Influence of power to liquid fuels on the emissions of modern passenger cars

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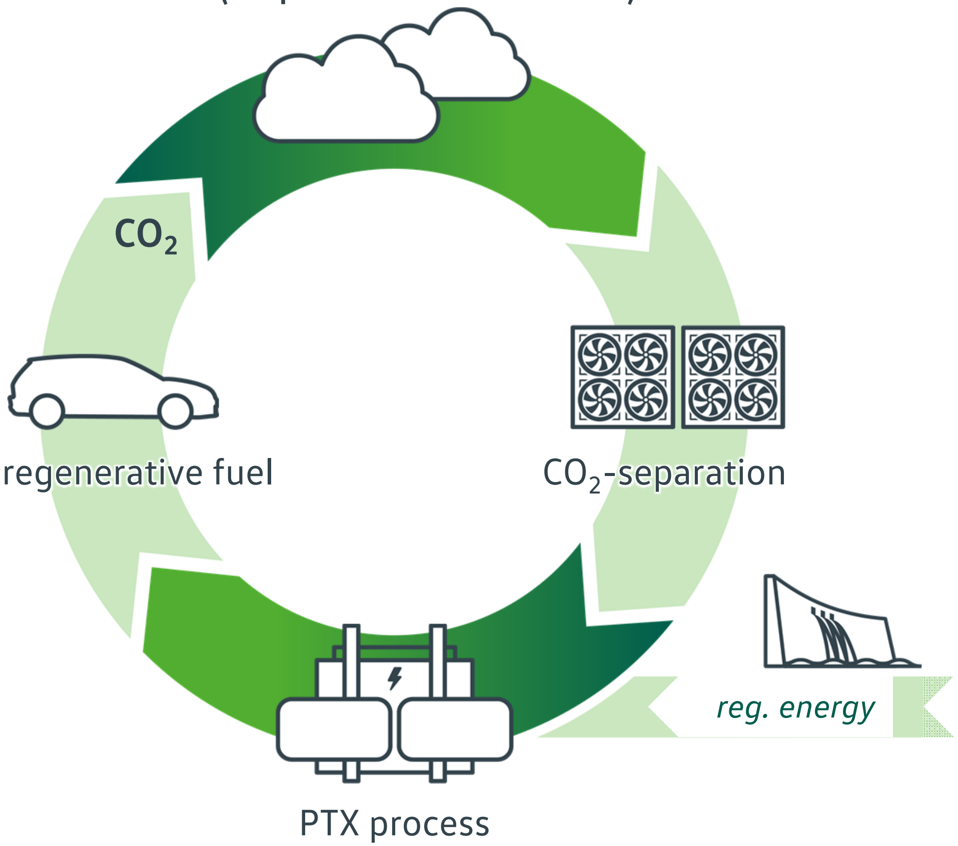
Motivation for e-fuels

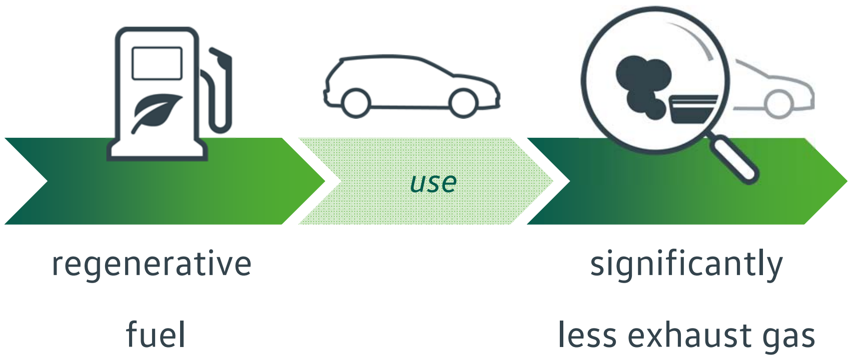
climate protection

CO_2-neutral fuels
(dependent on crude)



air quality

optimized fuel properties
(dependent on fuel chemistry)



Influence of power to liquid fuels on the emissions of modern passenger cars

climate

- Necessity of increased efforts concerning climate protection
- Climate protection in the traffic sector
- E-fuels: production, potential and market introduction

air quality

- Technical demands on future liquid fuels
- Selected results of gasoline fuels
- Selected results of diesel fuels

product

- Roadmap gasoline
- Roadmap diesel
- Best practice: R33 Blue Diesel

- Conclusion

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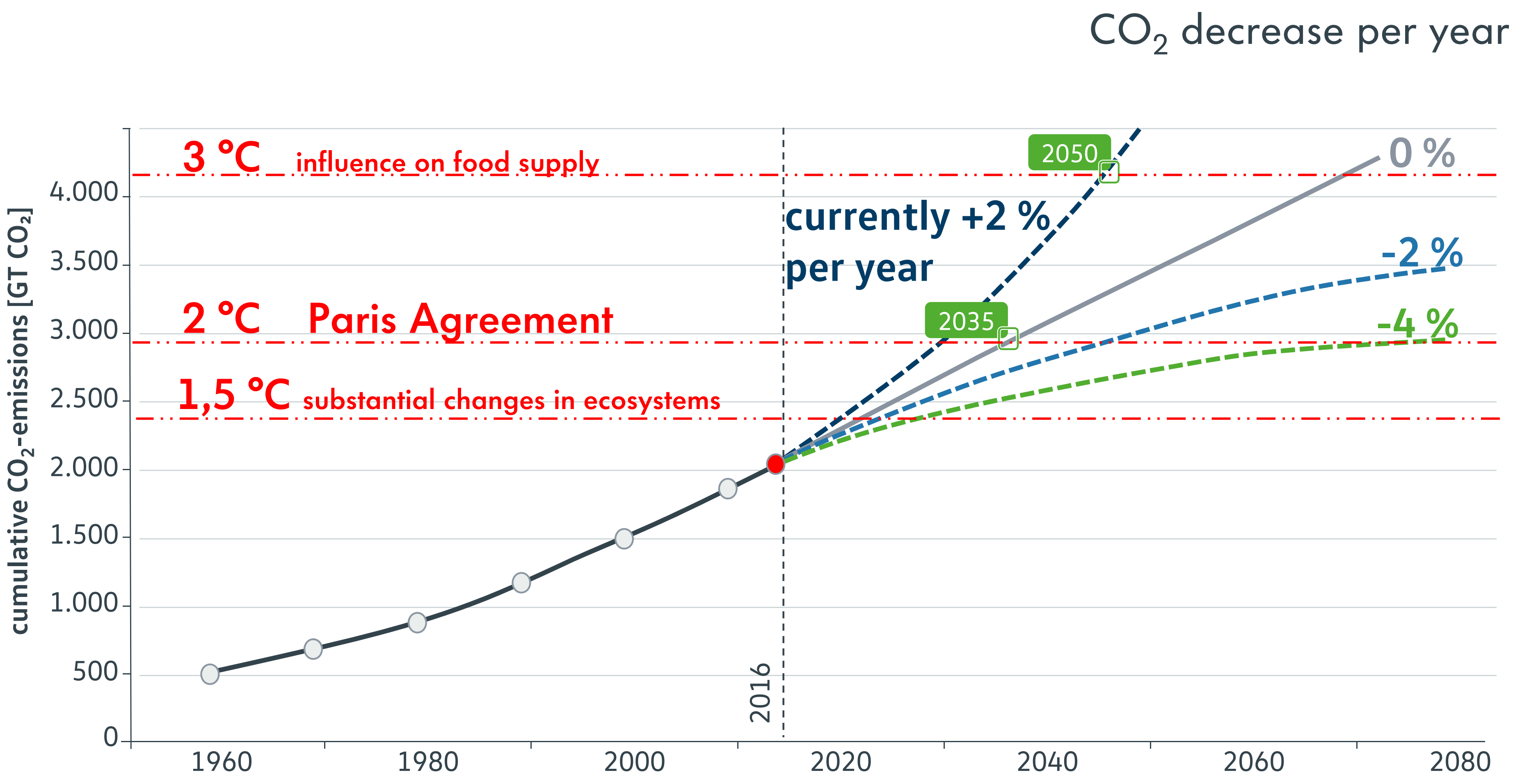
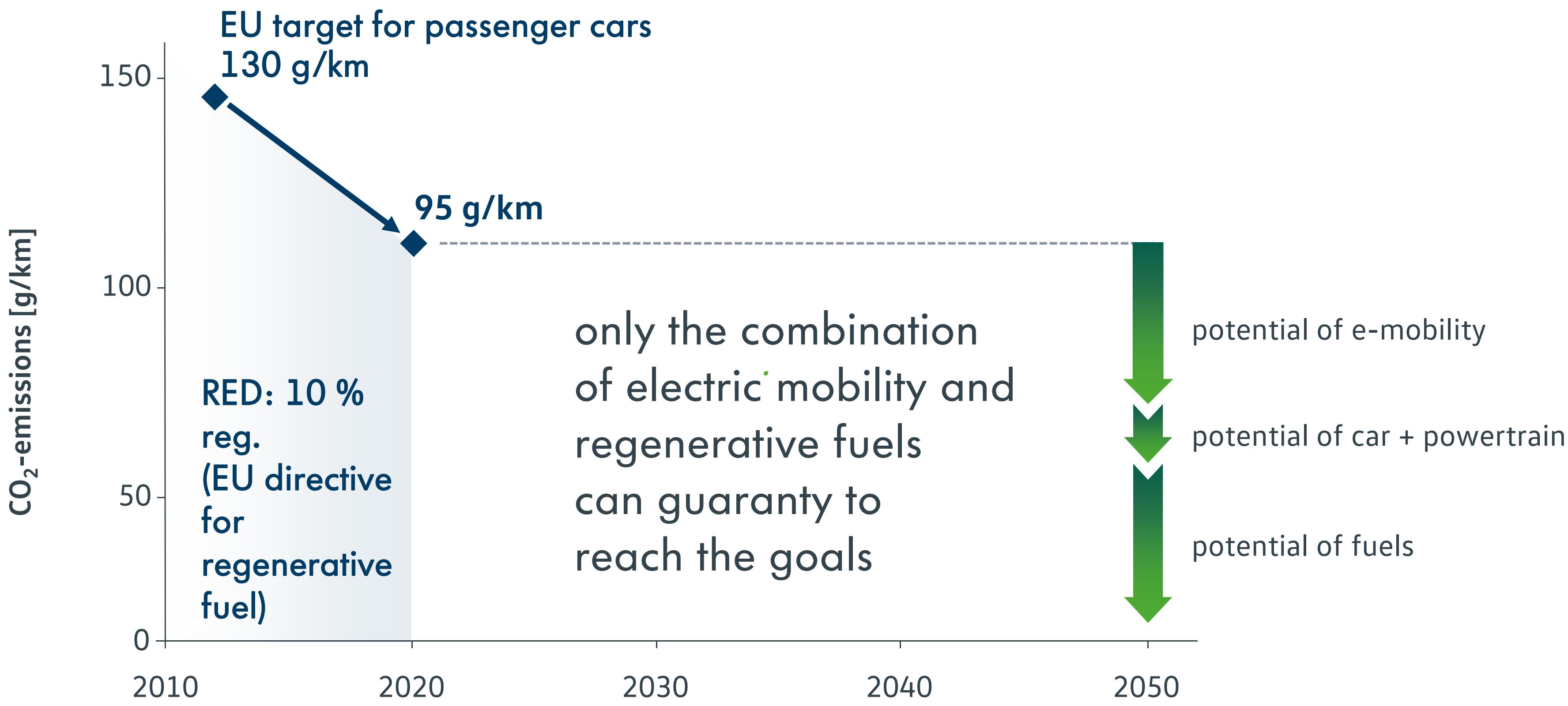
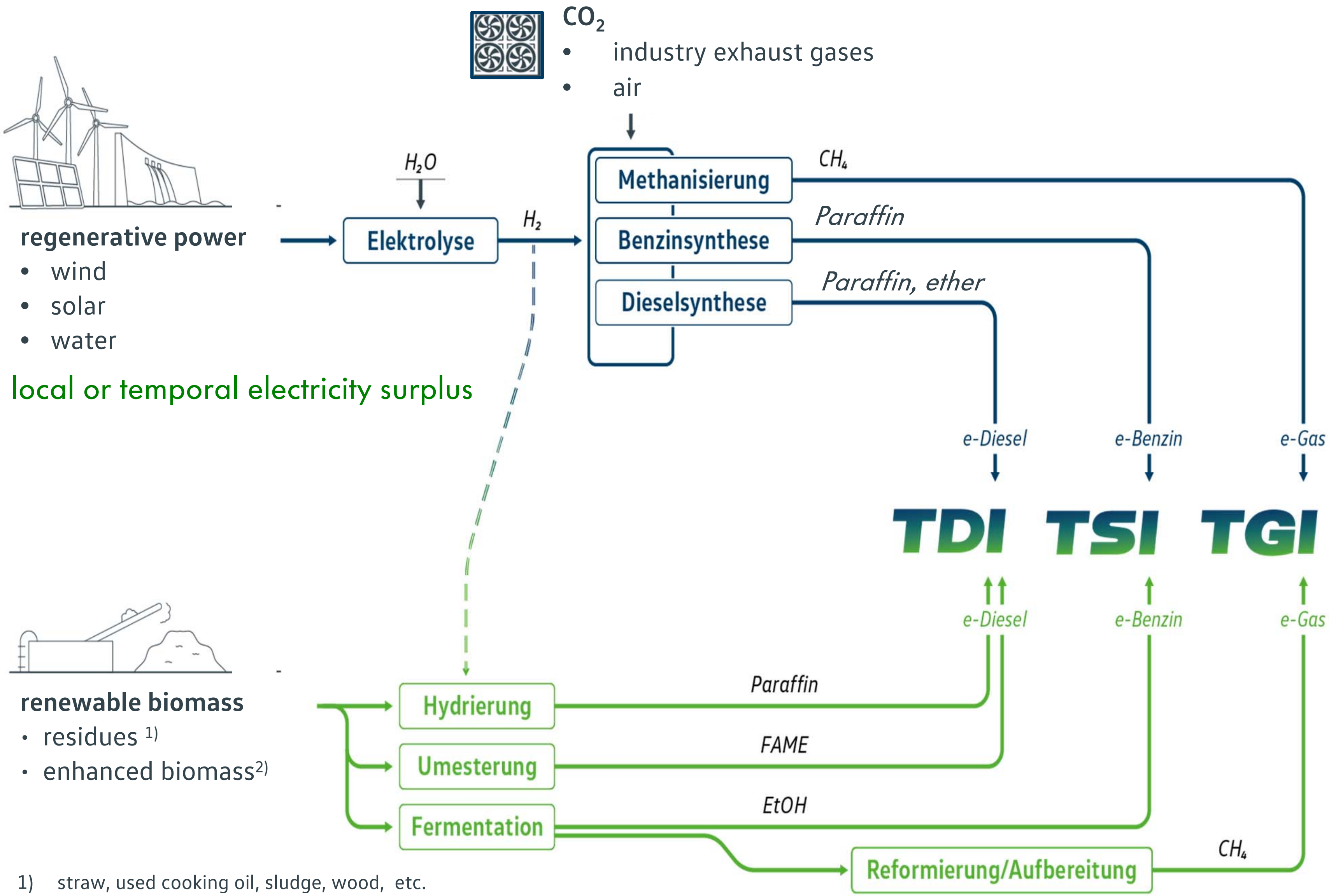
Prognosis of CO_2-emissions and global warming



Consequences for the traffic sector



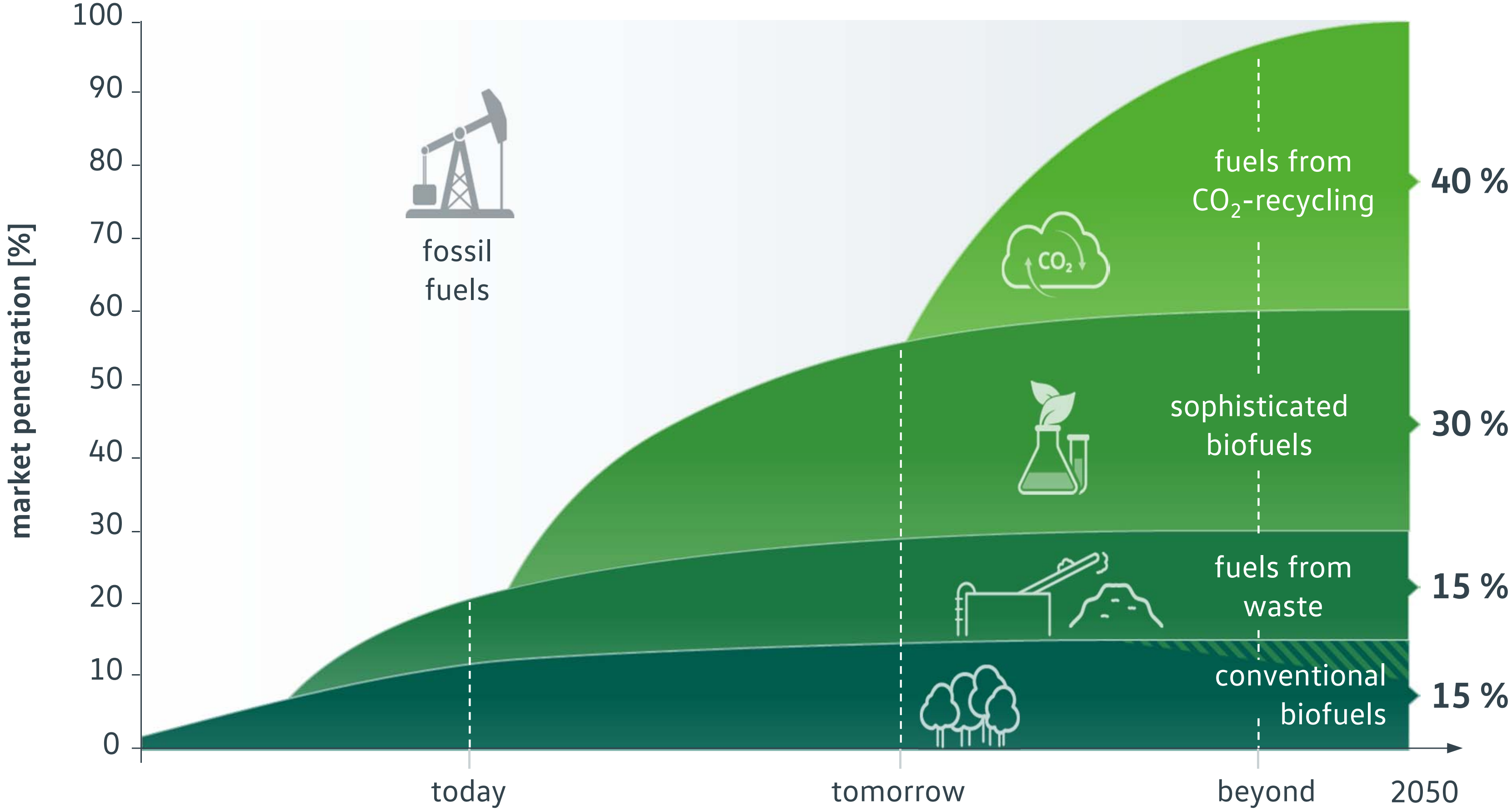
Production of e-fuels



1) straw, used cooking oil, sludge, wood, etc.

2) algae, yeast, etc.

Introduction of e-fuels into the market



Influence on the existing car fleet

regulated (95 g in 2020)

12 Mio. EU-new cars p.a.

228 Mio. EU-existing fleet

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Technical demands on future fuels*

- clean combustion, low (zero?) particulate raw emission
- good ignition and good burn out for high efficiency
- support for long time engine stability
- compatibility with engine, aftertreatment system and car adjustment
- suitable for PHEV
- (certain) downward compatibility

Development of new fuels, powertrains and vehicles has to go hand in hand.

*basis: current fuel quality EN 228, EN 590

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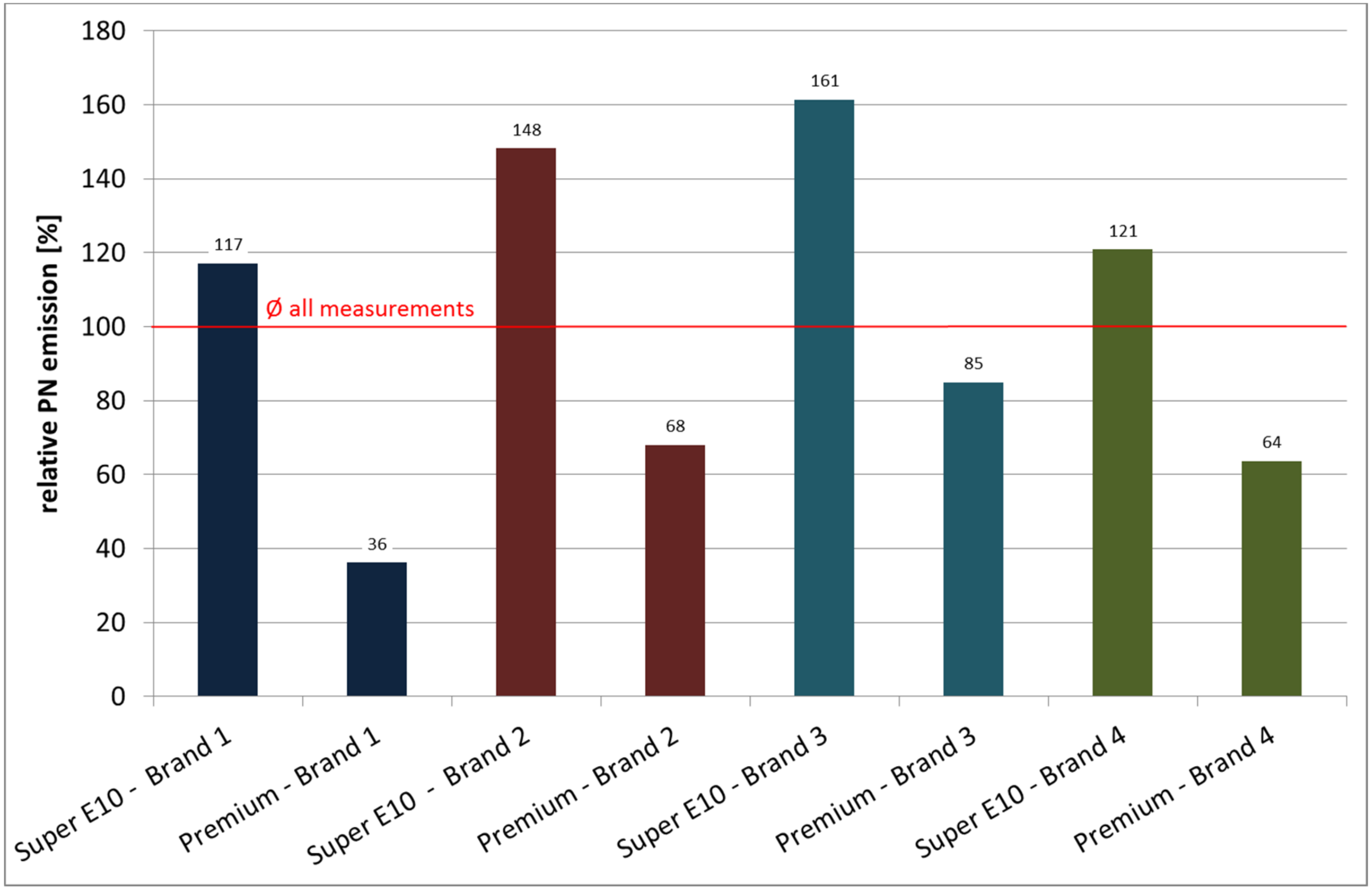
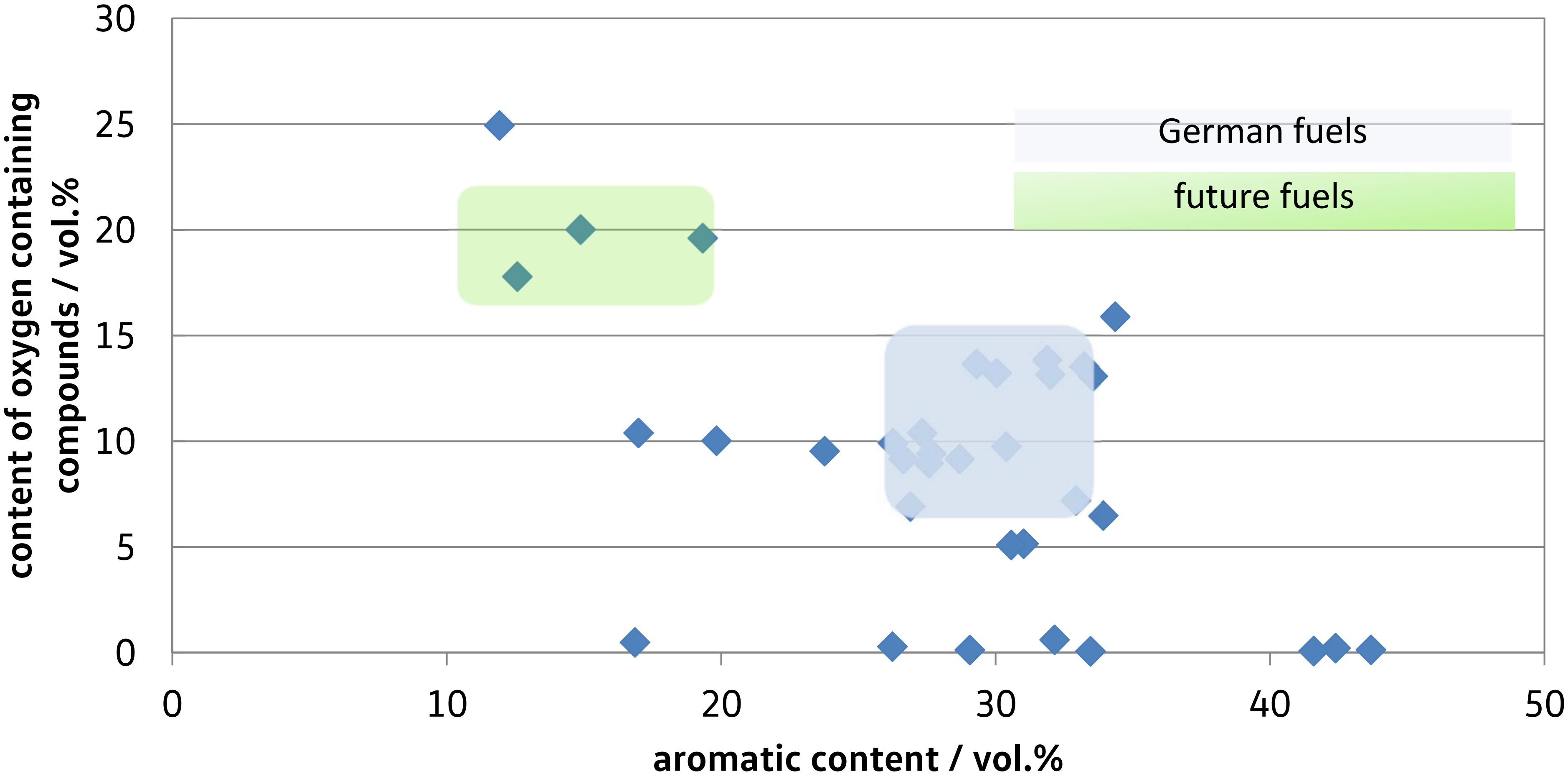
Difference in PN emission from field fuels

1.4 L Turbo GDI 103 kW EU5 @ load point 1150 rpm / 32 Nm



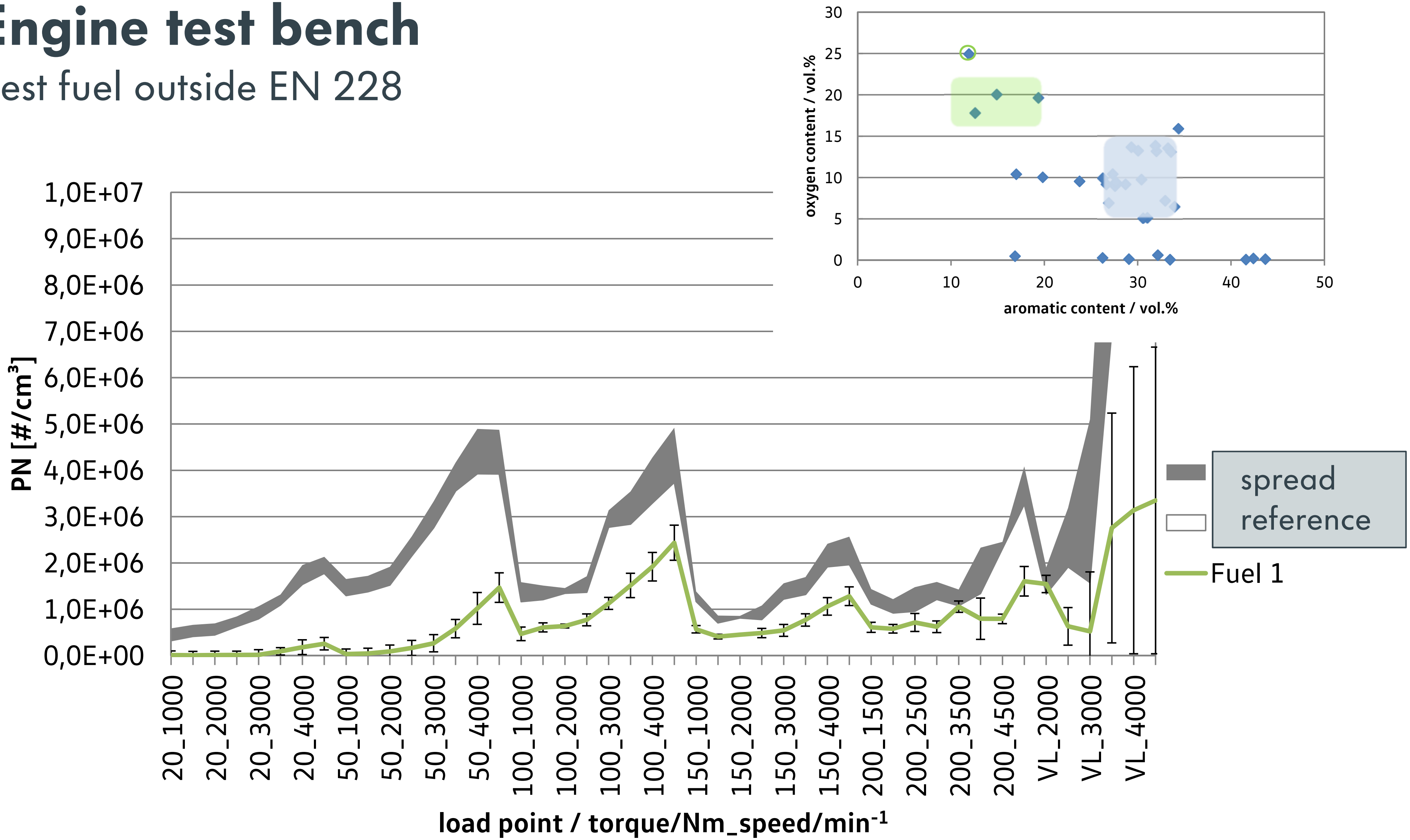
8 fuels from 4 different gas stations in one German city, bought during 3 months

Fuel selection for systematic test program



Engine test bench

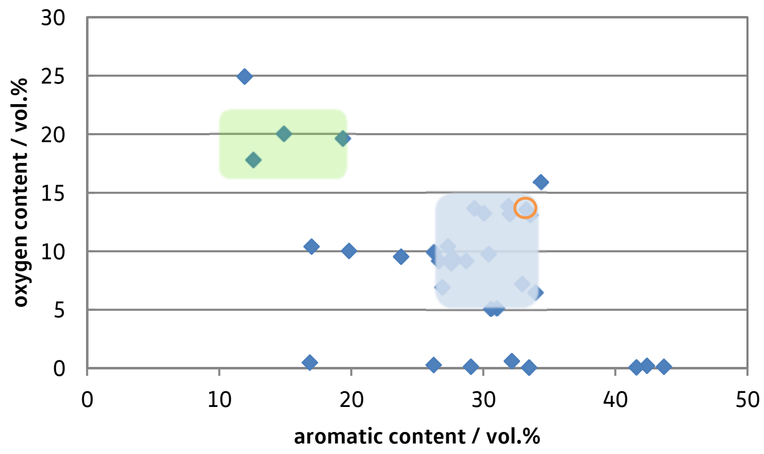
best fuel outside EN 228

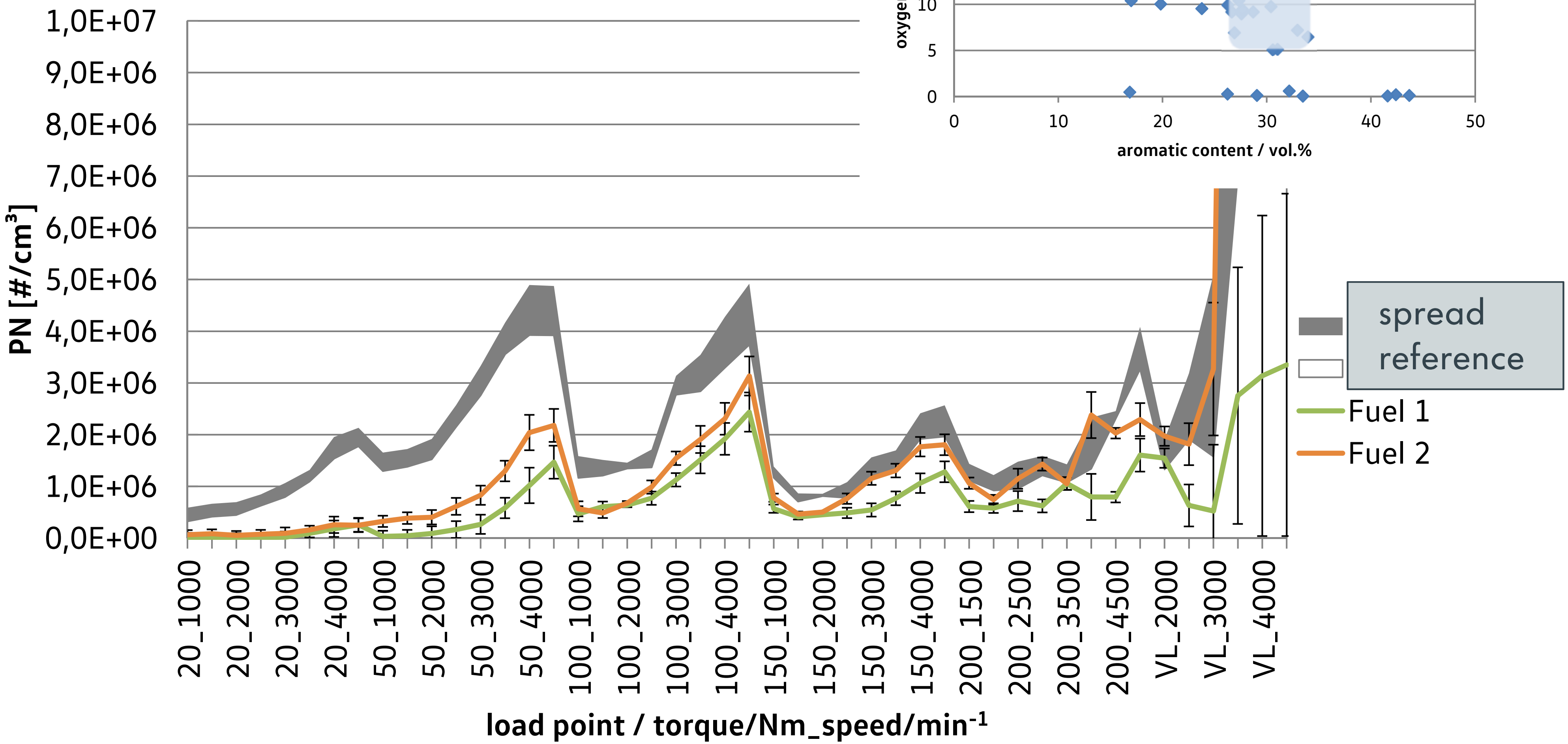


CONFIDENTIAL
VERTRAULICH

Engine test bench

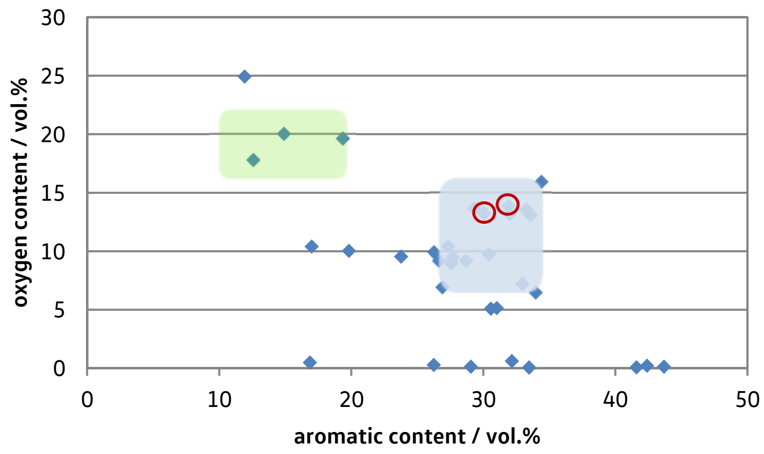
best fuel inside EN 228

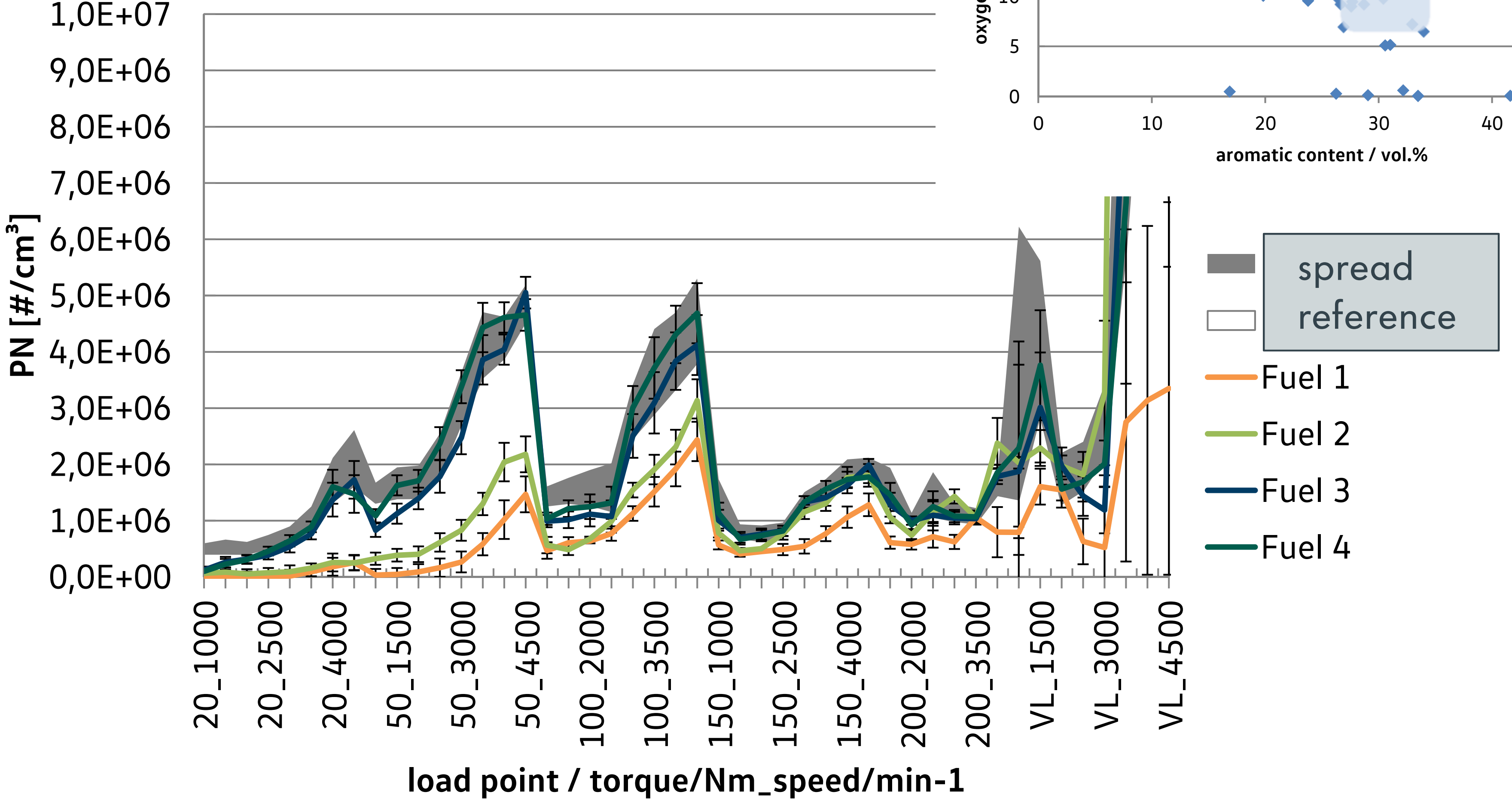




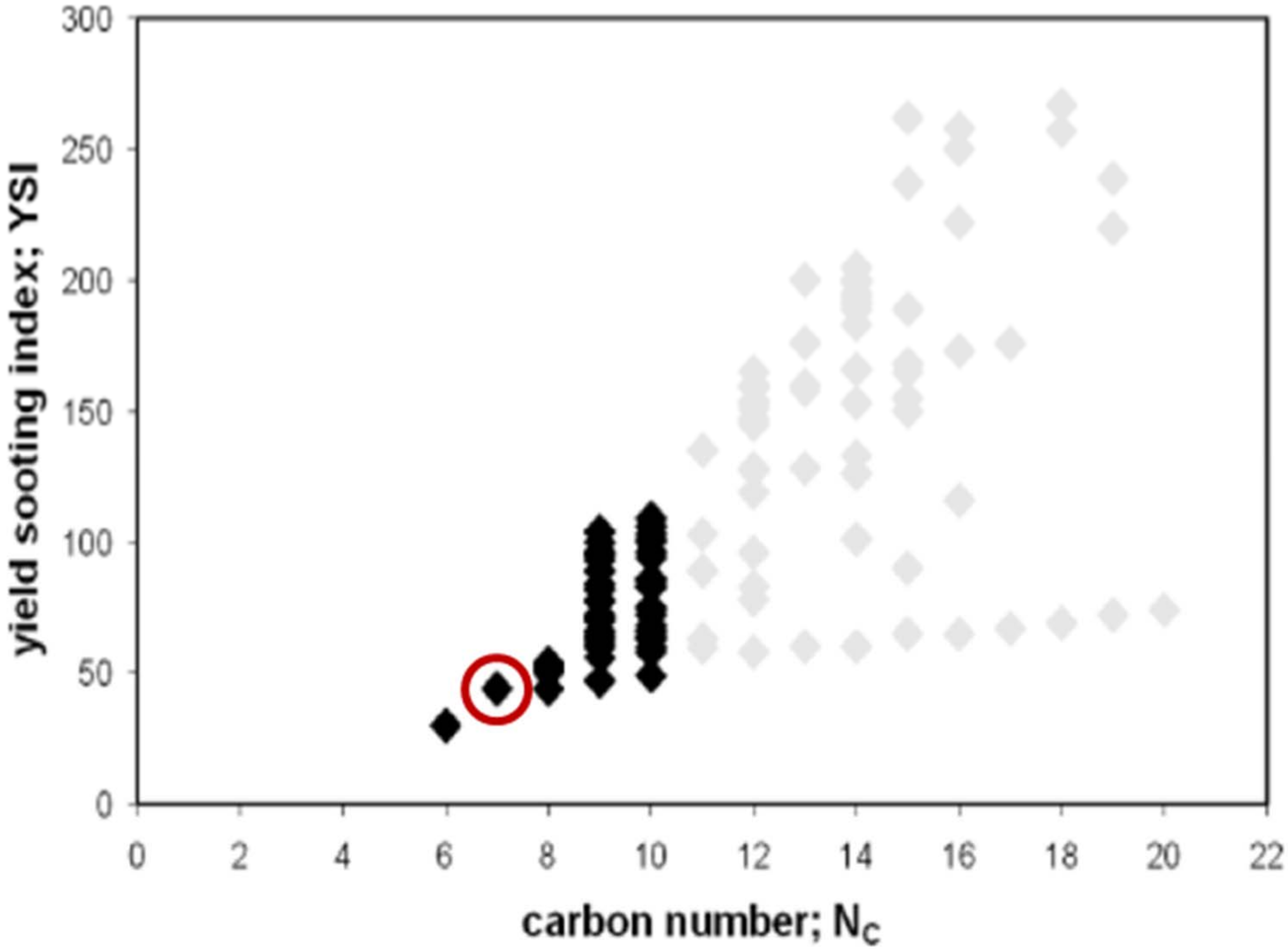
Engine test bench

other test fuels



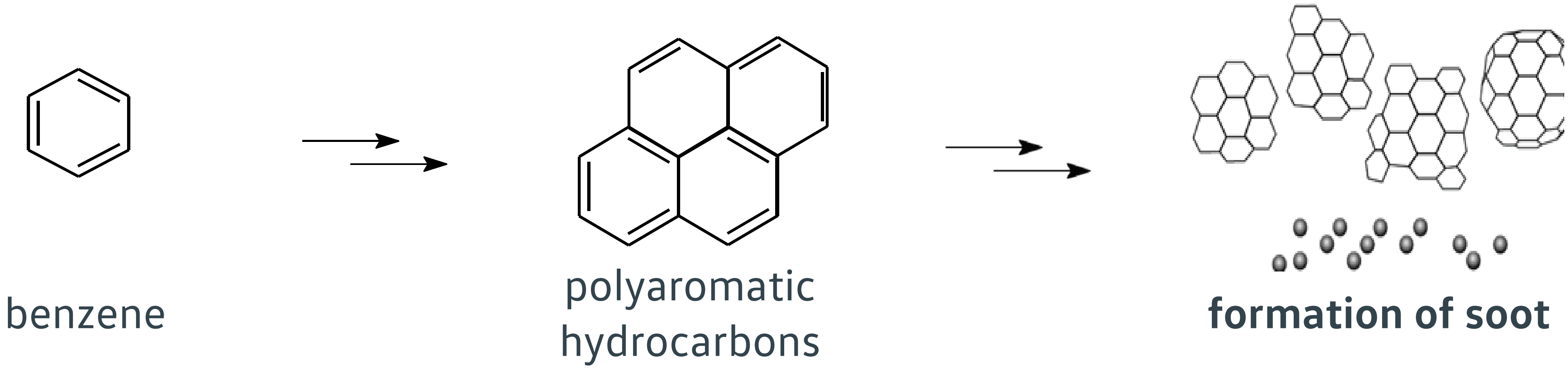


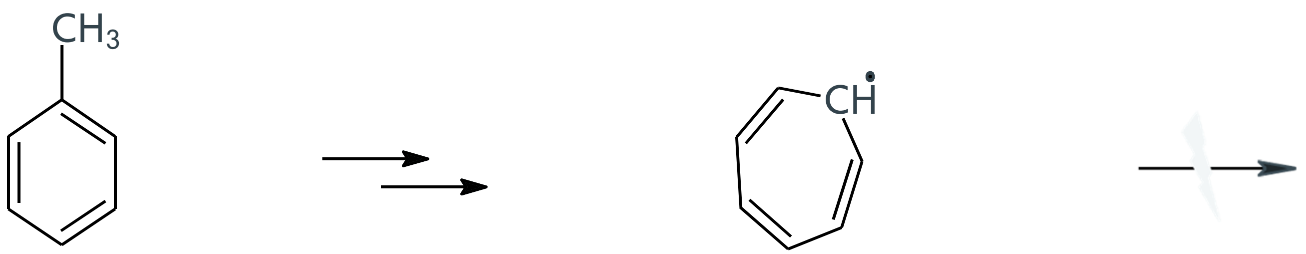
Sooting tendencies of aromatic hydrocarbons



Source: Combustion Generated Fine Carbonaceous Particles, Karlsruhe University Press, 2009

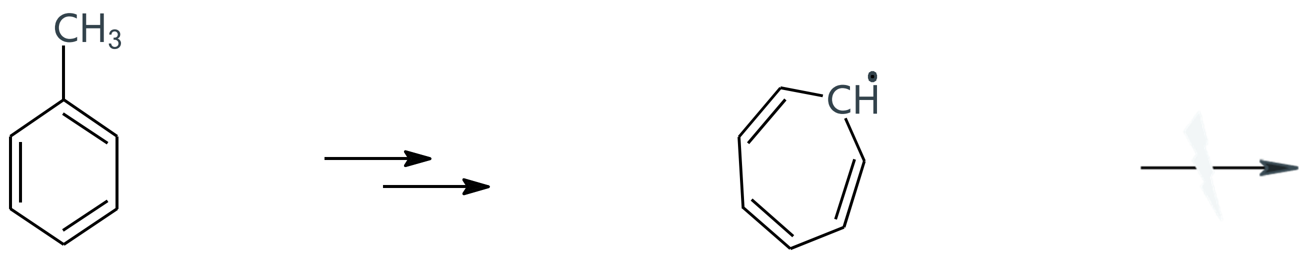
Influence of aromatic compounds on particle formation





Reduction of particle formation by reducing content of aromatic compounds with more than eight carbon atoms.

Influence of aromatic compounds on particle formation



toluene

tropylium radical

reduced formation of soot

- disorder of the conjugated π-electron system
  - inhibition of particle formation

Reduction of particle formation by reducing content of aromatic compounds with more than eight carbon atoms.

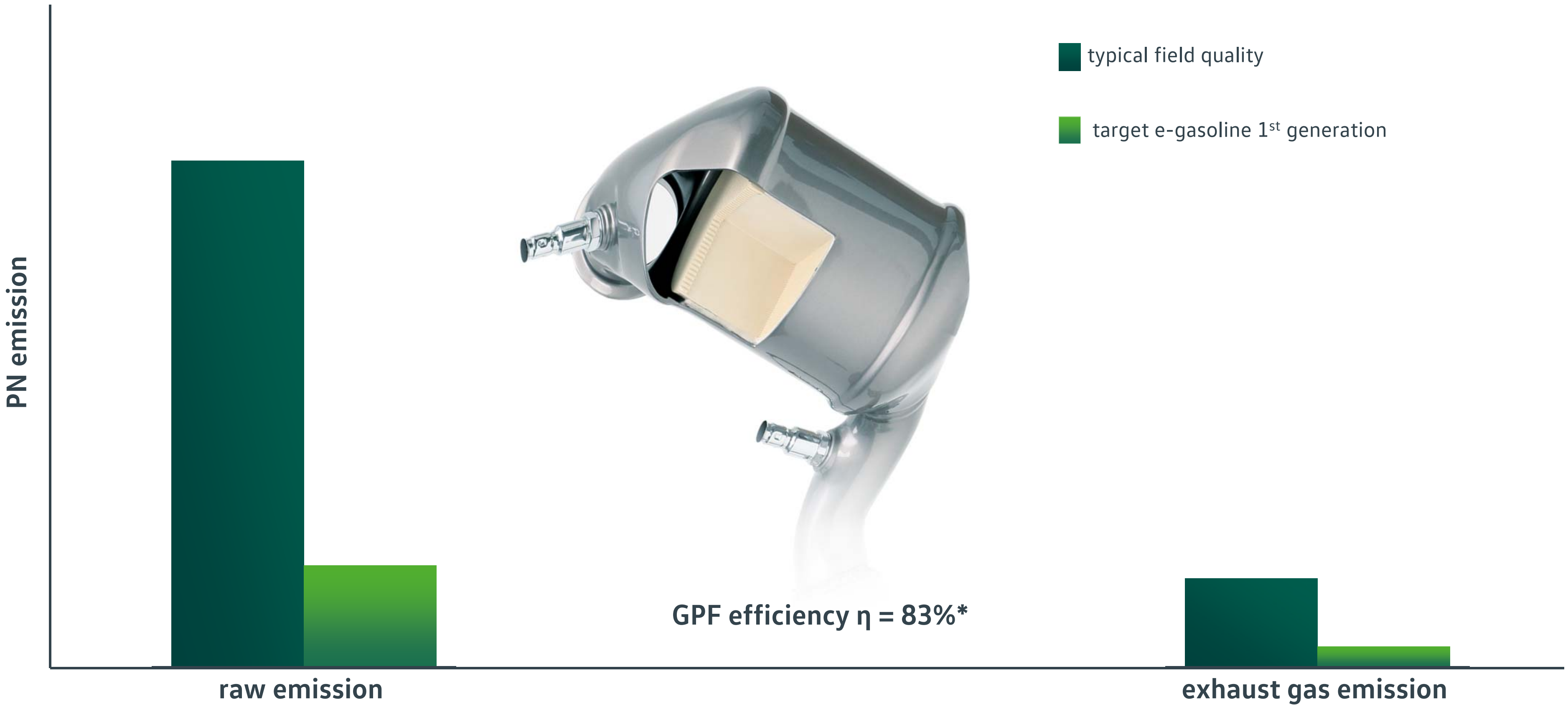
Correlation of different fuel properties to PN emissions

1.4 L Turbo GDI 103 kW EU5, Golf, meaningful sections from different drive cycles

Correlation coefficients from linear regression of eight fuels

Property	Cold start	Acceleration	High load
Total aromatics	0,86	0,67	0,36
Aromatics ≥ C8	**0,90**	**0,97**	0,79
Aromatics ≥ C9	0,87	**0,94**	0,78
Ethanol content	-0,53	-0,48	-0,34
E150	**-0,97**	**-0,91**	-0,60
T80	**0,96**	**0,90**	0,67
T90	0,86	0,77	0,75
Final boiling point	0,69	0,74	0,88
Density	**0,88**	0,63	0,24

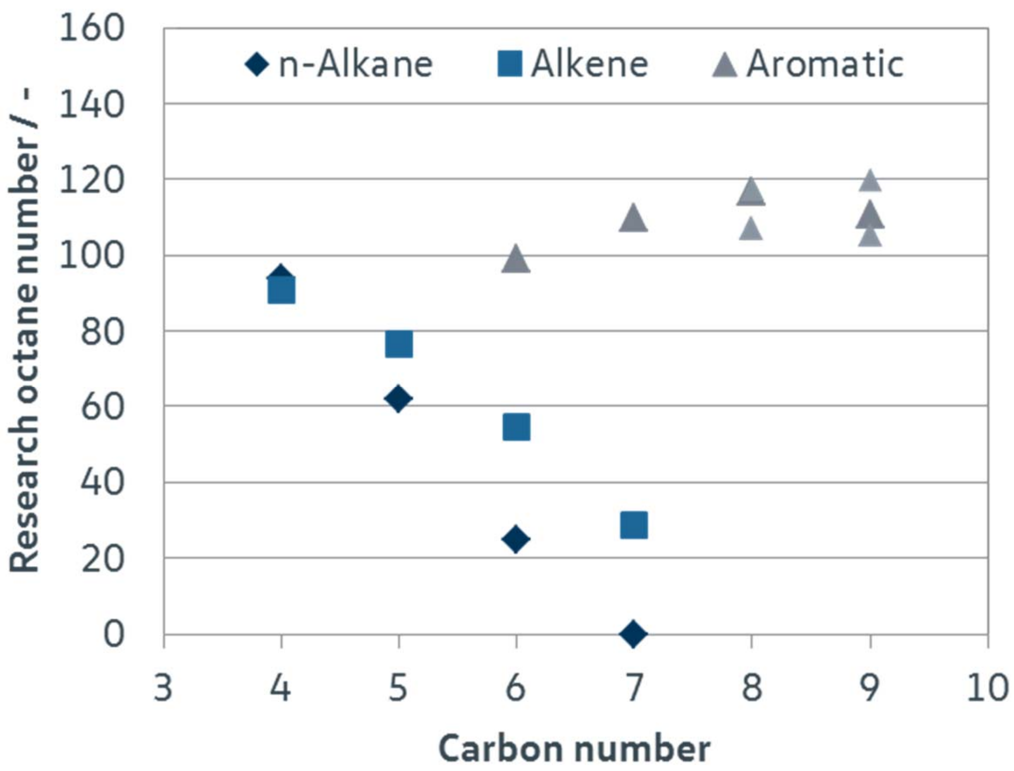
PN reduction by the use of e-gasoline 1st generation
(5 cars in WLTP)



Source: ACEA

Knocking tendency

Research octane number of specific fuel components



Ethanol: 130

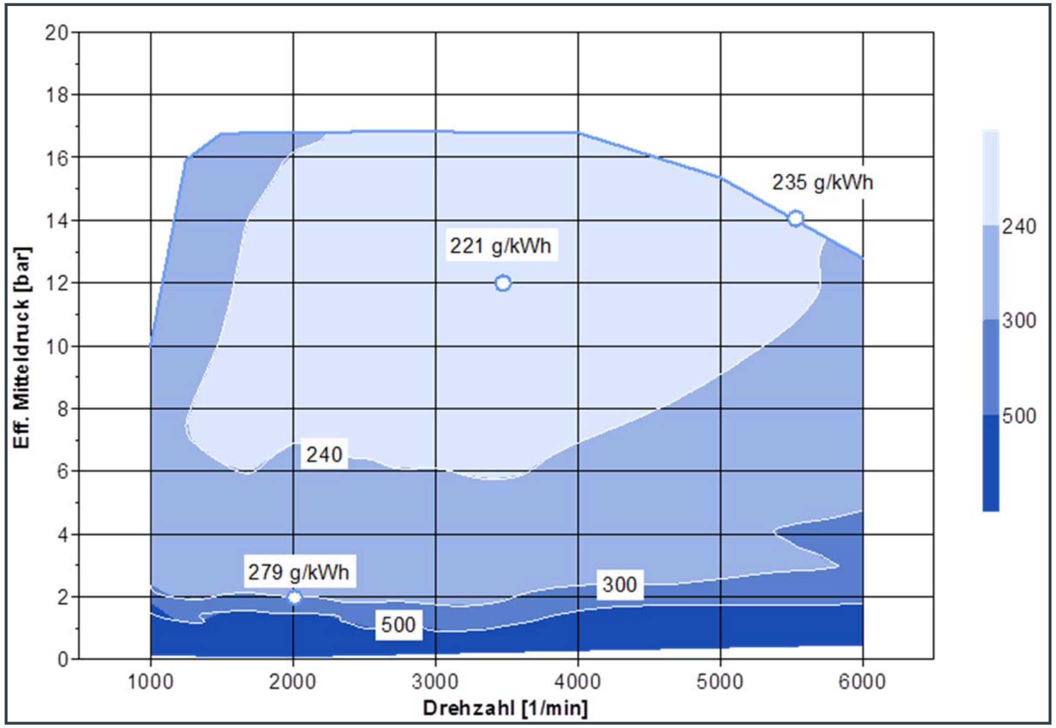
ETBE: 118

Emission optimized + High RON must be based on oxygenates.

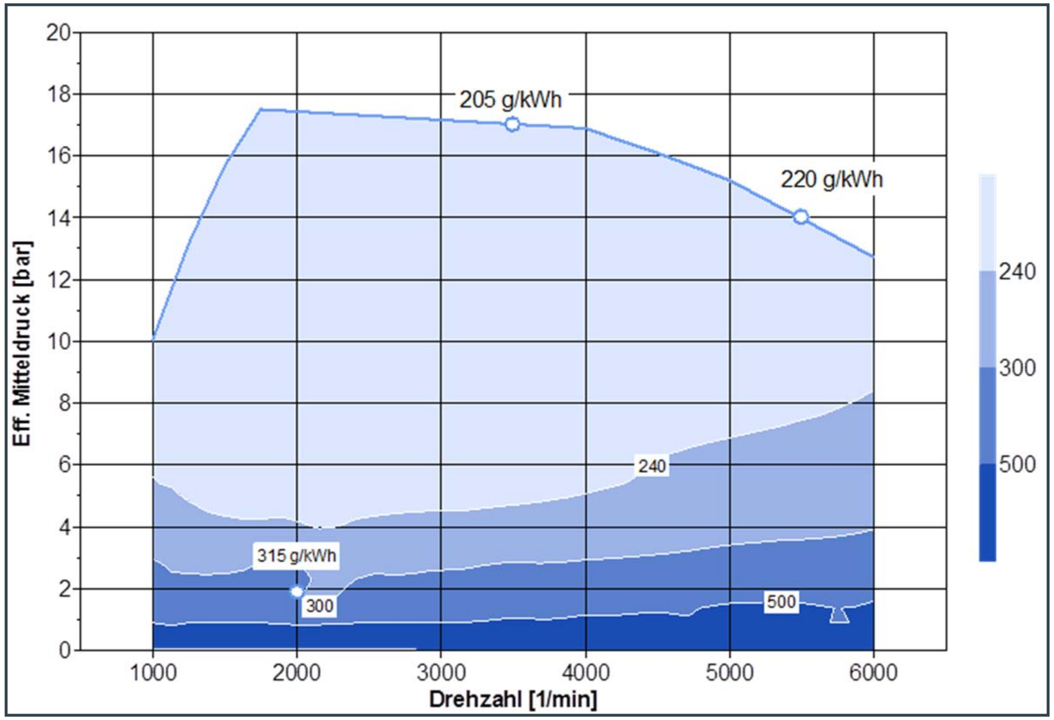
→ **E20 RON 102**

Fuel consumption on test bench

1.5L TGI EA 211evo

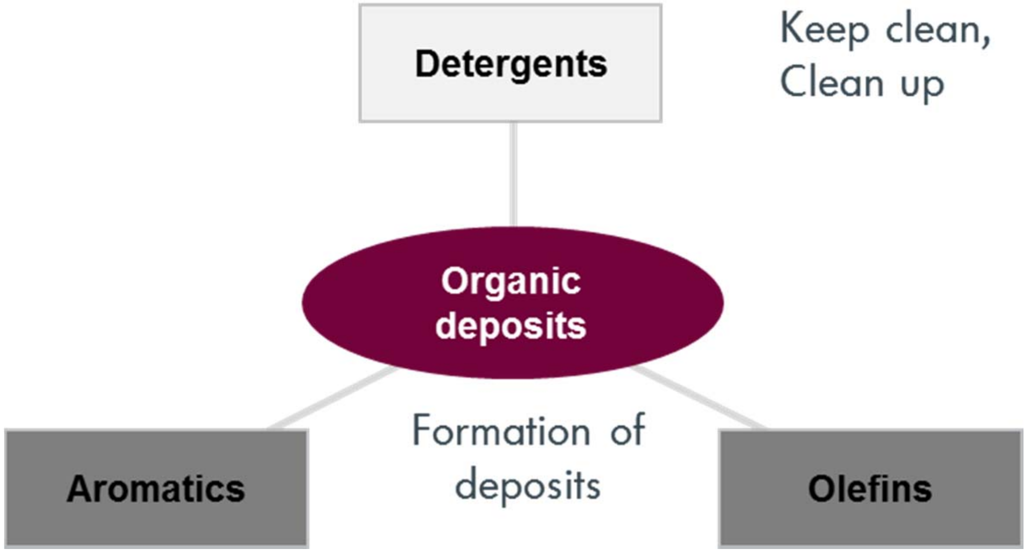


E10 ROZ 95



E20 ROZ 102 - dedicated engine

Long term effects by formation of organic deposits



organic deposits

- injector coking
- coking of inlet valve
- coking of intake tract
- throttle coking

possible effects

- negative impact on gas flow, spray pattern, mixture behavior
- inner flow handicap
- risk of pre-ignition

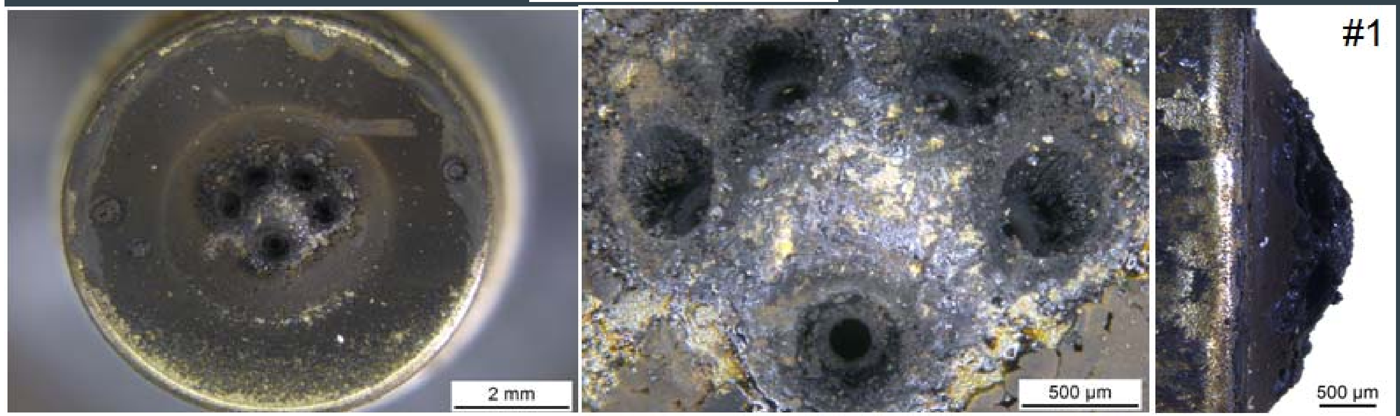
results

- OBD mistakes
- higher emissions
- risk of engine deposits

Influence of fuel additives on injectors

1.4 L Turbo GDI 103 kW EU5, engine high load ageing run

Fouled Injectors



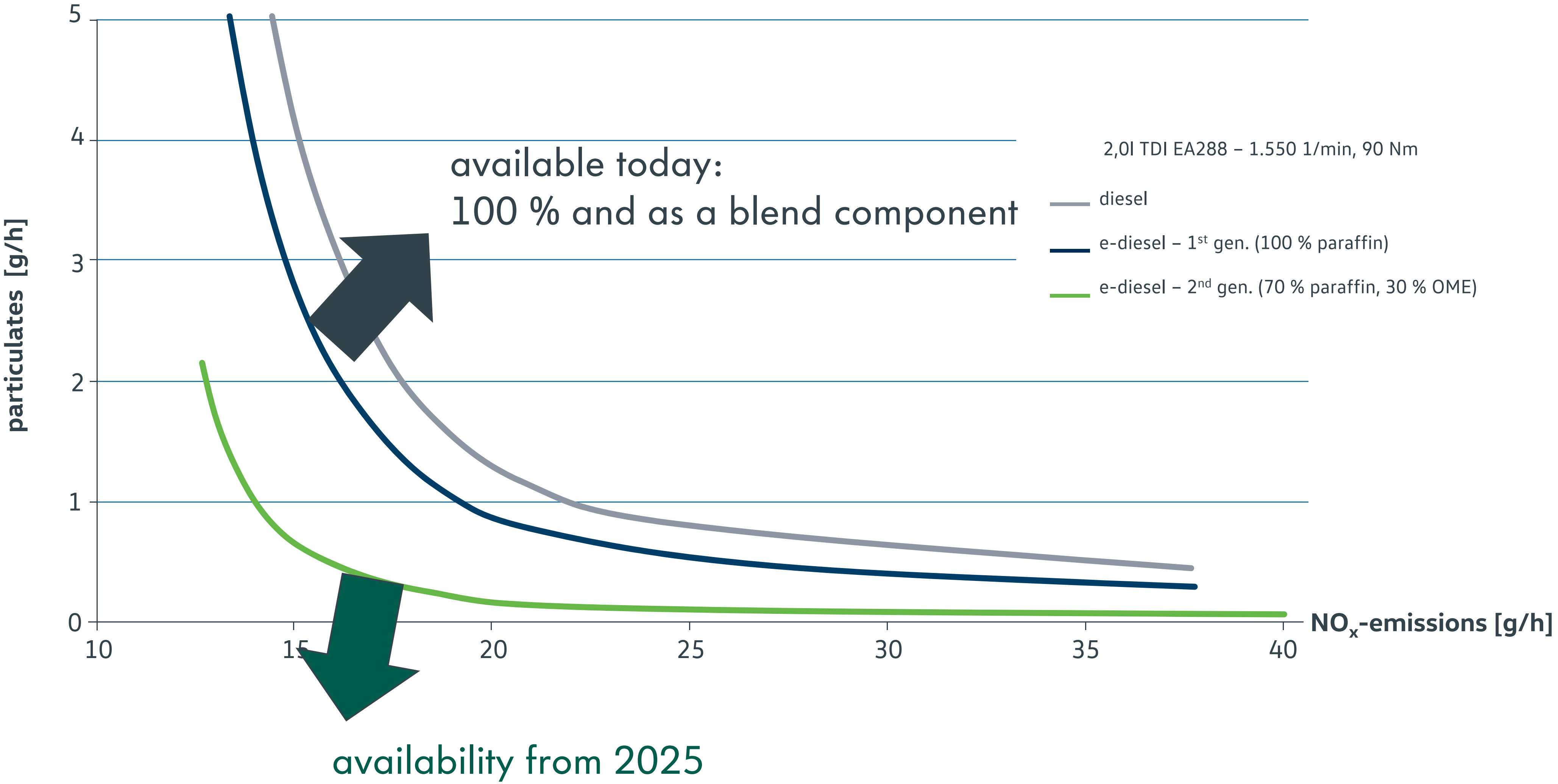
Outer deposits | *In-hole deposits* | *Outer deposits*

Keep-clean injectors

Outer deposits | *In-hole deposits* | *Outer deposits*

Source SGS Conference 2014, ShanghaiJohnny Shen, Alex Cantlay, Thomas Garbe

Raw emission advantages by the use of e-diesel



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Approach for e-gasoline

fuel

improved specification

- combustion behavior
- oxygenates → E20
- low soot formation tendency
- stability and all year quality

production of e-fuels

- energy- und CO_2-optimized production
- production of optimized base quality
- optimization additive package

gasoline vehicles

efficient powertrains

- use of improved combustion properties
- use of lower soot potential

plug in concepts

- use of improved stability
- use of all year quality

Engine design for new gasoline fuels

drop in:
no modification

EN 228

E10

paraffin from MTG process

slight modifications:
fuel detection, higher compression rate
combustion optimization

EN 228 mod
E20 eq

E20 ROZ 102

E20
E20 with ethanol equivalents
paraffin from MTG process

Roadmap gasoline fuels

2020 | 2025 | 2030 | 2035 | 2040

EN 228
main grade

E10 penetration in whole Europe
quality optimization for low PN emissions

for specific use
option: „city-gasoline“

EN228 Mod
main grade

E20 ROZ 102, min. PN emissions

Also see „Auto Fuel Studies 1+2“ at E4tec and Roland Berger

Approach for e-diesel

fuel

specification

- introduction of paraffinic diesel into the market
- new spec. for fuels containing OME
- improved stability

production of e-fuels

- energy- und CO_2-optimized production
- production of optimized base quality
- optimization additive package

diesel cars

identification of use for air quality improvement

efficient powertrains

- use of improved combustion properties
- use of low soot potential

basic investigation

- concept OME blend engine

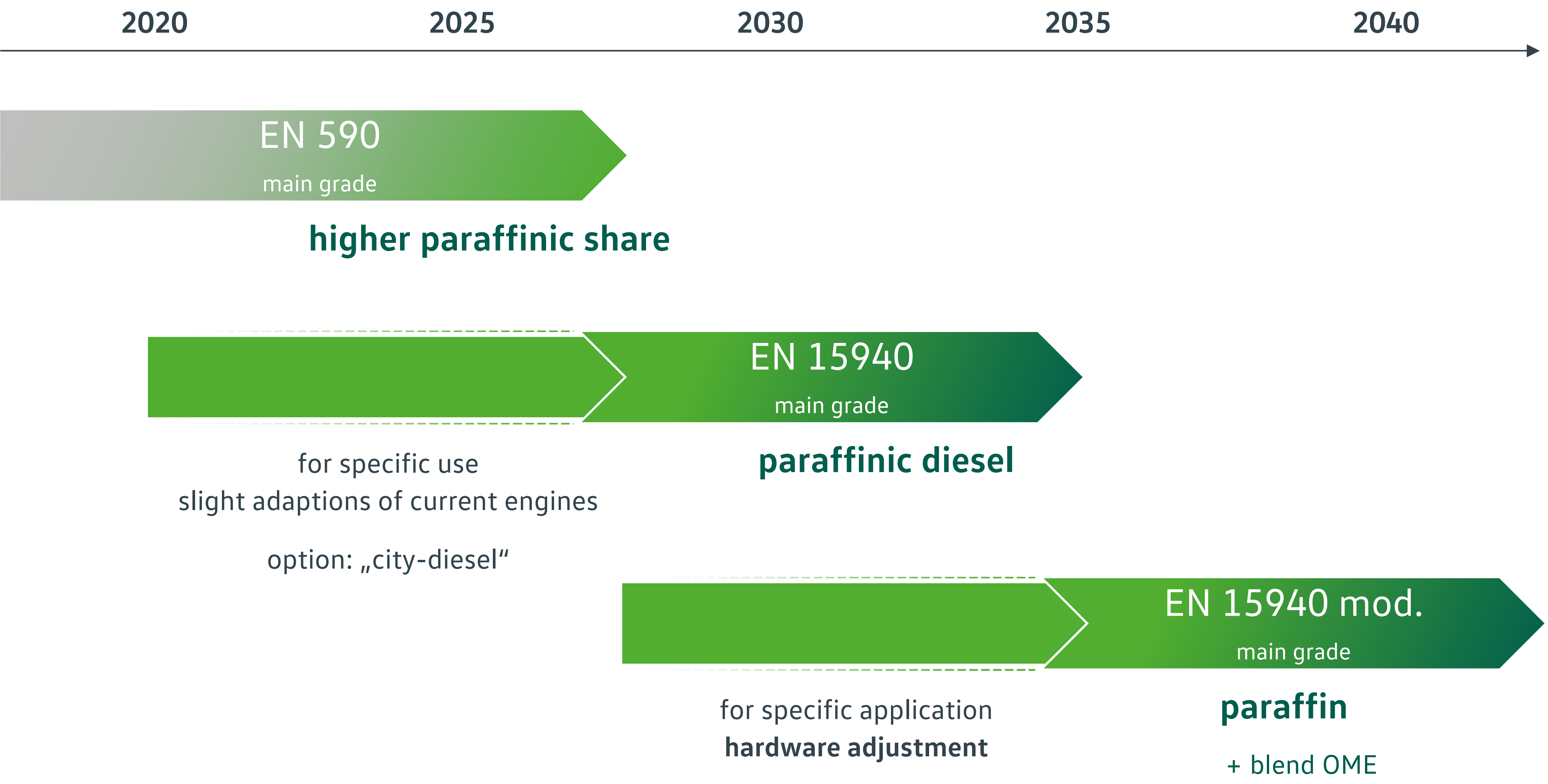
plug in concepts

- use of improved stability
- use of all year quality

Engine design for new diesel fuels

drop in: no modification	EN 590 EN 15940	high paraffinic share max. 5 % OME, fleet compatible
slight modifications: fuel detection, material	EN 15940 mod	30 % OME, can also be operated with diesel or paraffinic diesel
„dedicated vehicle" OME engine, new fuel system, expensive material	OME standard	100 % OME, no operation with diesel or paraffinic fuel possible

Roadmap diesel fuel

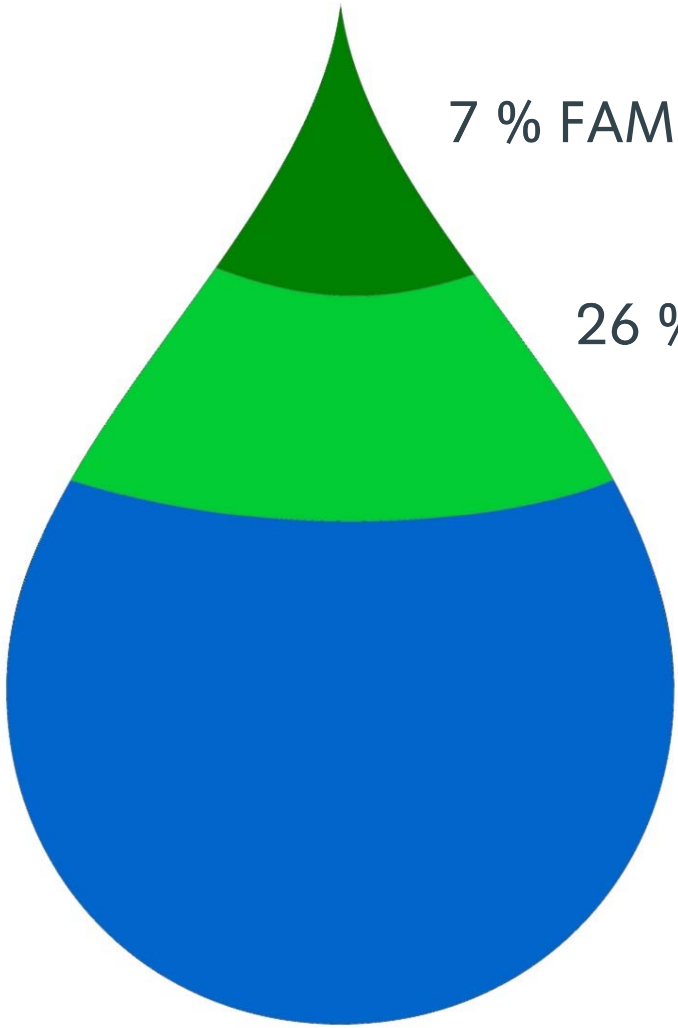


Concept Diesel R33

- fuel for every diesel vehicle
- same or lower exhaust emissions
- high quality
- suitability for future vehicle concepts

→ acceptance of customers, public and politics

R33* Blue Diesel



7 % FAME from used cooking oil

26 % paraffinic diesel
from used cooking oil

67 % diesel fuel with
performance additive package

20 % CO_2-saving

R33Blue Diesel
regenerative

R33* tested in over 280 vehicles

Introduction of R33 Blue Diesel at Volkswagen main gas station 2018/01/30


R33Blue Diesel
AdBlue®
Super 95 E10
10
9
9


R33Blue Diesel
regenerative
mehr als 20%


R33Blue
Diesel
regenerative
mehr als 20%
CO2-Minderung !
WOB CW 107
DT1

Conclusions

climate

- The ideal future fuel mix:
  Green electricity and **regenerative hydrocarbon fuels.**
- Backbone for fuel decarbonization:
  Ethanol, methanol to gasoline, paraffinic diesel fuel and methane.

air quality

- **Gasoline fuel** has to be optimized for **low particulate emissions** by optimizing the chemical composition, blending oxygenates and dosing additives.
- **Paraffinic diesel fuels** realizes **benefits in short time frame** and can be **improved in the future** by blending **OME.**
- **Methane fueled (CNG)** cars guaranty very low emissions immediately.

product

- **Robust roadmap** for regenerative fuels integrates sustainability and fuel quality for immediate effects on climate and air quality.
- Research and investments have to be **concentrated now to achieve a high impact till 2030.**

Do not put off till tomorrow what you can do today. Thanks for your attention.