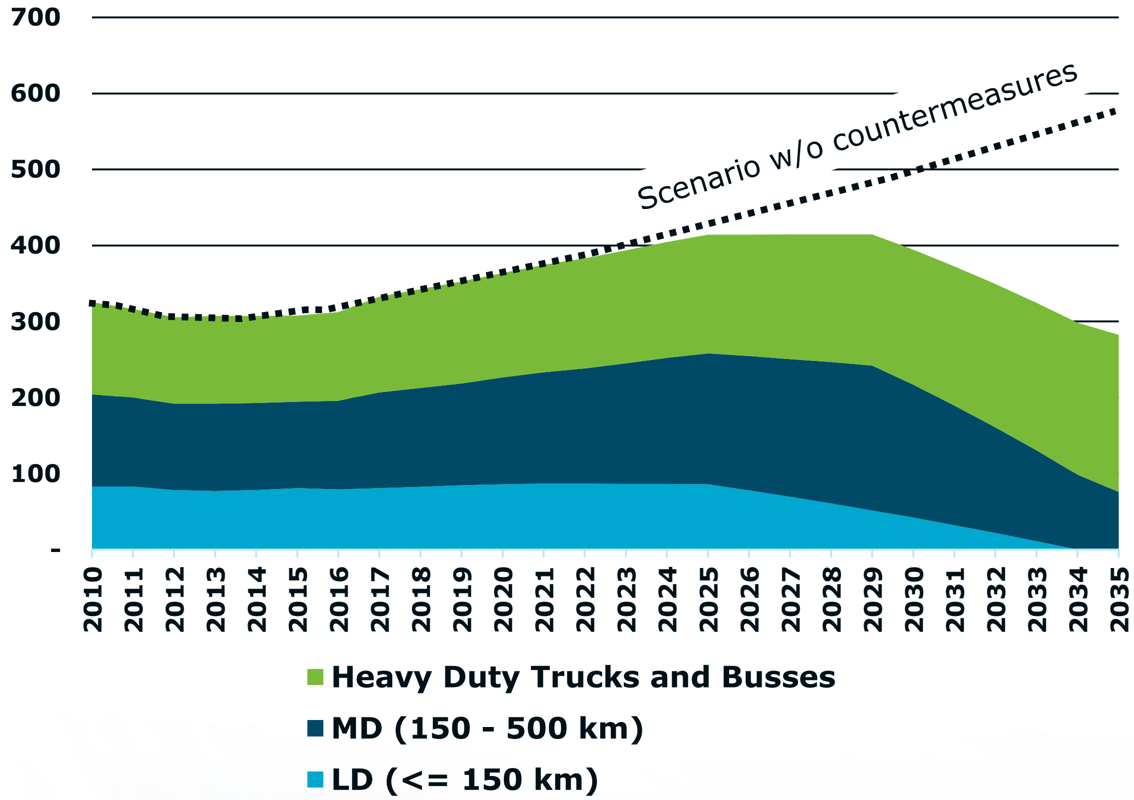
*compared to scenario w/o countermeasures

Requirements of CV on future energy carriers
Future transport scenario EU28

Fast introduction of BEV & FCEV (Mio. Vehicles)



CO_2 Scenario: Fast Introduction BEV & FCEV*

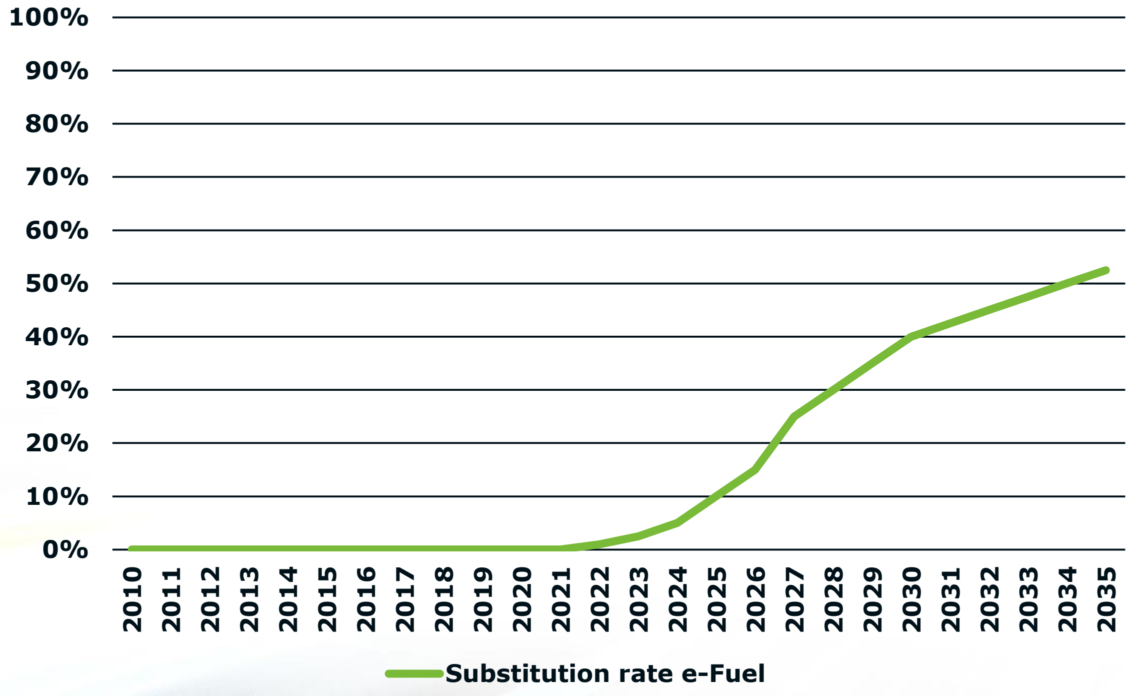


* in mio. tons

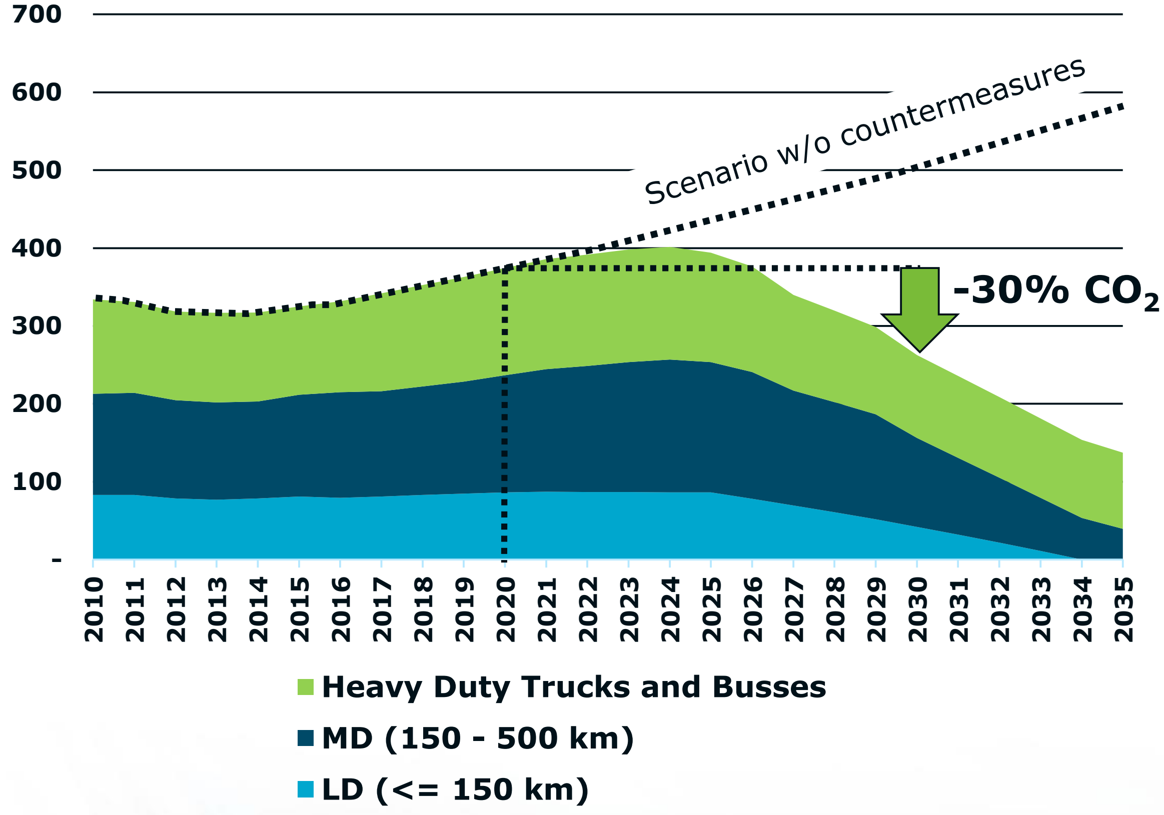
100% LD BEV and 100 % MD FCEV compensates the expected transport growth rate by 2030

Requirements of CV on future energy carriers
Future transport scenario EU28

Ramping in of e-Fuel for HD Long Haul applications



CO_2 Scenario: BEV & FCEV & e-Fuel*

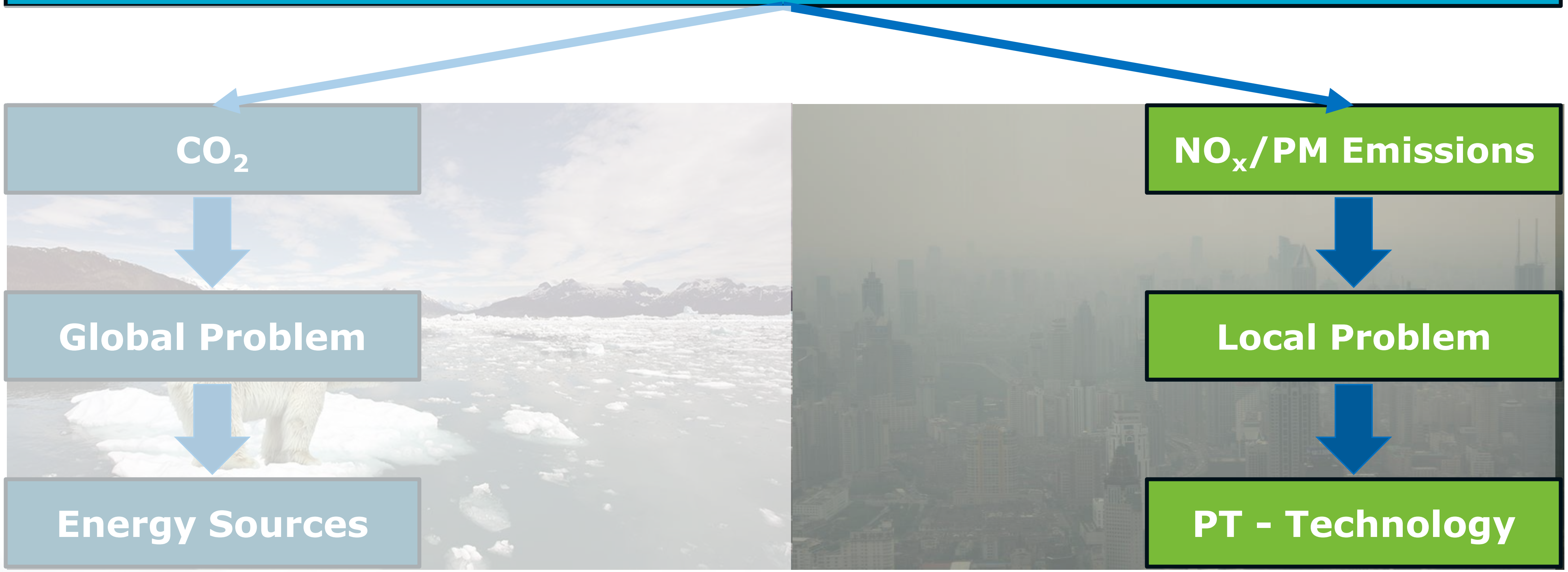


* in mio. tons

30% CO_2 reduction by 2030 requires additional the introduction of 40 % e-Fuel share

Requirements of CV on future energy carriers
Classification of emissions

Problem of global CO_2 Emissions and local NO_x/PM… emissions



We need an economical and commercial solution in the next 10 years

Requirements of CV on future energy carriers
Future ICE pollutant trends – global

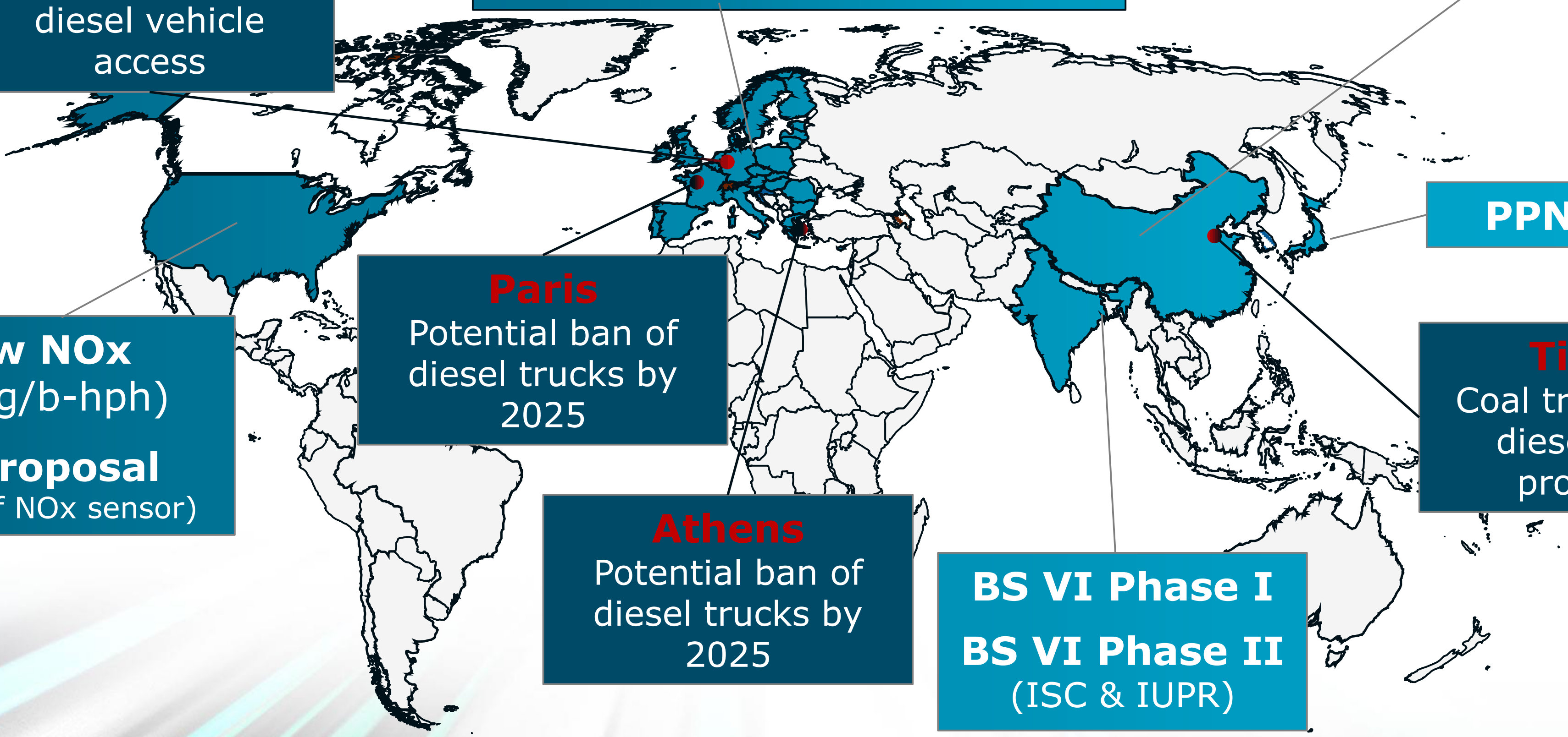
Stuttgart, Düsseldorf, Munich
Restriction of diesel vehicle access

EU VI E

Post EU VI
– 50 % or more NO_x reduction,
On board measuring (malfunctions)

China VI B
Ambient conditions (2400m), PN PEMS,
Remote emission management

PPNLT



CARB **ultra low NOx proposal** (0,05 g/b-hph)

NO_x tracking proposal
(Emissions and status of NOx sensor)

Paris
Potential ban of diesel trucks by 2025

Athens
Potential ban of diesel trucks by 2025

BS VI Phase I

BS VI Phase II
(ISC & IUPR)

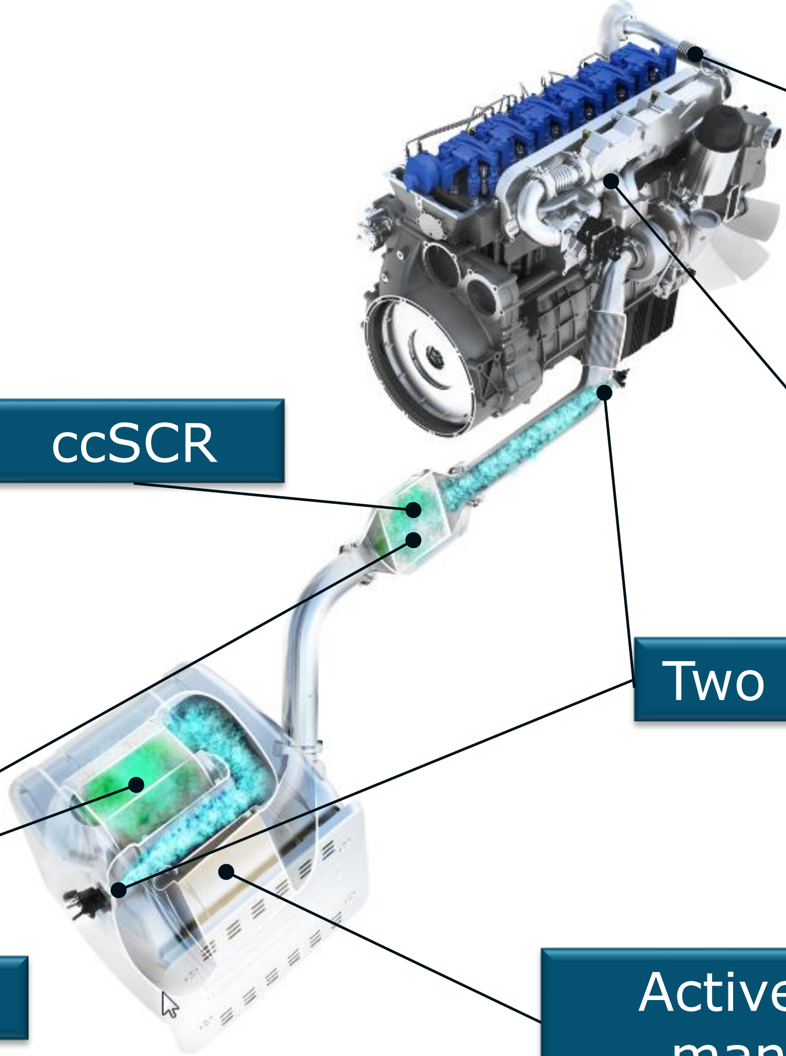
Tianjin
Coal transport by diesel trucks prohibited

Key enabler for future ICE based powertrains is to master emission requirements !

Requirements of CV on future energy carriers
The way to ZERO IMPACT emissions

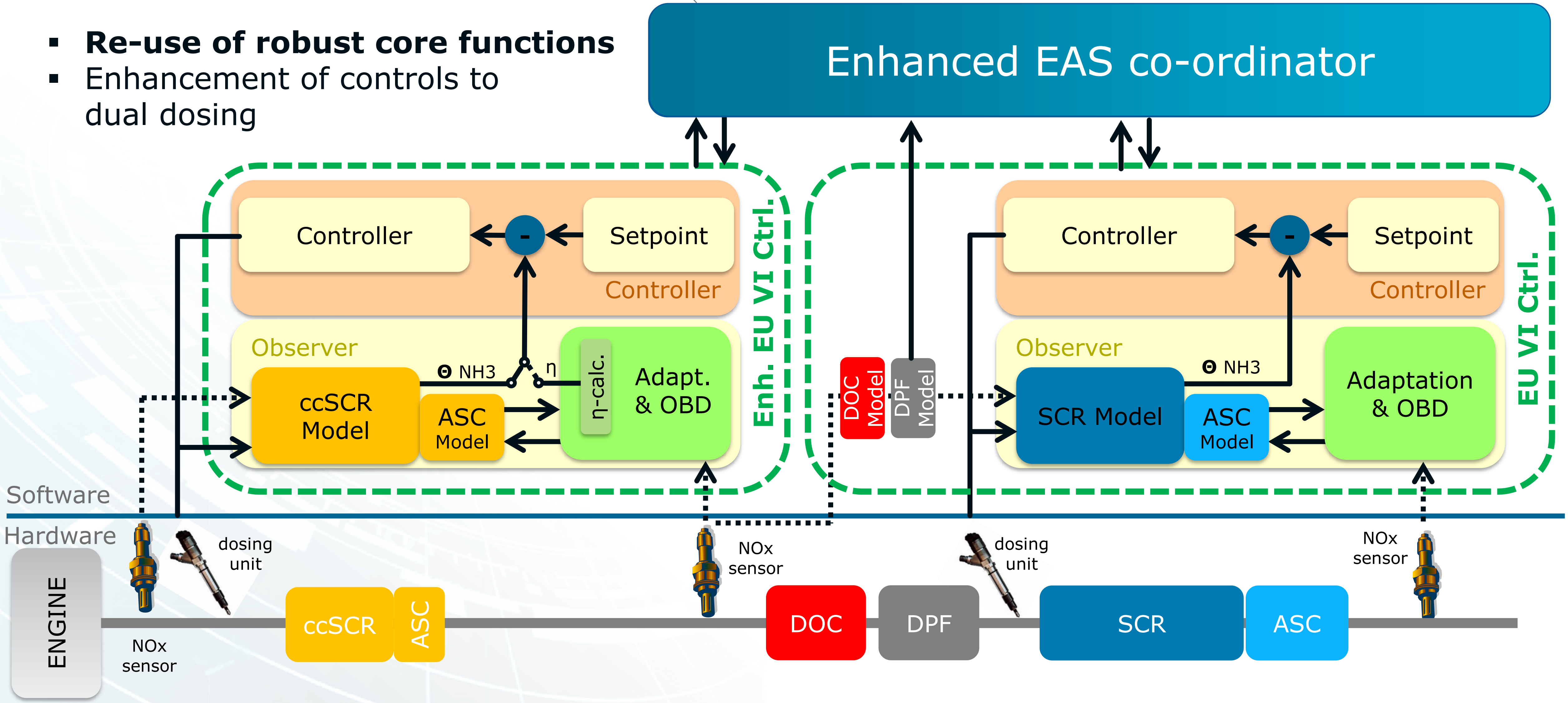
Mastering emissions is **key enabler** for **ICE** based powertrains

Requires additional **measures** in engine and **aftertreatment technology**

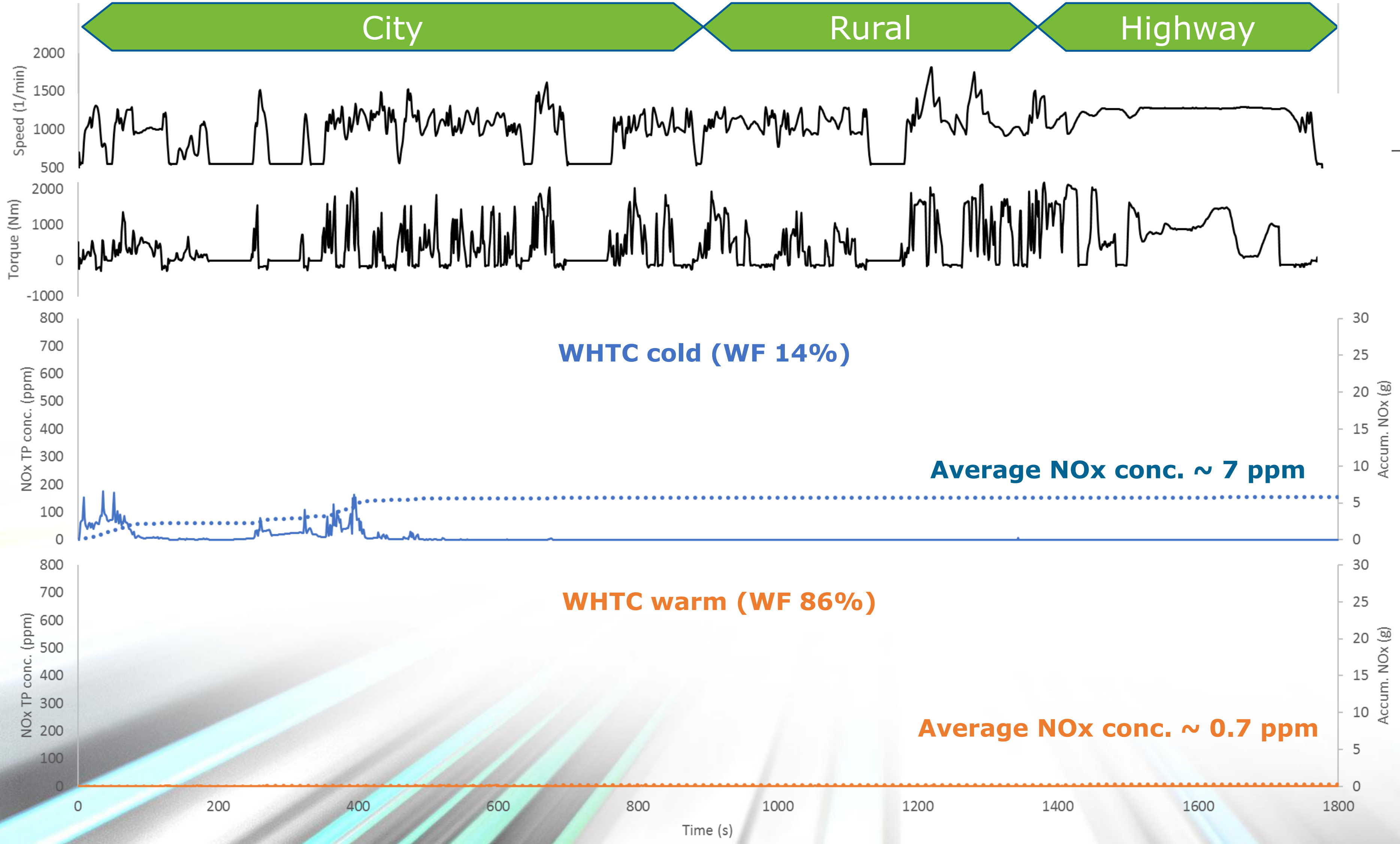


Requirements of CV on future energy carriers
Ultra low NOx control strategy

- **Re-use of robust core functions**
- Enhancement of controls to dual dosing



Requirements of CV on future energy carriers
Pollutant & compliance



WHTC cold: 0.09 g/kWh

WHTC warm: 0.008 g/kWh

WHTC c/w: 0.02 g/kWh

SCR conversion > 95.5%

SCR conversion > 99.8%

Conclusion

- **With the right HW and SW for Engine and After treatment system extremely low NOx and PM emissions are achievable ➔ not impacting the environment**
- To achieve a sustainable CO2 reduction all energy should come from **sun, wind or water**
- The first conversion step is always electrical energy, followed by hydrogen and e-fuel production for transport and also for energy storage
- The CO_2 emission of the commercial road transport contributes with 35% to the traffic related emissions.
- In the next 10 years the road transportation will increase by ~ 35%
- From legislation we have a global trend to reduce the CO_2 emission until 2030 by 30%, AVL can provide the required technology
- Mainly due to the cost, battery electric vehicles will be limited by a range of 200 km
- The range of fuel cell electric vehicles, with today design, is limited by 500 km, new vehicle designs will allow up to 1000 km range
- To reduce the CO_2 emissions of Long haul trucks effectively a blend able CO_2 neutral e-Fuel is required
- Even with a very aggressive introduction scenario of Battery and Fuel cell electric vehicles we will see the CO_2 peak 2030
- Only the availability of blend able e-Fuels in combination with optimized vehicles and powertrains will lead to a significant CO_2 reduction after 2030.

Thank You

AVL

www.avl.com