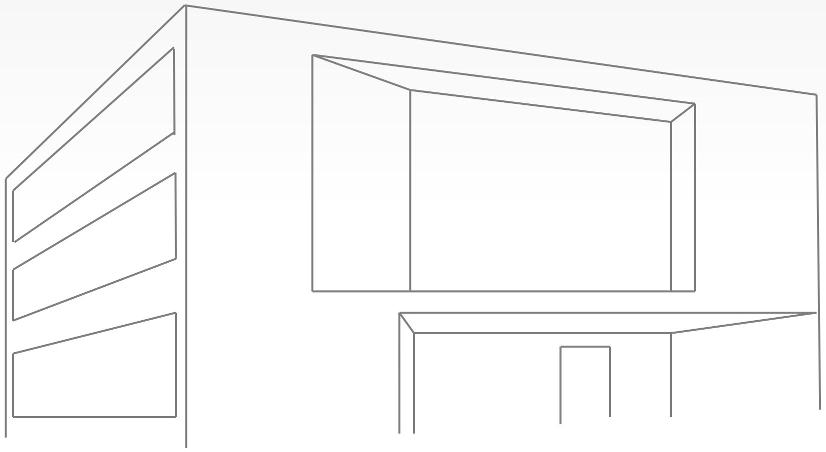
Biodiesel content of 10 vol% (Bente)
Project Report

Document prepared for
Project documentation
27.01.2025, Coburg

Project supported by:



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Biodiesel content of 10 vol% (Bente)

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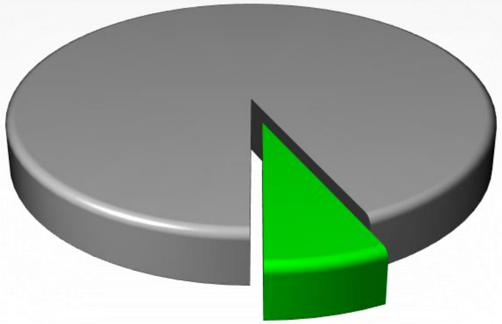
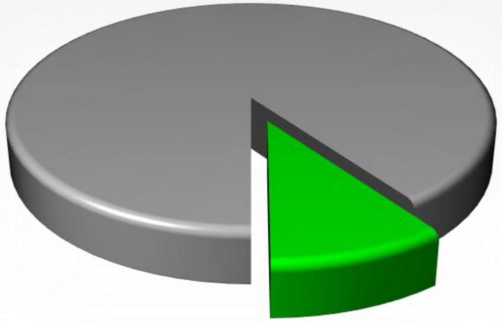
7 vol% FAME
93 vol% fossil

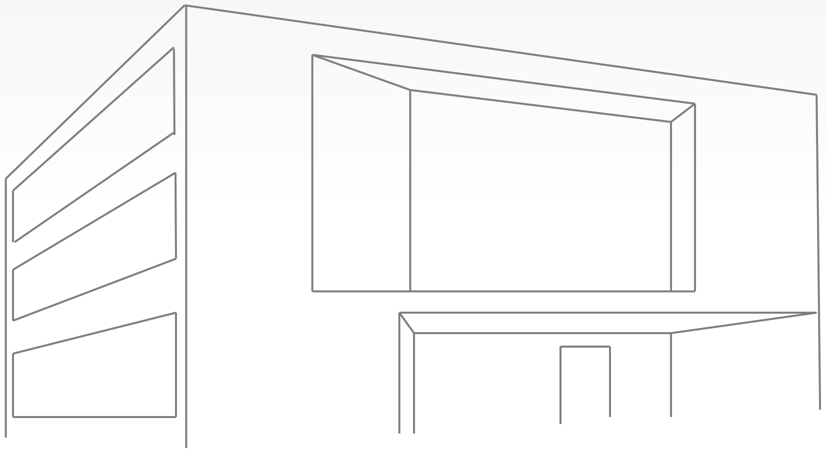


DIN EN 590

10 vol% FAME
90 vol% fossil



DIN EN 16734



FAME: fatty acid methyl ester
HVO: hydrotreated vegetable oil

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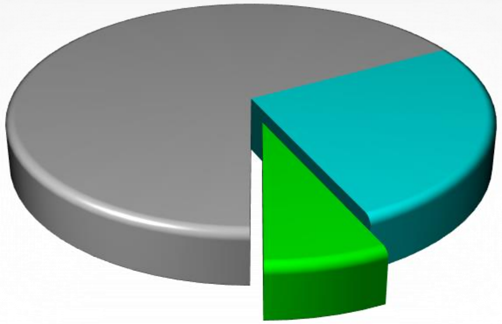
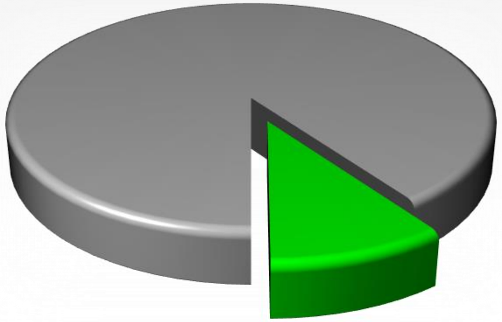
7 vol% FAME
26 vol% HVO
67 vol% fossil

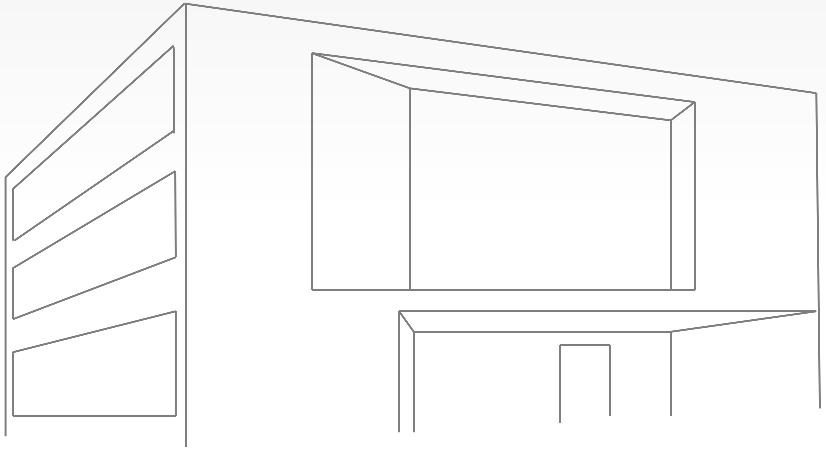


DIN EN 590
$\varphi_{min,R33}$ = 820 kg/m³

10 vol% FAME
90 vol% fossil



DIN EN 16734



FAME: fatty acid methyl ester
HVO: hydrotreated vegetable oil

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7 vol% FAME
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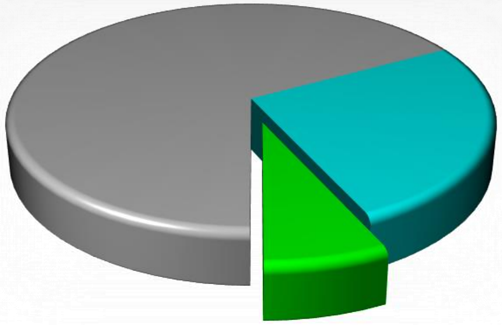
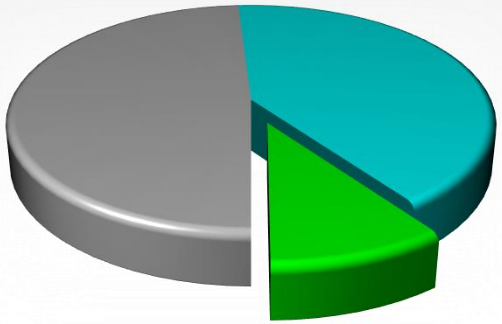
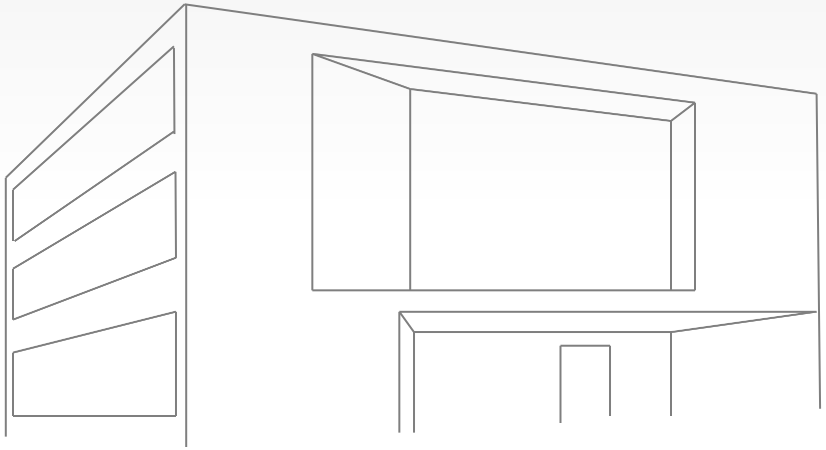


DIN EN 590
$\varphi_{min,R33}$ = 820 kg/m³

10 vol% FAME
41 vol% HVO
49 vol% fossil



DIN EN 16734
$\varphi_{min,R51}$ = 815 kg/m³



FAME: fatty acid methyl ester
HVO: hydrotreated vegetable oil

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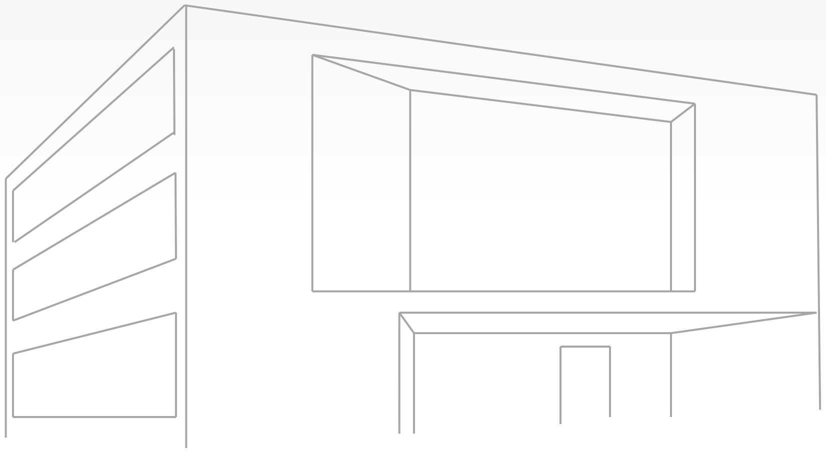
Agenda:

- Executive summary
- Theoretical introduction
- Methods and Materials
- Experimental results
    - Task A: Chemical analysis of fuels and oils
    - Task B: Reception of test vehicles
    - Task C: WLTC emission testing
    - Task D: WLTC oil dilution tests
    - Task E: Real-driving oil dilution testing
    - Task X: Thermodynamic raw-emissions
- Executive summary and outlook
- Acknowledgment
- Contact information



Executive summary

Executive summary (1/8) - Overview

This project is focused on the investigation of properties and engine-oil dilution of drop-in capable partially regenerative diesel blends including varying shares of fatty acid methyl esters (FAME or biodiesel) and paraffinic diesel (here: hydrotreated vegetable oil - HVO).

Therefore, the project tested a variety of different fuel blends listed below.

B10
- 10 % FAME
- 90 % fossil fuel

Diesel R51
- 10 % FAME
- 41 % HVO
- 49 % fossil fuel

Diesel R33
- 7 % FAME
- 26 % HVO
- 67 % fossil fuel

B30
- 30 % FAME
- 70 % fossil fuel

B7 gas station
- 7 % FAME
- 93 % fossil fuel

B0 fossil fuel as reference fuel

FAME: fatty acid methyl ester
HVO: hydrotreated vegetable oil

Executive summary

Executive summary (2/8) – Fuel analysis and aging
The results of the chemical fuel investigations show: ○ A blend of 10 vol% FAME and 41 vol% HVO (called R51) still provides a density ρ = 815 kg/m³ and therefore fulfills the DIN EN 16734. The R51 is therefore the fuel blend with the highest regenerative share in the context of this project. ○ All tested fuel blends achieve induction times of more than 40 hours in thermo-oxidative aging, which is significantly longer than required by the standard. ○ Furthermore, the aged B10 and R51 are fairly identical regarding the formation of CO absorption bands within the FTIR spectrum, which shows that the HVO share does not have a visible effect influence regarding the storage stability. ○ However, the aging experiments also show that a diesel R33 shows a lower deposit formation tendency after 80 hours thermo-oxidative aging compared to a B10 and R51. Therefore, the results can find a different fuel aging behaviour after extended thermo-oxidative aging.

Executive summary

Executive summary (3/8) – Fuel and engine-oil analysis
The investigations of the fuel and engine-oil aging interactions are also done at thermo-oxidative conditions. Here, the fuel-oil samples are applied with a fixed mixing ratio of 20 vol% fuel to 80 vol% engine oil. Moreover, the tests include a variation of the 0W20 engine oil coming from Shell and Castrol. The results of the fuel and engine-oil aging experiments show: o All fuel-oil blends show an increase in density and kinematic viscosity over the duration of thermo-oxidative aging. In contrast, the oils, which are aged without being blended with a fuel are fairly stable regarding density and kinematic viscosity, which indicates an aging interaction within the fuel-oil blends. o The comparison between the different fuels shows no major differences between the aging behavior. This means that the amount of oil aging can be assumed to be similar as long as the amount of oil dilution is at a comparable level. o Moreover, the GPC results show a decrease of smaller molecules and an increase of larger molecules over the duration of aging. However, it needs to be noted that aging apparatus is constantly scavenged with air. As a result, it is possible that volatile components are leaving the sample over time. o The results of the GCMS allow for a differentiation between the the Shell and Castrol base oil.

Executive summary

Executive summary (4/8) – Chassis dynamometer tests

The investigations of the emission behavior and the oil dilution behavior of the test fuels are done with three series production vehicles, which are operated in different testing conditions.

- Vehicle A is a non-instrumented 2.0l TDI Passat (FWD) provided by the AGQM
- Vehicle B is an instrumented 2.0l TDI Passat (FWD) provided by Volkswagen
- Vehicle C is a non-instrumented 2.0l TDI Passat (AWD) operated by Volkswagen.

- Vehicle A is tested in WLTC emission test cycles with 2 fuels and in short-distance driving with 2 fuels
- Vehicle B is tested in WLTC emission test cycles with 5 fuels and in an artifical oil-dilution test using an adapted ECU while operating the vehicle in WLTC with 2 fuels.
- Vehicle C is tested in a long-distance driving profile with 2 fuels.

Executive summary

Executive summary (5/8) – Emissions

The investigations of the emission behavior of the test fuels are done with three series production vehicles, which are operated in different testing conditions.

The results of the WLTC emission tests show:

- The emission results of vehicle A and vehicle B are very comparable using B10 and R33 with no issues regarding Euro 6 emissions and no issues regarding CH_2O, NH_3 or N_2O. The only noticable difference between vehicle A and B is that vehicle A achieves good PN emission results and vehicle B achieves very good PN emission results.
- The emission results of vehicle B with B10, R33, B0, R51 and B30 show that none of the tested fuels shows issues regarding emissions or operational stability. Vehicle C is tested in a long-distance driving profile with 2 fuels. Therefore, none of the tested fuels is assumed to be critical regarding Euro 6 emissions. Moreover, none of the tested fuels shows significant emission concentrations regarding CH_2O, NH_3 or N_2O. It is therefore assumed that the tested fuels are also capable for upcoming Euro 7 legislations.

CH_2O: Formaldehydde, NH_3: Ammonia, N_2O: Nitrous oxide

Executive summary

Executive summary (6/8) – Engine oil dilution
The investigations of the oil dilution behavior of the test fuels are done with three series production vehicles, which are operated in different testing conditions. The results of oil dilution tests show similar levels of oil dilution with slightly indifferent tendencies: ○ The oil dilution tests with vehicle A are done in a short-distance driving profile by a nursery service. These results show that B7 provides a higher total oil dilution than B10 with vehicle A in a short-distance profile. ○ The oil dilution tests with vehicle B are done at the chassis dynamometer with adapted ECU. These results show R33 provides a slightly higher total oil dilution than B10 in these testing conditions. ○ The oil dilution tests with vehicle C are done on a long-distance driving profile for 15.000 km each. These results show that B10 provides a slightly higher total oil dilution than B7 in these conditions. ○ The differences between these results can be attributed to two points. Firstly, all three tests are very different regarding the achievable maximum oil temperature, which can affect the re-evaporation. Secondly, it is possible that the applied test fuels are different regarding the base fuel properties. ○ However, none of the tests shows major differences between the test fuels. And this result is important, since similar amounts of oil dilution show similar oil aging effects in the chemical experiments.

Executive summary

Executive summary (7/8) – Thermodynamic engine tests

Finally, the report also includes the results of thermodynamic parameter variations at the heavy-duty engine applied at Coburg University. Here, the tests include EGR variations with fixed MFB50 and single injection operation with R33, R51, HVO and B100.

The results of thermodynamic engine tests show:

- The raw-emission results of R51 are in-between the raw emission results of R33 and HVO. This verification is important to confirm that the R51 fuel blend provides no unusual emission tendencies.
- In detail, all fuels show increasing PN and CO emissions while decreasing the NOx emission via EGR.
- However, increasing EGR also shows beneficial results regarding decreased NH_3 and N_2O emissions as a result of decreased nitrogen reactions following decreased peak flame temperatures.
- Moreover, increased EGR also shows benefits regarding decreased combustion sound levels.

PN: particle number, CO: Carbon monoxide NH_3: Ammonia, N_2O: Nitrous oxide
EGR: Exhaust gas recirculation, MFB50: center of combustion (50 % conversion)

Executive summary

Executive summary (8/8)
The results of this research project show that partially regenerative fuel blends such as the R51 provide major potentials for the defossilization of the existing fleet. ○ All tested fuels provide induction times of more than 40 hours. ○ All tested fuels show no issues in emission regarding Euro 6, CH_2O, NH_3 or N_2O. ○ All tests show that the oil dilution tendencies of B7 and B10 fuel blends are on a similar level. ○ And the chemical results show that the oil-fuel aging interactions are on a similar level as long as the oil dilution tendency is on a similar level as well. ○ As a result, B10 and R51 are very promising fuel blends that contain an increased proportion of regenerative fuels.

Agenda:

Executive summary

Theoretical introduction

Methods and Materials

Experimental results

- Task A: Chemical analysis of fuels and oils
- Task B: Reception of test vehicles
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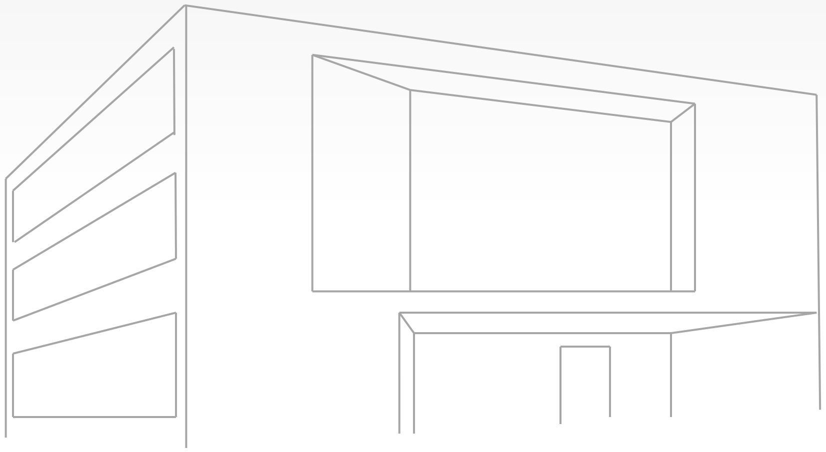
- Task D: WLTC oil dilution tests
- Task E: Real-driving oil dilution testing
- Task X: Thermodynamic raw-emissions
- CO_2 potentials within the german vehicle fleet

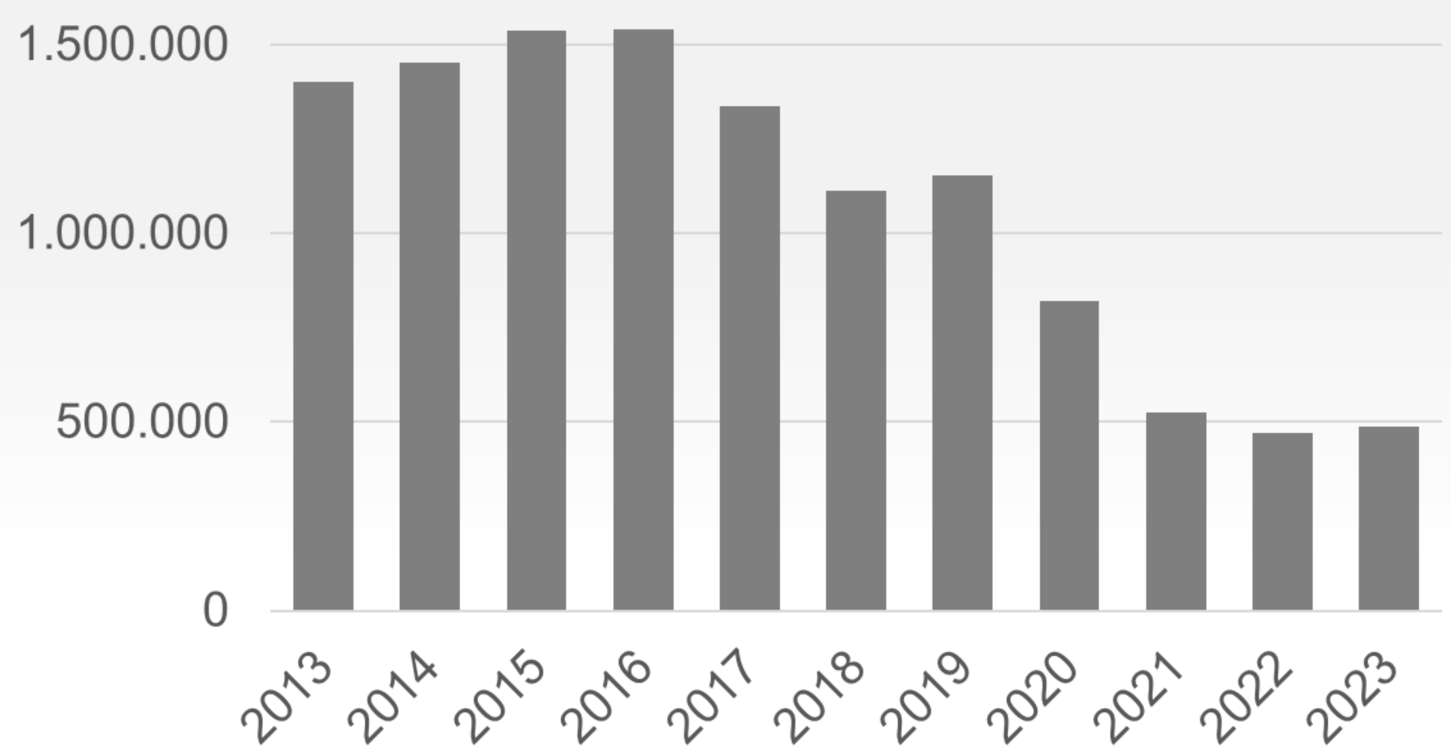
Summary and conclusion

Contact information



Project motivation

Annual diesel-car registrations in Germany



Imagesource: https://de.statista.com/statistik/daten/studie/184465/umfrage/zugelassene-diesel-pkw-in-deutschland/ Date:18.03.2024

Explanation:

Germany has a decreasing number in diesel-car registrations

Technical potential:
The spare biodiesel share could be used for improved decarbonization of diesel engine vehicles by applying a B10, B30 or R50$^+$

Technical question:
Which effects could appear with increased biodiesel shares on vehicle emissions, engine oil aging and short distance driving?

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Executive summary and outlook

Acknowledgment

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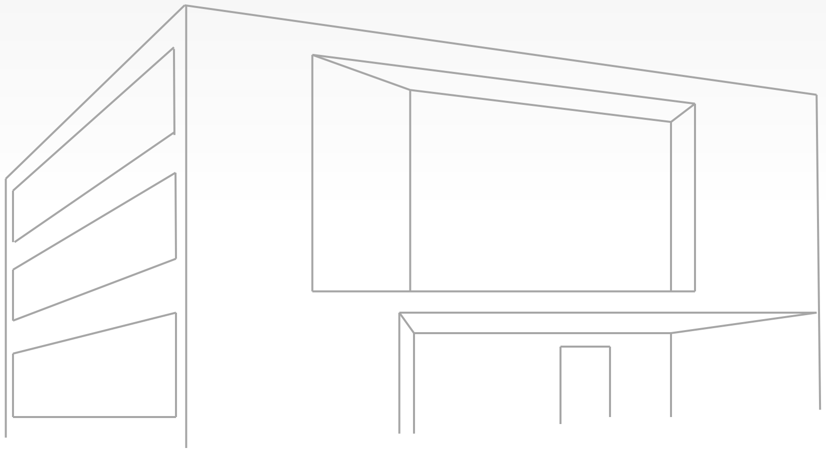

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The project data includes 4 technical parts

a) Fuel and oil samples are chemically analyzed
b) Fuels are tested on thermodynamic test-bench
c) Emission test-cycles are done in Coburg
d) Real-life testing is done by VW and AGQM

Fuel research at Coburg University

Fuel synthesis

Chemical laboratories	Sensor development	Multi-cylinder engine testing	Vehicle dynamometer	Real-life test driving	Fuel fleet testing
HSCO		HSCO	HSCO	VW, AGQM	

Customer use

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Methods and Materials – Test car: Vehicle A

Vehicle dynamometer	Illustration	Description

		○ Transmission: DQ381 (DSG/FWD)
		○ Emissioning: Euro 6d (EA288 EVO)
		○ Engine: 2.0l TDI SCR
		  ○ 400 Nm @ 1750 - 3500 rpm
		  ○ 147 kW @ 3500 - 4000 rpm
		○ Certified consumption:
		  ○ 4,7 l/100 km
		  ○ 124 g/km
		○ Used in task C and task E

Methods and Materials – Test car: Vehicle B

Vehicle dynamometer	Illustration	Description

		○ Transmission: DQ381 (DSG/FWD)
		○ Emissioning: Euro 6d (EA288 EVO)
		○ Engine: 2.0l TDI SCR
		  ○ 400 Nm @ 1750 - 3500 rpm
		  ○ 147 kW @ 3500 - 4000 rpm
		○ Certified consumption:
		  ○ 4,7 l/100 km
		  ○ 124 g/km
		○ Used in task C and task D

Data source: VW configurator
Date: 28.06.2024

Methods and Materials – Test car: Vehicle C

Vehicle dynamometer	Illustration	Description

		○ Transmission: DQ381 (DSG/4WD)
		○ Emissioning: Euro 6d (EA288 EVO)
		○ Engine: 2.0l TDI SCR
		  ○ 400 Nm @ 1750 - 3500 rpm
		  ○ 147 kW @ 3500 - 4000 rpm
		○ Certified consumption:
		  ○ 4,7 l/100 km
		  ○ 124 g/km
		○ Used in task E

Methods and Materials – Test conditions

Vehicle dynamometer	Illustration	Description
		○ The tests of task C and Task D are done at the vehicle chassis dynamometer at Coburg University using the WLTC driving profile. ○ The emission tests (Task C) are started with a cold powertrain at T_{air} = 21.5 °C with one test per day. ○ The oil dilution tests (Task D) are started with cold powertrain at at T_{air} = 21.5 °C but with four tests per day with dwell times of 10 minutes each.

Framework conditions

Fuel selection

B0 fossil fuel as reference fuel

Diesel R33
- 7 % FAME
- 26 % HVO
- 67 % fossil fuel

B10
- 10 % FAME
- 90 % fossil fuel

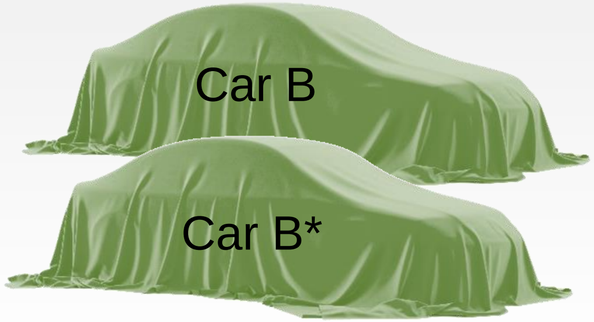
Diesel R51
- 10 % FAME
- 41 % HVO
- 49 % fossil fuel

B30
- 30 % FAME
- 70 % fossil fuel

B7 gas station
- 7 % FAME
- 93 % fossil fuel

Vehicle selection

Midclass 1
TDI 2,0 L; 145 kW
w/ DPF and SCR
(un-instrumented)



Midclass 1 (C1)
TDI 2,0 L; 145 kW
w/ DPF and SCR
(instrumented)

*same car w/ adapted ECU

One series production vehicles
(un-instrumented)

FAME: fatty acid methyl ester
HVO: hydrotreated vegetable oil

Framework conditions

	Chemical laboratory	Vehicle dynamometer	Short-distance driving (nursing)	Conventional distance driving
	B0 R33 B10 R51 B30			
Car A		R33 B10	B10 B7 g.s.	
Car B		B0 R33 B10 R51 B30		
Car B*		R33 B10		
Car C				R33 B10

*adapted ECU
g.s.: gas station

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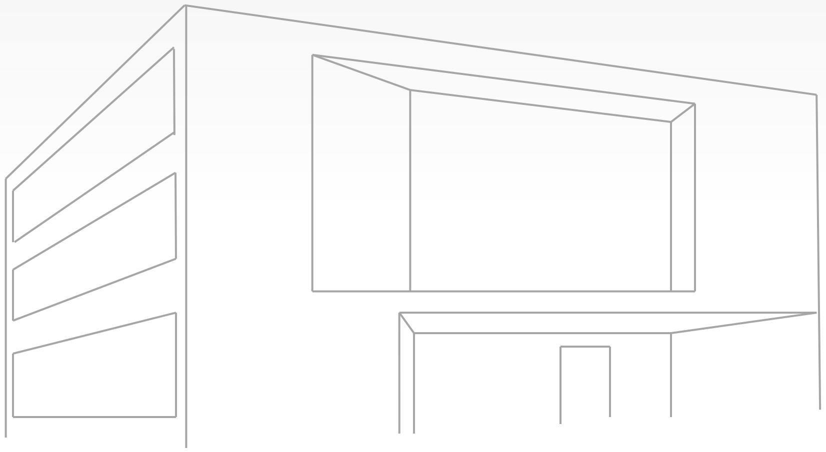

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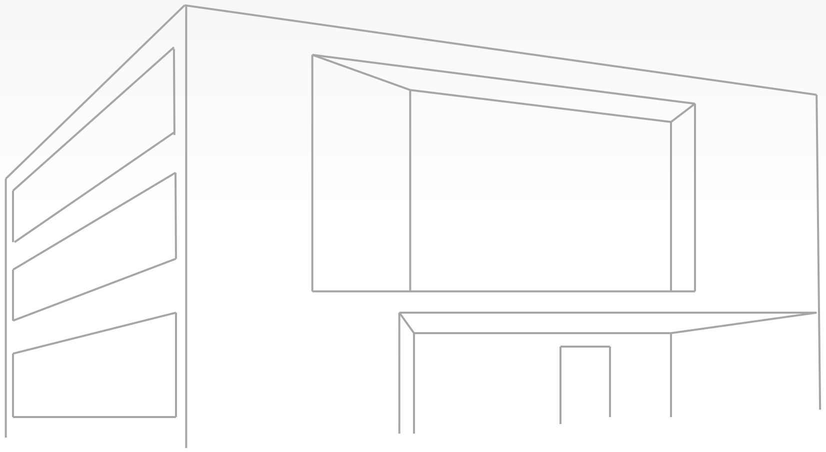
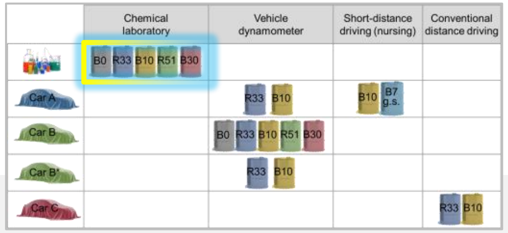
Experimental results

- Task A: Chemical analysis of fuels and oils
  - Mixture determinations
  - Aging experiments
  - FTIR analysis
  - GPC analysis
  - GCMS analysis

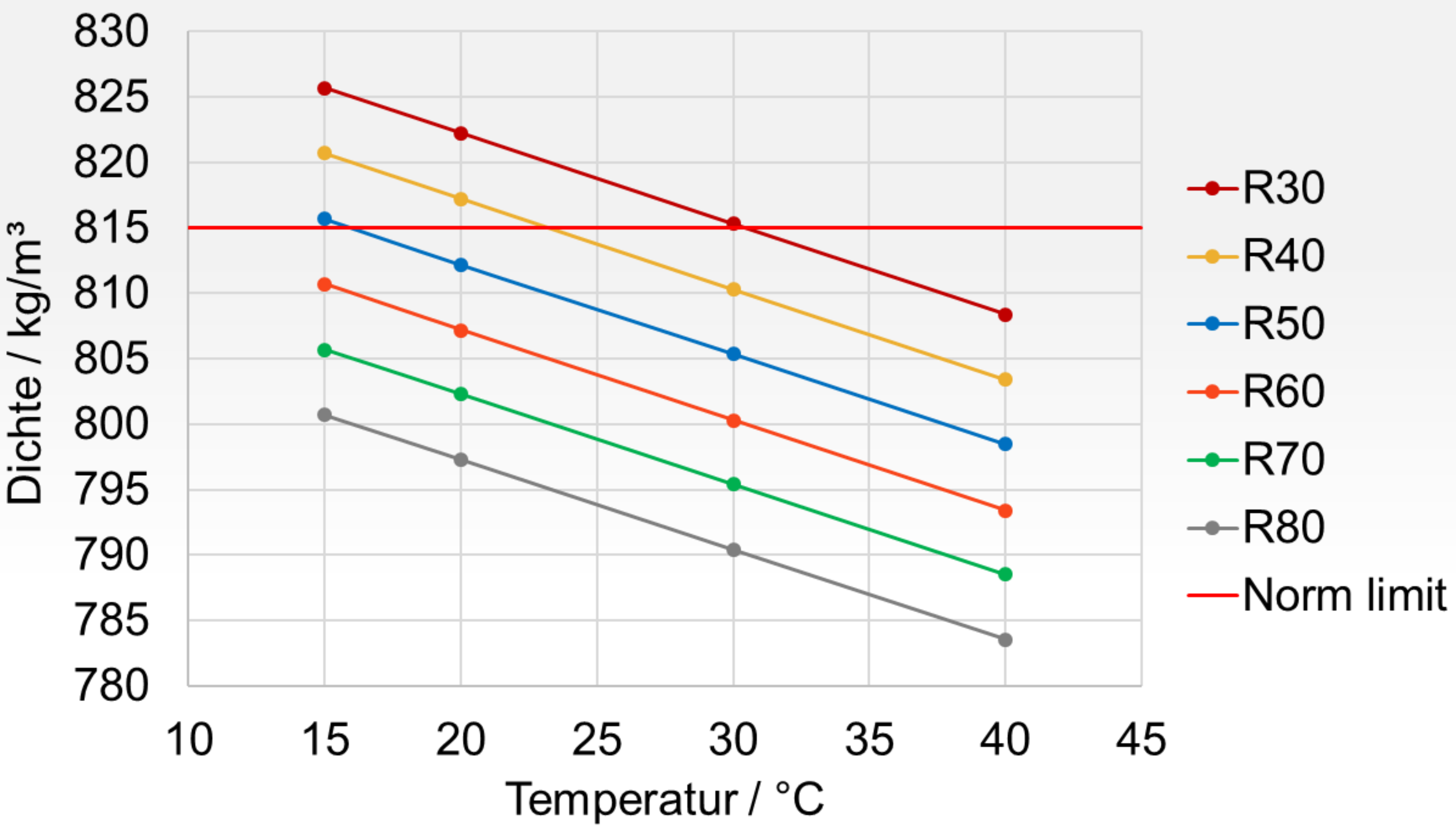
- Task B: Reception of test vehicles
- Task C: WLTC emission testing





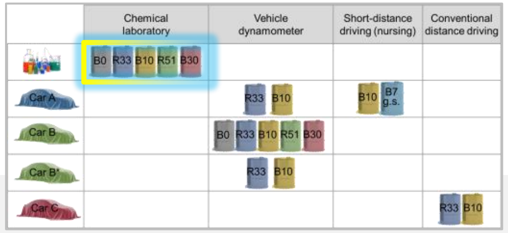
Task A2: Determine R50+ in density

Illustration	Description



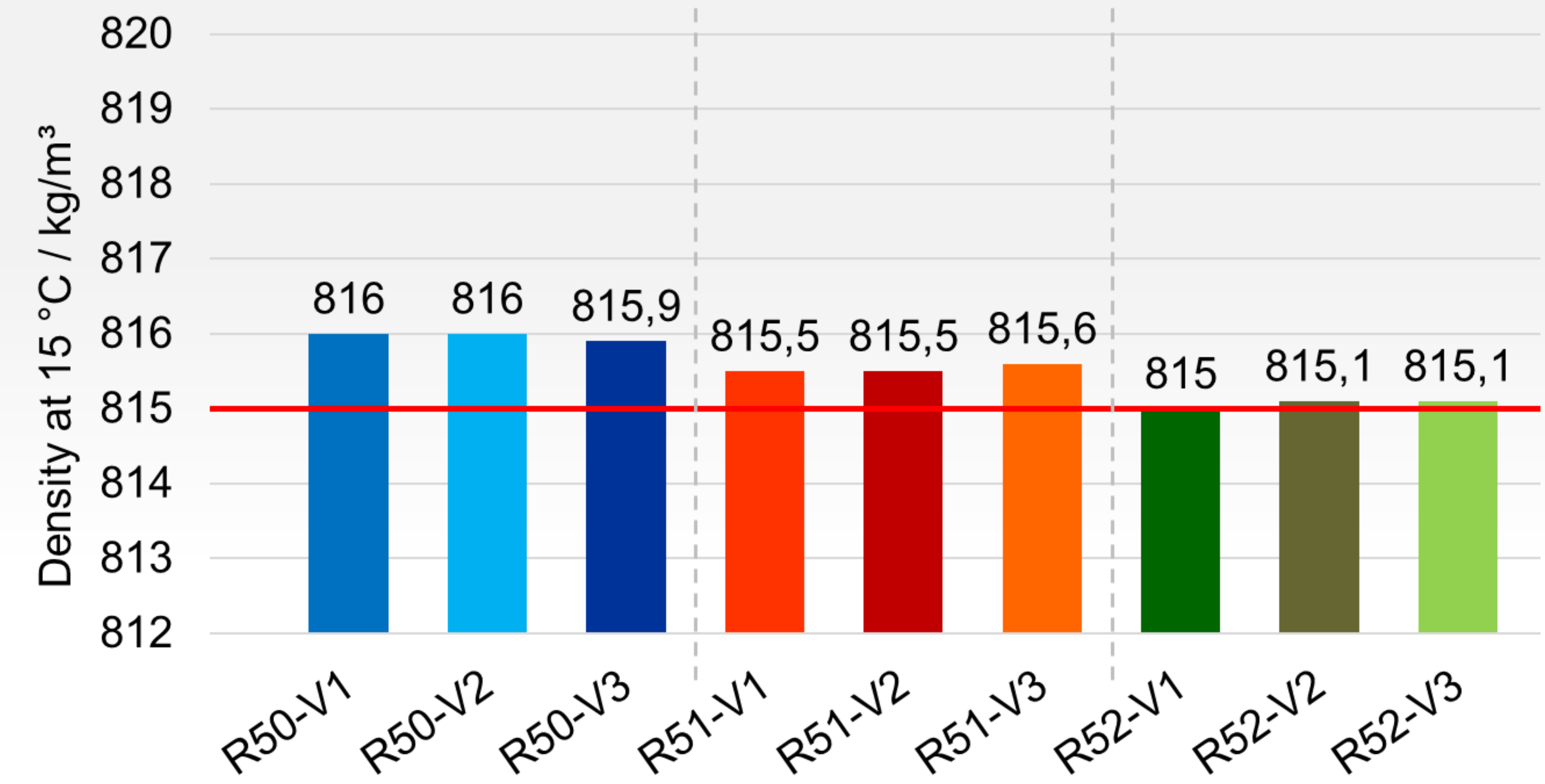
- The R50 consists of
  10 vol% FAME
  40 vol% HVO
  50 vol% Diesel fuel
- The R50 provides a density of 815.7 kg/m³ at T = 15 °C
- In EN 16734 the lower limit for density for a B10 is 815,0 kg/m³ at T = 15°C.

FAME: fatty acid methyl ester
HVO: hydrotreated vegetable oil



Task A2: Determine R50+ in density

Illustration

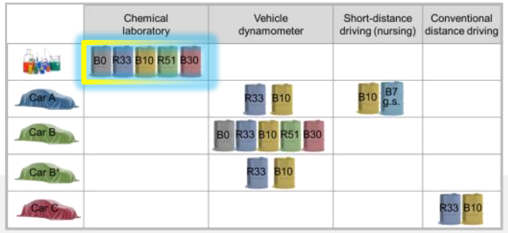


Description

- Composition of a R50+ diesel fuel blend with 10 vol% FAME and a maximized regenerative content of HVO
- Maintaining the density of 815 kg/m³ given in EN 16734

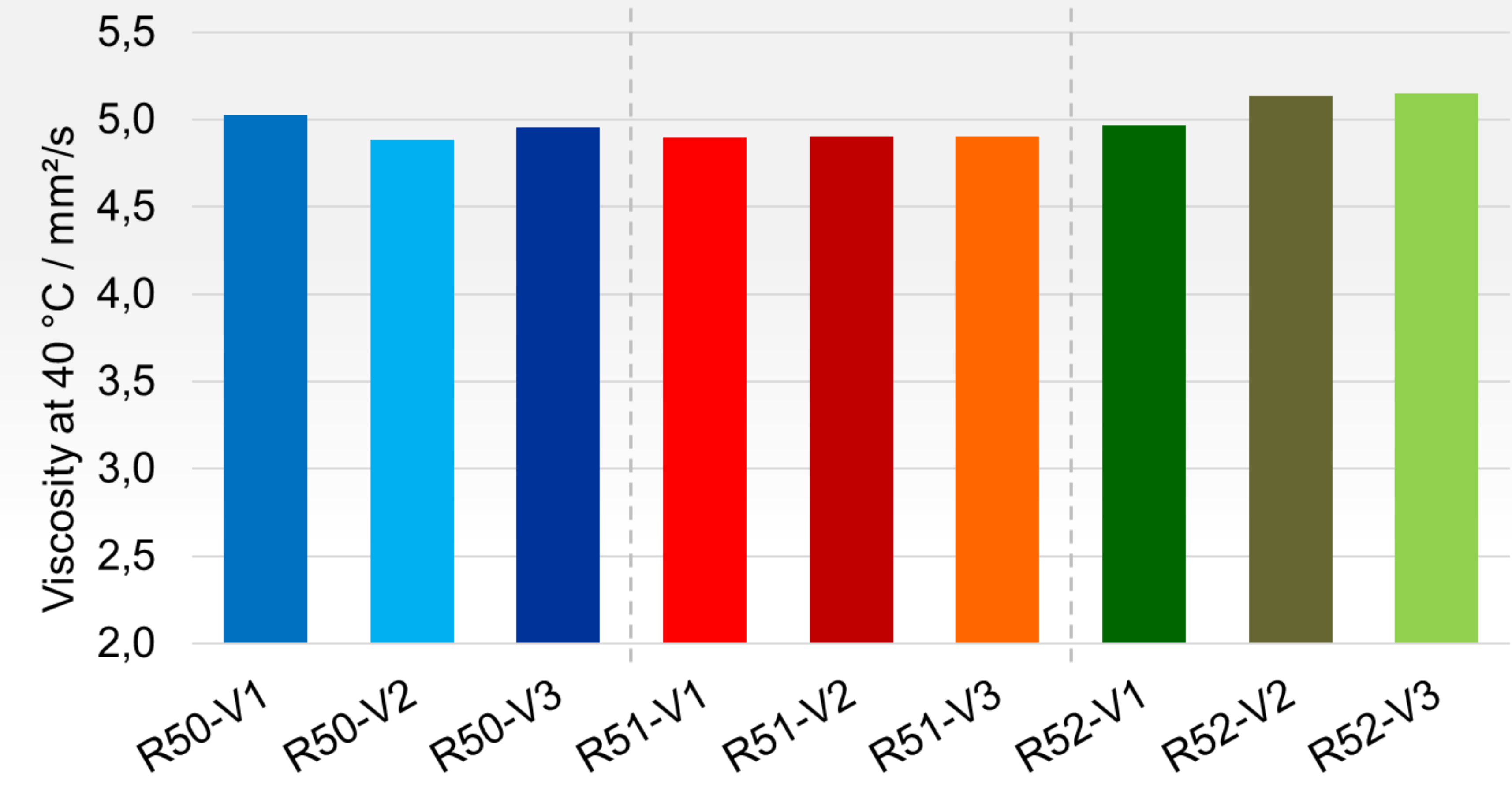
→ R52 would be borderline regarding density limits

→ R51 will be used



Task A2: Determine R50+ in viscosity

Illustration



Description

- The R50 consists of
  10 vol% FAME
  40 vol% HVO
  50 vol% Diesel fuel
- The R51 consists of
  10 vol% FAME
  41 vol% HVO
  49 vol% Diesel fuel
- The R52 consists of
  10 vol% FAME
  42 vol% HVO
  48 vol% Diesel fuel

Agenda:

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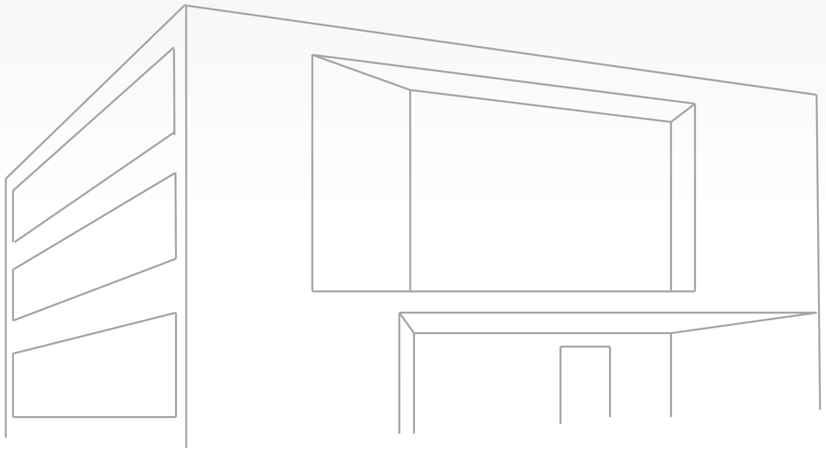
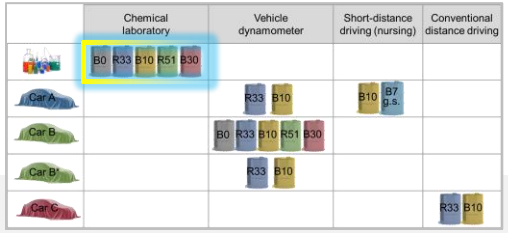
  - FTIR analysis
  - GPC analysis
  - GCMS analysis

- Task B: Reception of test vehicles
- Task C: WLTC emission testing

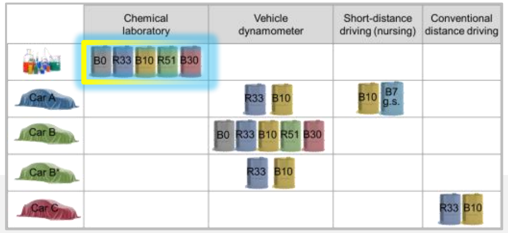




Task A3: Aging of fuels regarding phase separation

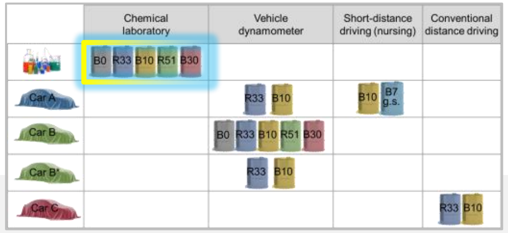
Illustration	Description

	○ Aged fuels in task A3:
	R40, R45, R50, R51 and R61 (with constant Biodiesel content of 10 vol%)
	
	○ Parallel setup in two separate oil baths and two separate heating plates
	  ○ Samples 1 – 5 (R40 – R61) are in the left oil bath
	  ○ Samples 6 – 10 (R40 – R61) are in the right oil bath
	
	○ Aging at 110 °C with 300 ml/min air supply (non dried) for 80 hours.



Task A3: Aging of fuels regarding phase separation

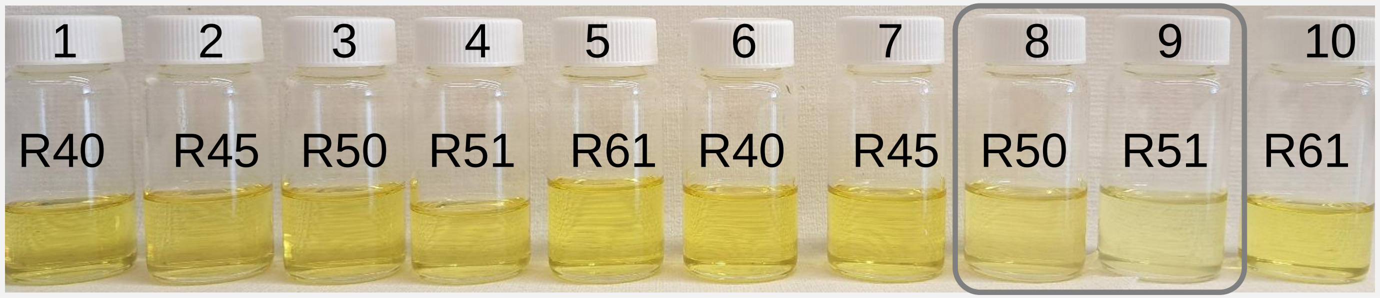
Illustration	Description
	○ Each gas washing bottle has its own pump, which ensures a constant flow of air. ○ A thermometer in each oil bath ensures a temperature check. ○ Intervals of 10 hours each day with overnight resting periods for formation of sediments. ○ Sampling of each aging level (20 h, 40 h, 60 h and 80 h) with a volume of 5 ml for analysis.



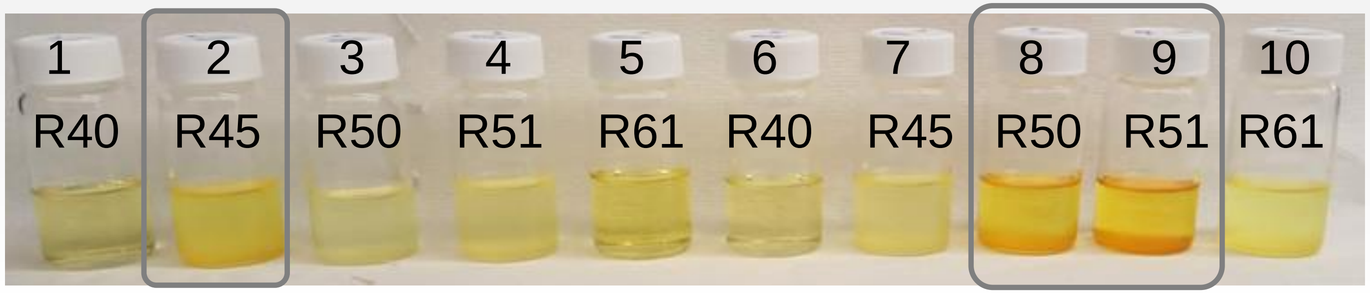
Task A3: Visual inspection of the samples

Illustration

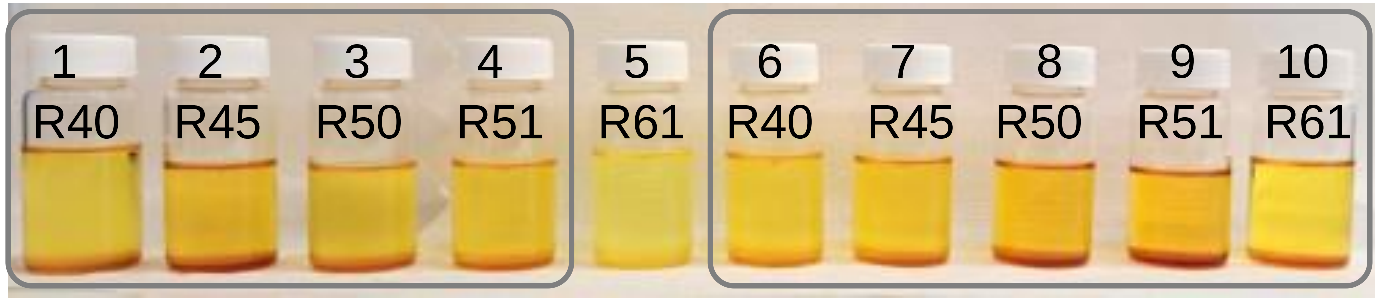
40 h



60 h



80 h



Description

- After 40 h of aging, sample 8 and 9 show a pale decoloring and all samples show no deposit formation
- After 60 h of aging, sample 2, 8 and 9 show a dark color and almost all fuels show a slight precipitation.
- After 80 h of aging, sample 5 shows the least decoloring and the least deposit formation.

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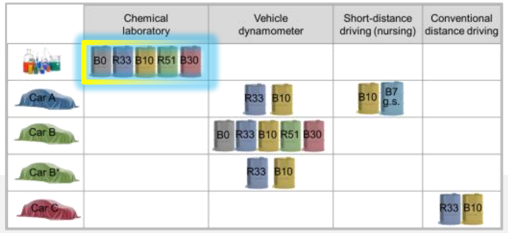
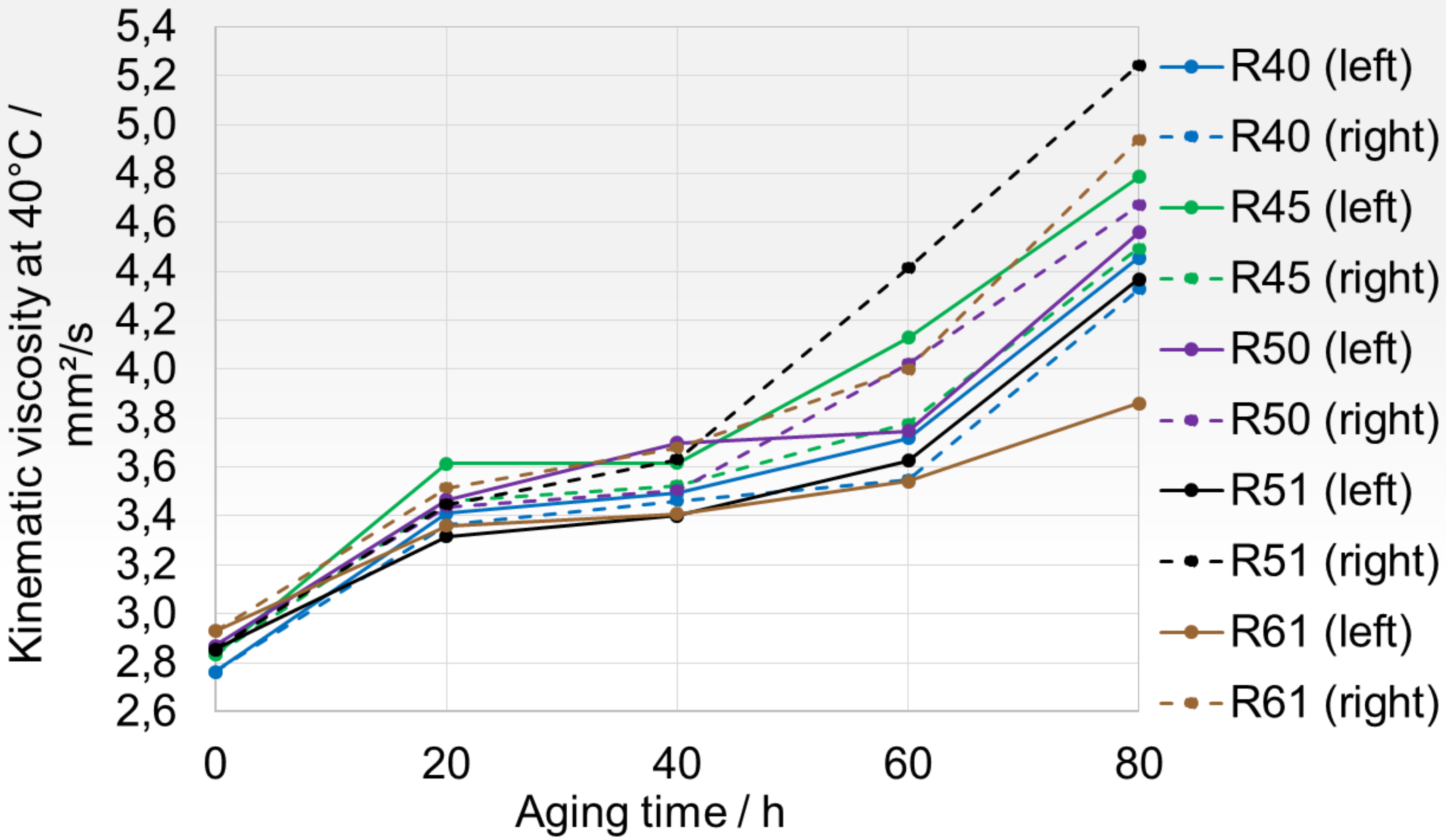
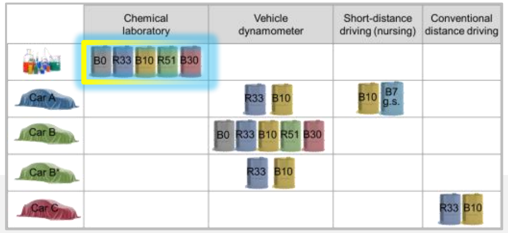


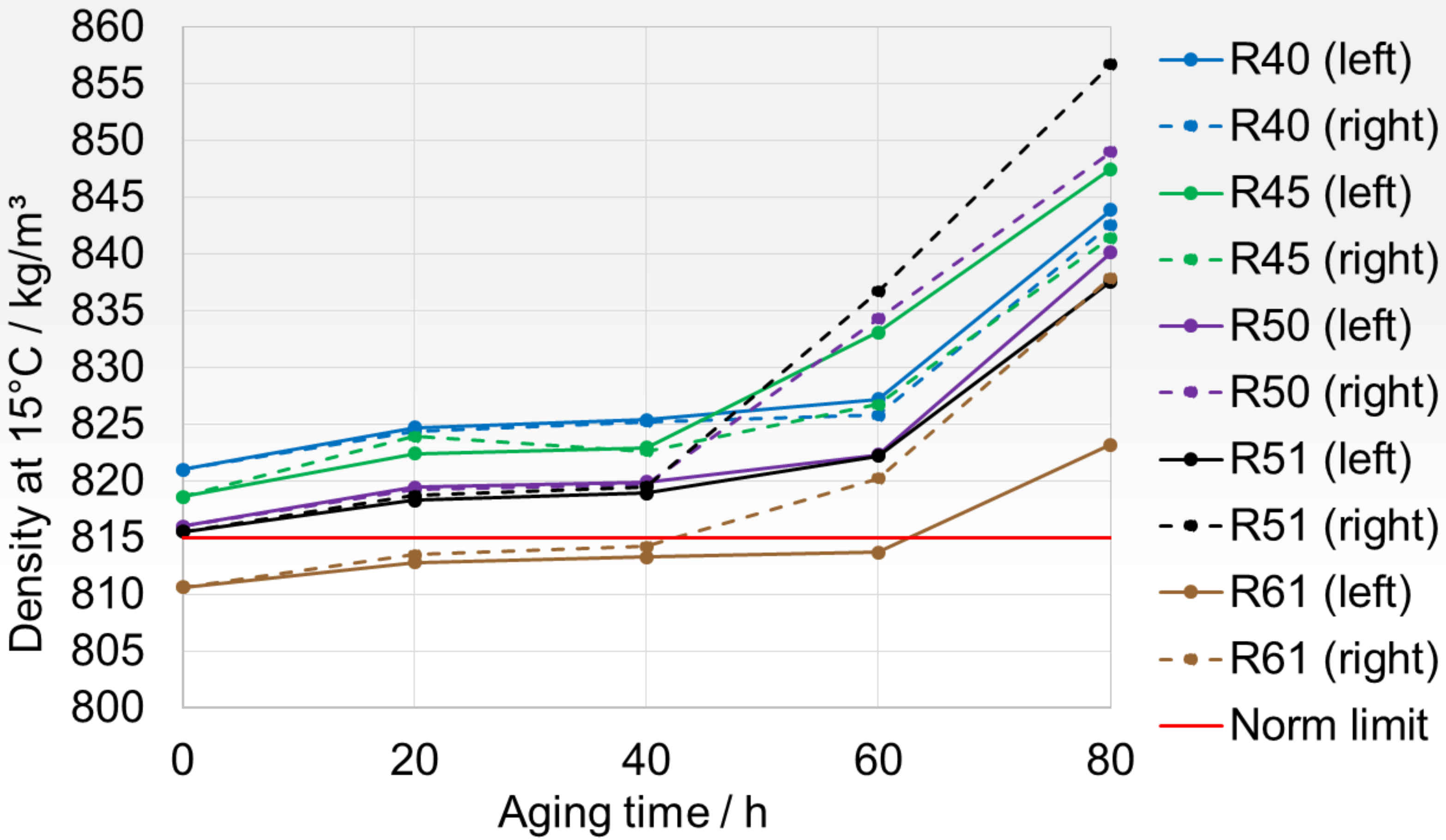
Task A3: Viscosity of the samples

Illustration	Description
	○ Decreased viscosity increase in the period between 20 to 40 h of aging ○ Early increase in viscosity of some samples after exceeding 40 h of aging ○ Increasing viscosity for all samples after exceeding 60 h of aging ○ One of the R61 samples with the lowest increase in viscosity after 80 h aging



Task A3: Density of the samples

Illustration



Description

- Early increase in density of some samples after exceeding 40 h of aging
- Increasing density for all samples after exceeding 60 h of aging
- One R61 sample still below the density limit of EN 16734 after 60 h of aging

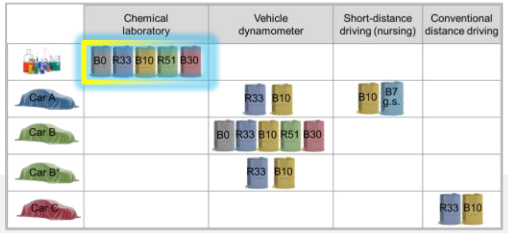
	Chemical laboratory	Vehicle dynamometer	Short-distance driving (nursing)	Conventional distance driving
	B0 R33 B10 R51 B30			
Car A		R33 B10	B10 B7 g.s.	
Car B		B0 R33 B10 R51 B30		
Car B*		R33 B10		
Car C				R33 B10

Task A4: View of the real apparatus for fuel oil aging

Illustration

Description

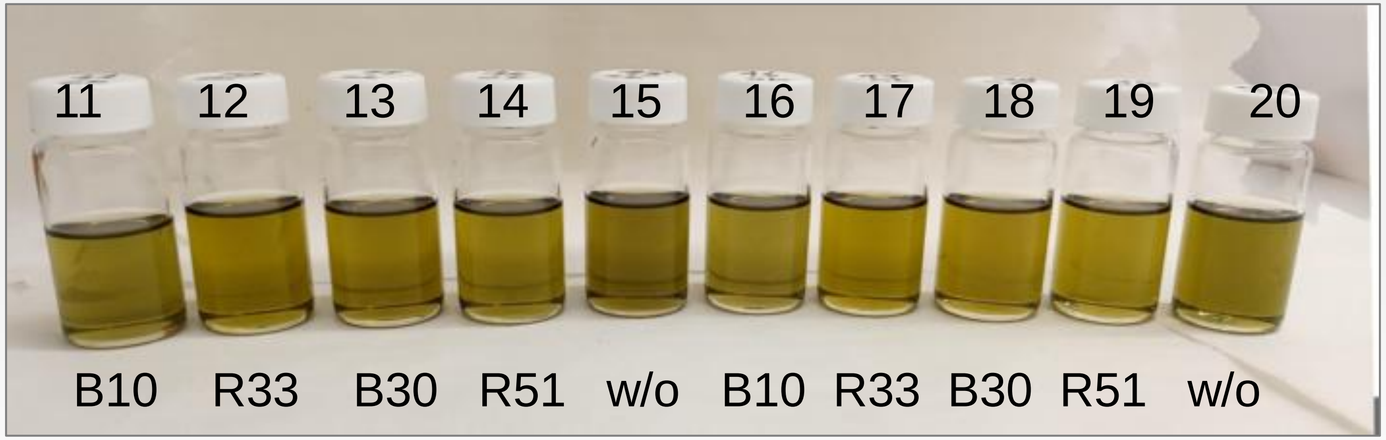
- The tests on task A4 are planned to be done with 20 vol% fuel and 80 vol% common light engine oil.
- Aged fuels in task A4:
  R33, B10, R51 and B30
- Engine oils in task A4:
  - Shell oil 0-W-20
  - Castrol oil 0-W-20
- Aging at 170 °C with 300 ml/min air supply (non dried) for 80 hours.



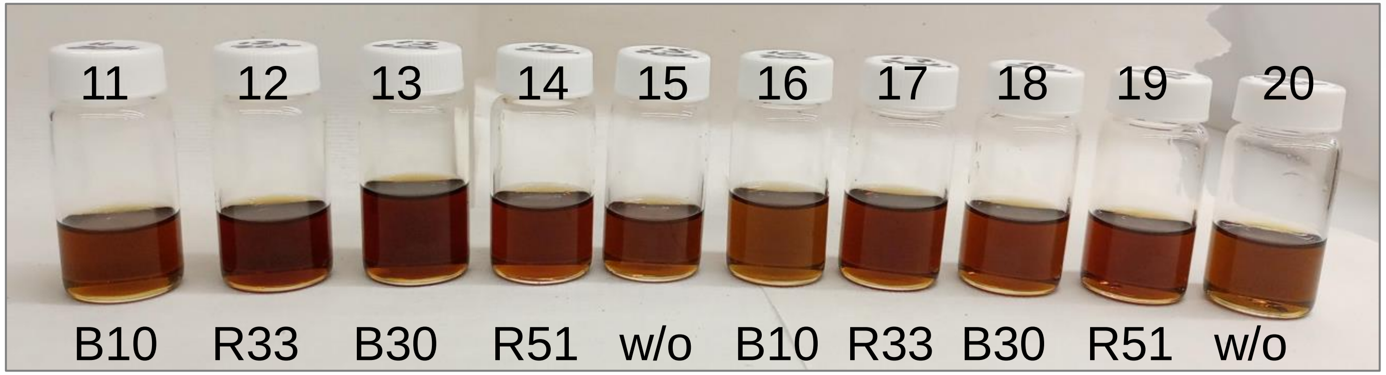
Task A4: Visual inspection of the samples (Shell oil)

Illustration

0 h

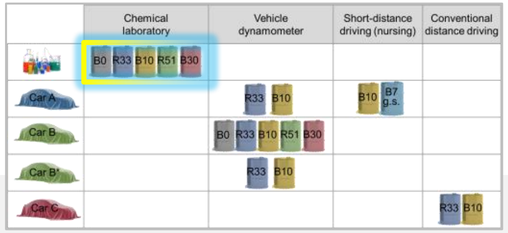


20 h



Description

- With no aging, the samples without fuel (15 and 20) show a slightly darker color than the samples mixed with fuel
- After 20 h of aging, all samples show a dark color and no signs of deposit formation



Task A4: Visual inspection of the samples (Shell oil)

Illustration

40 h

60 h

80 h

Description

- The samples 5 and 10, which only consist of oil show the least darkening and no signs of deposit formation after 40, 60 and 80 hours of aging
- The fuel-oil mixtures show similar color changes and no signs of deposit formation

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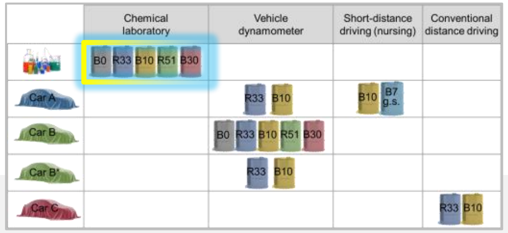
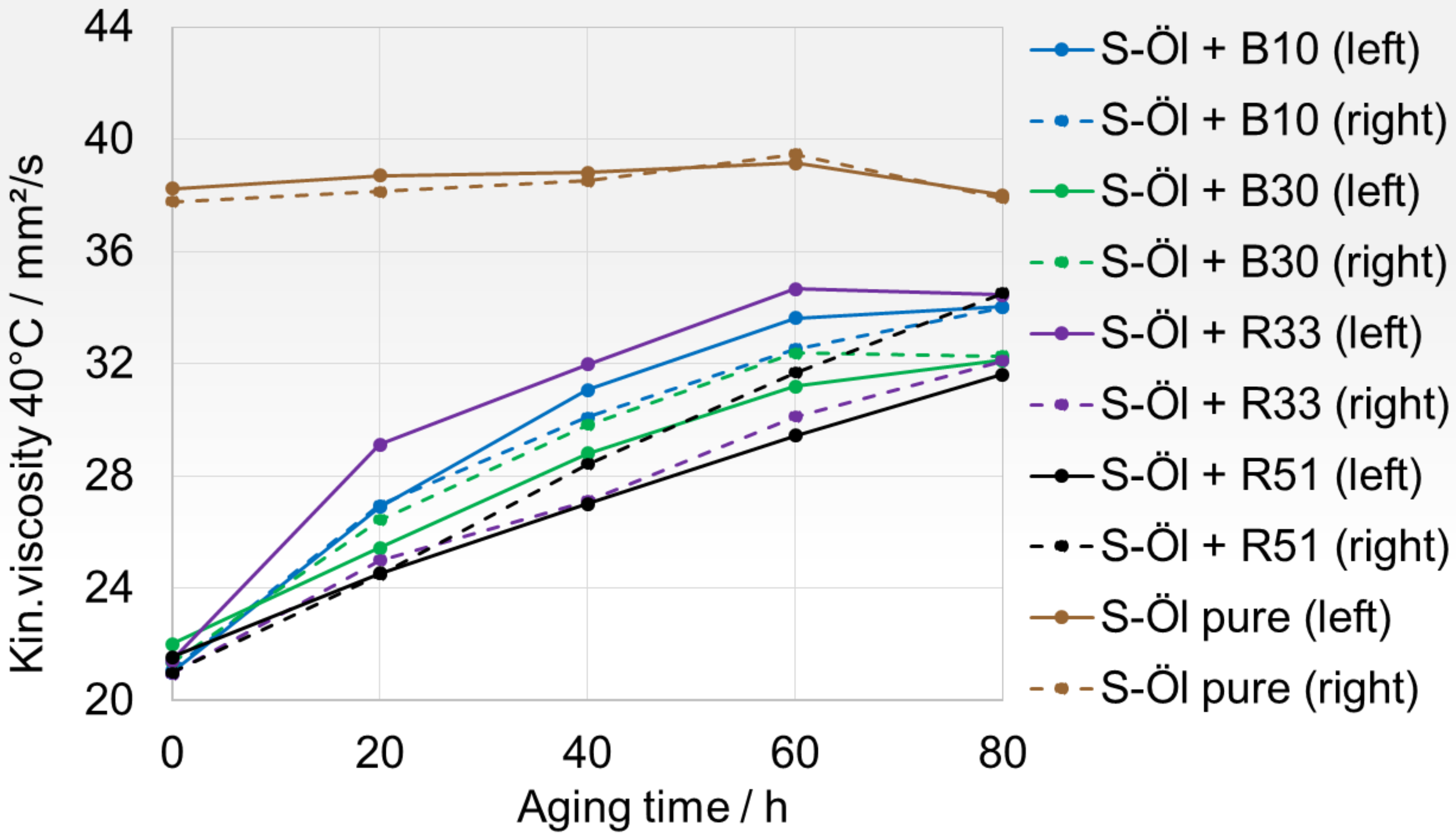
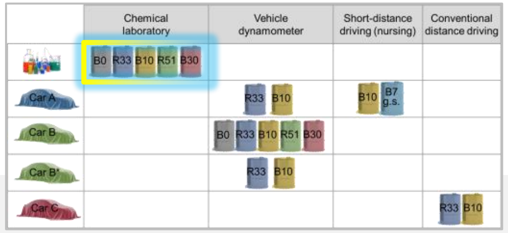


Task A4: Viscosity of the samples (Shell oil)

Illustration	Description
	

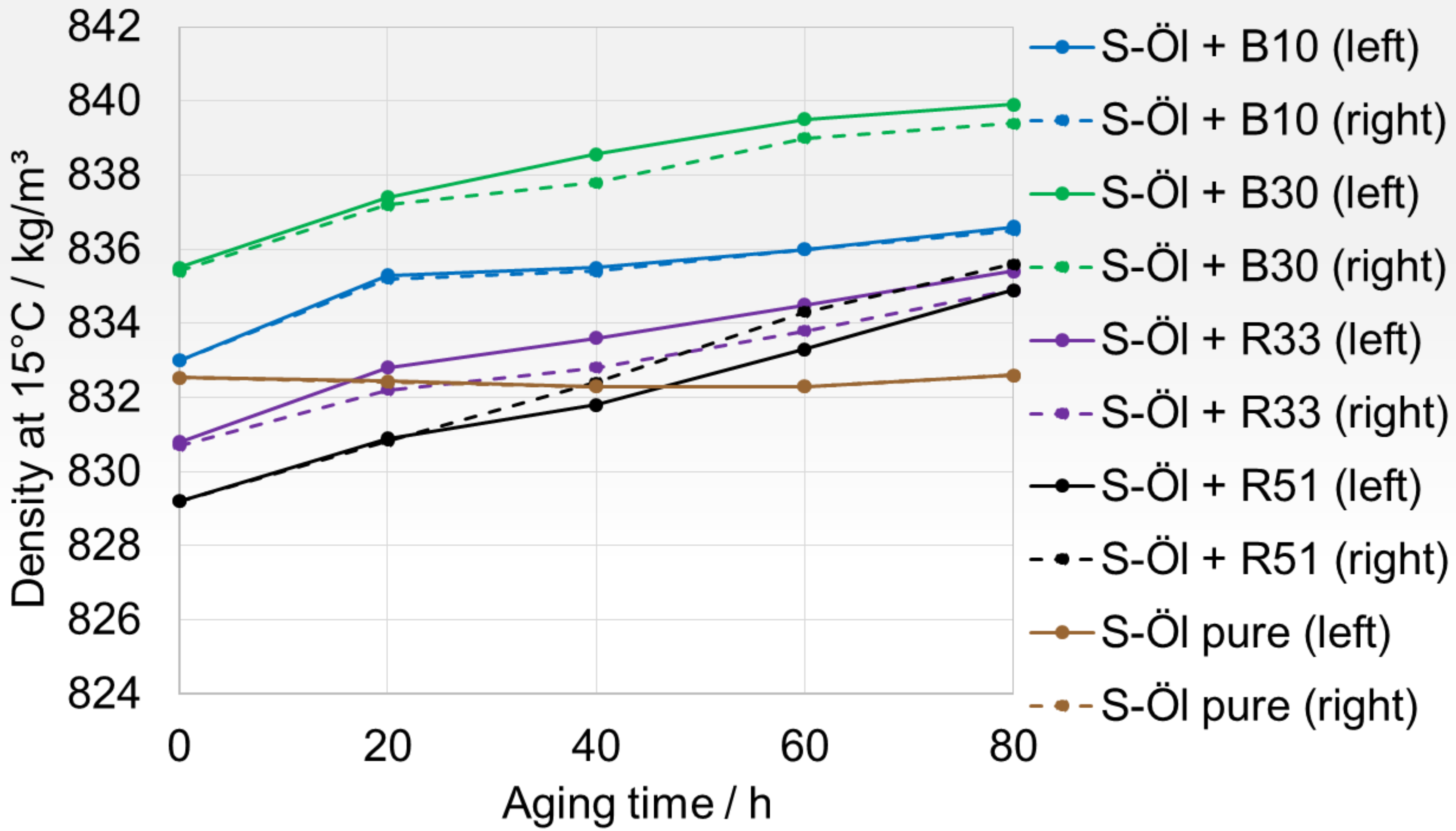
Description

- The oil itself doesn’t show significant changes regarding viscosity.
- The oil-fuel mixtures show an increase in viscosity over time, which needs to be correlated with fuel-oil aging interactions.
- The difference between sample “S-Öl + R51 (left)” and “S-Öl + R51 (right)” is consistent over time.



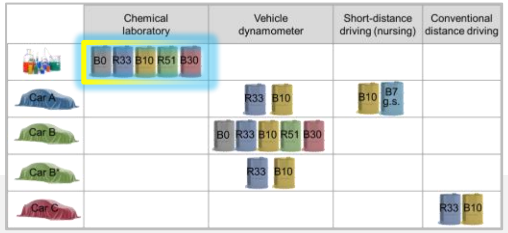
Task A4: Density of the samples (Shell oil)

Illustration



Description

- The oil itself doesn't show significant changes regarding density.
- The oil-fuel mixtures show an increase in density over time, which needs to be correlated with fuel-oil aging interactions.



Task A4: Visual inspection of the samples (Castrol oil)

Illustration

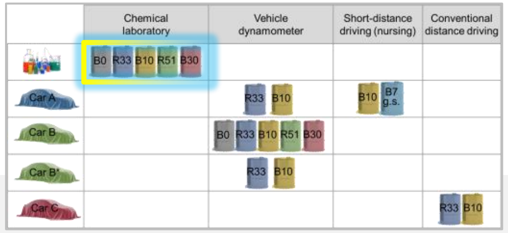
40 h

60 h

80 h

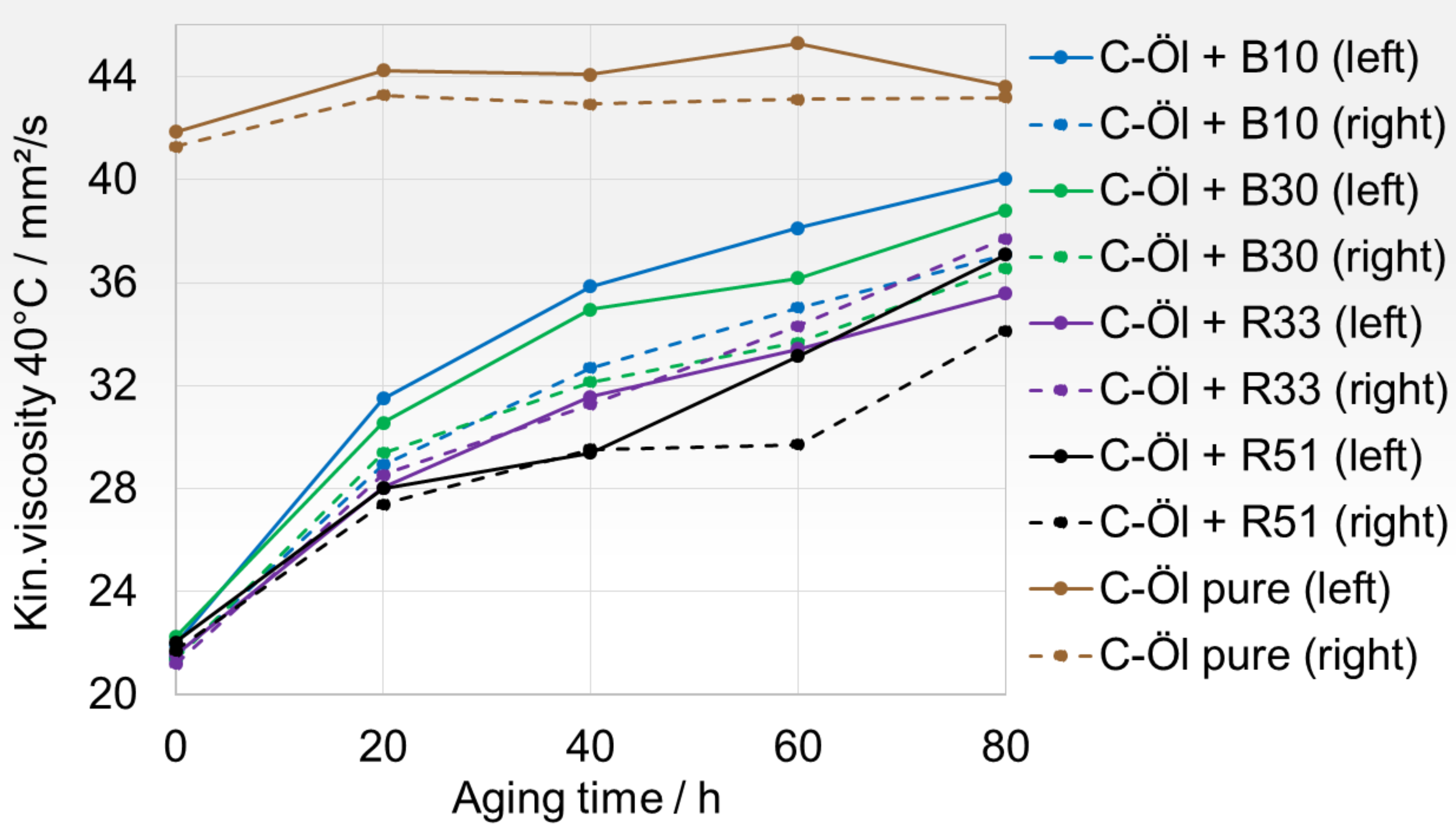
Description

- The samples 5 and 10, which only consist of oil show the least darkening and no signs of deposit formation after 40, 60 and 80 hours of aging
- The fuel-oil mixtures show similar color changes and no signs of deposit formation



Task A4: Viscosity of the samples (Castrol oil)

Illustration



Description

- The viscosity increases with advanced aging time.
- In the first 20 hours of aging a significant increase in viscosity of the oil/fuel mixtures can be detected.
- After the first 20 hours, the increase of viscosity slows down.

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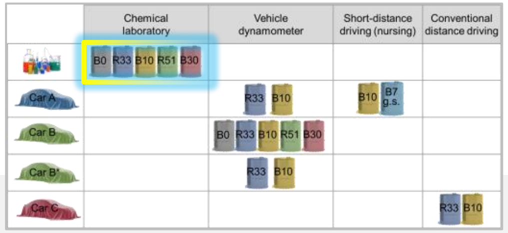
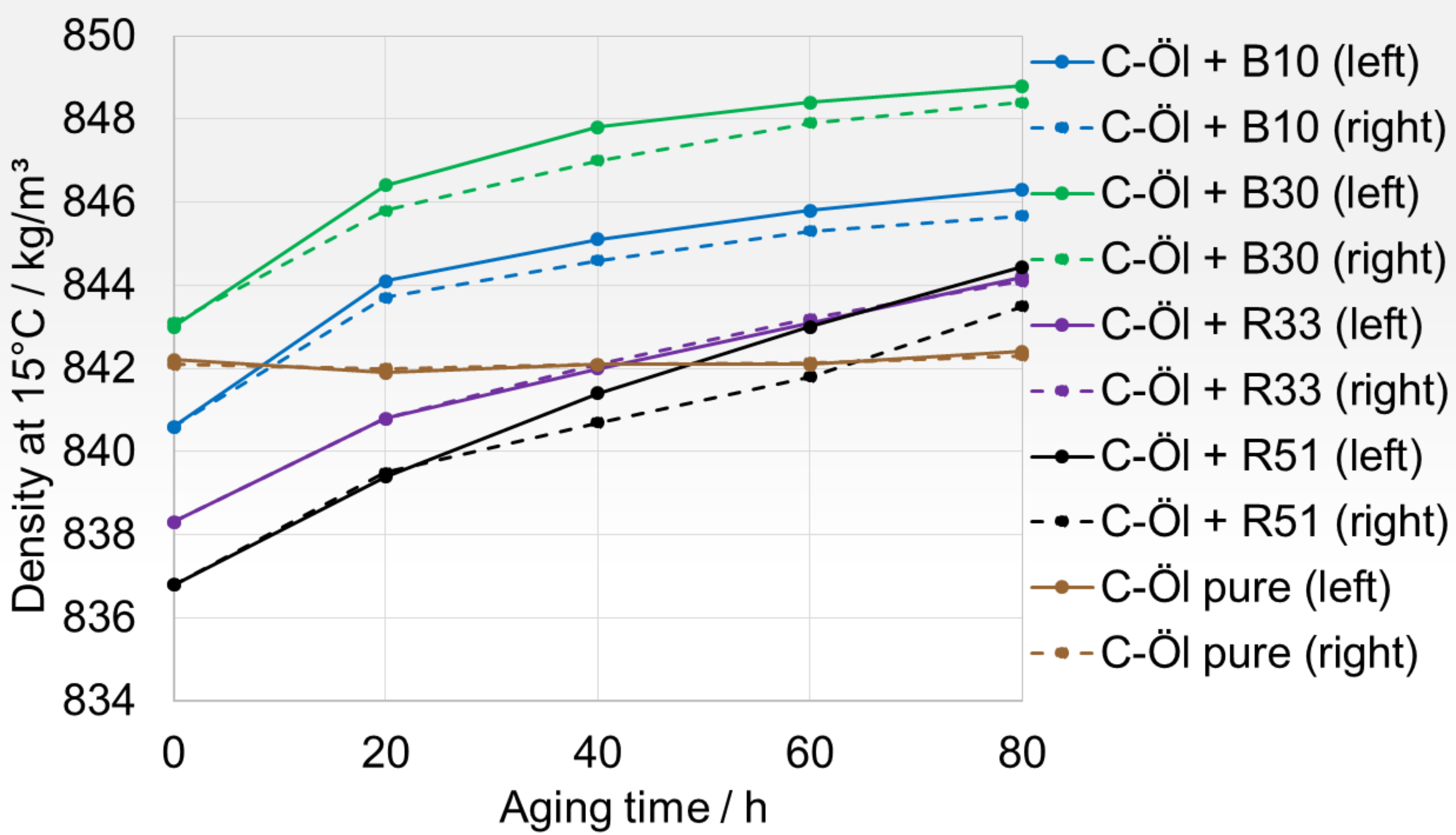


Task A4: Density of the samples (Castrol oil)

Illustration



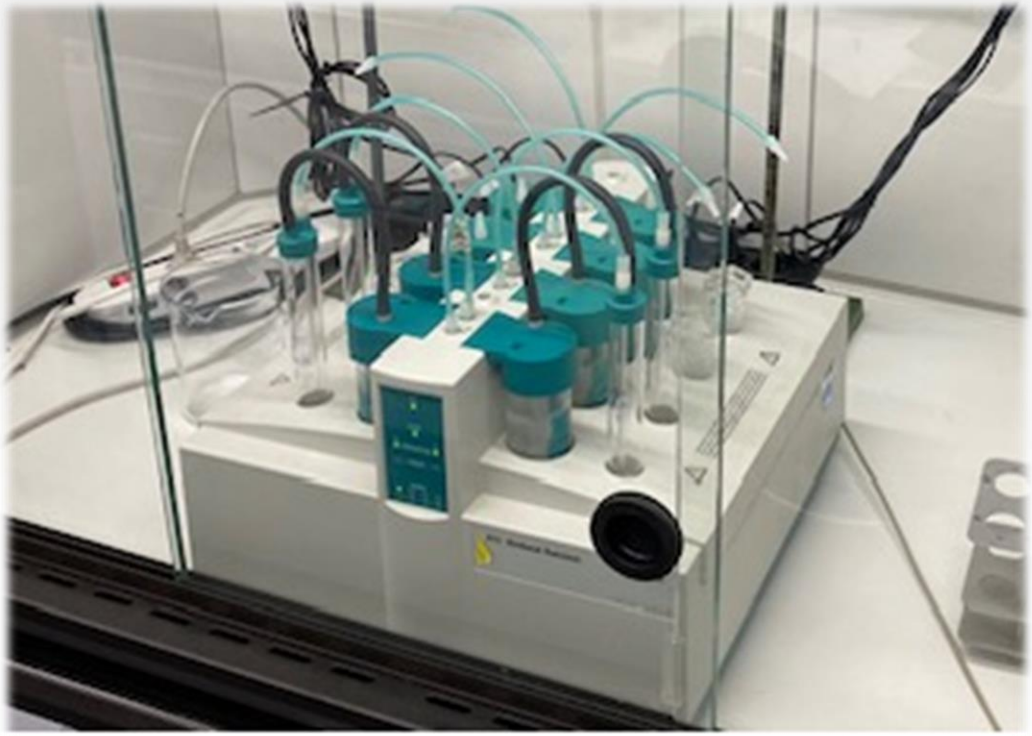
Description

- The density increases with advanced aging time.
- The pure Castrol oil (yellow lines) shows a constant density up to an aging time of 42 hours.

	Chemical laboratory	Vehicle dynamometer	Short-distance driving (nursing)	Conventional distance driving
	B0 R33 B10 R51 B30			
Car A		R33 B10	B10 B7 g.s.	
Car B		B0 R33 B10 R51 B30		
Car B*		R33 B10		
Car C				R33 B10

Task A4: Framework of sediment validation

Illustration



Description

- Task A3 includes the adapted tests
  - Fuels: R33, B10, R51
  - Durations: 20, 40, 60, 80, 100 h
  - Temperature: 110 °C
  - Air volume flow: 10 Liters/hours

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Agenda:

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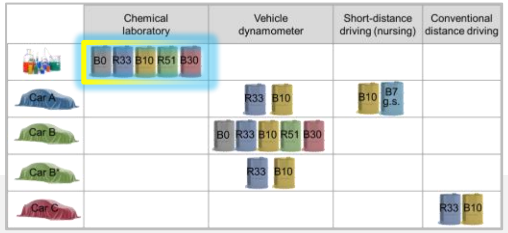
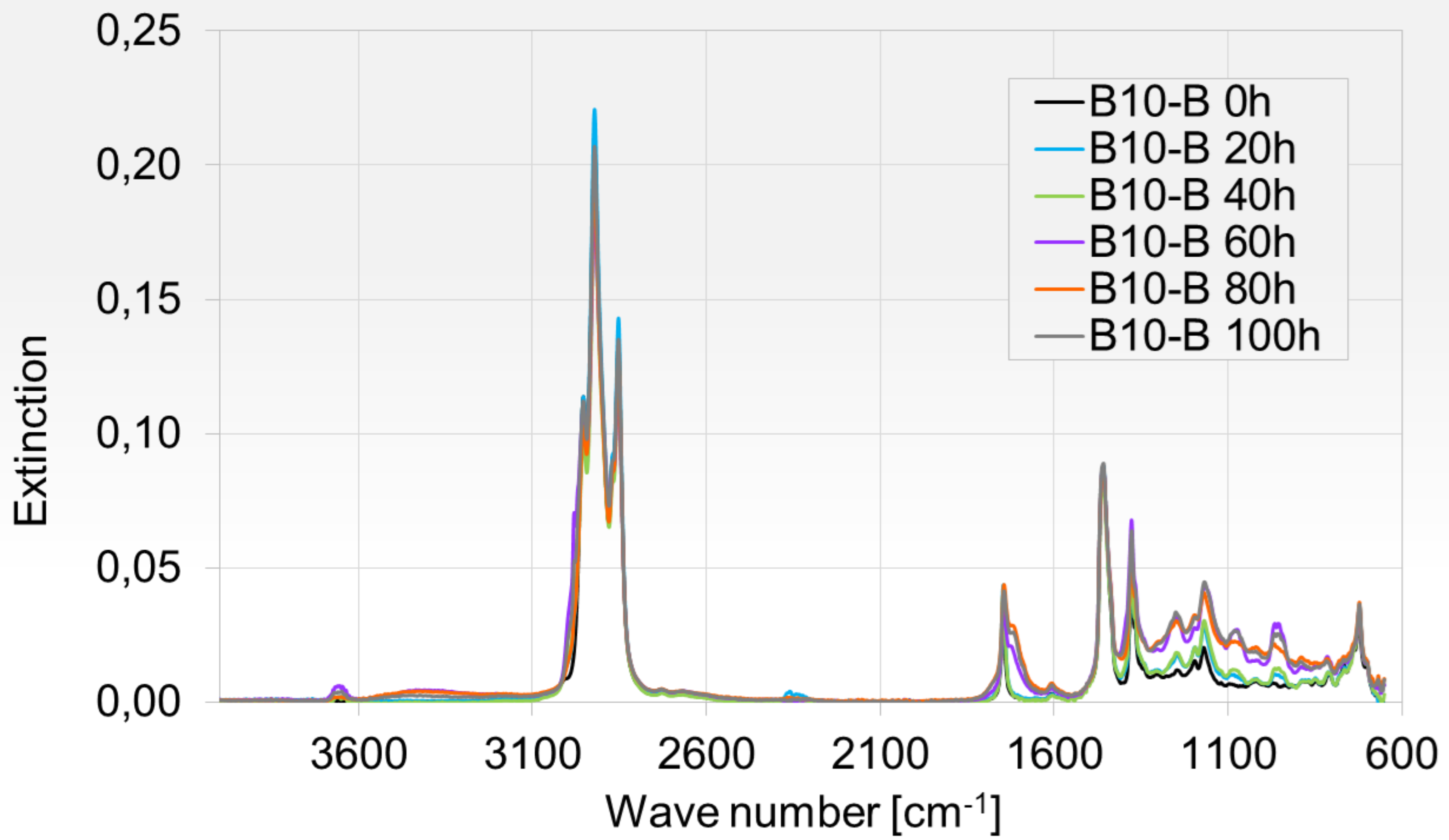
Experimental results

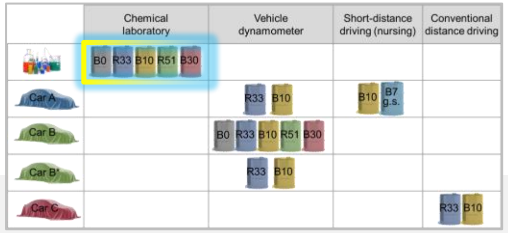
- Task A: Chemical analysis of fuels and oils
  - Mixture determinations
  - Aging experiments
  - FTIR analysis
  - GPC analysis
  - GCMS analysis

- Task B: Reception of test vehicles
- Task C: WLTC emission testing



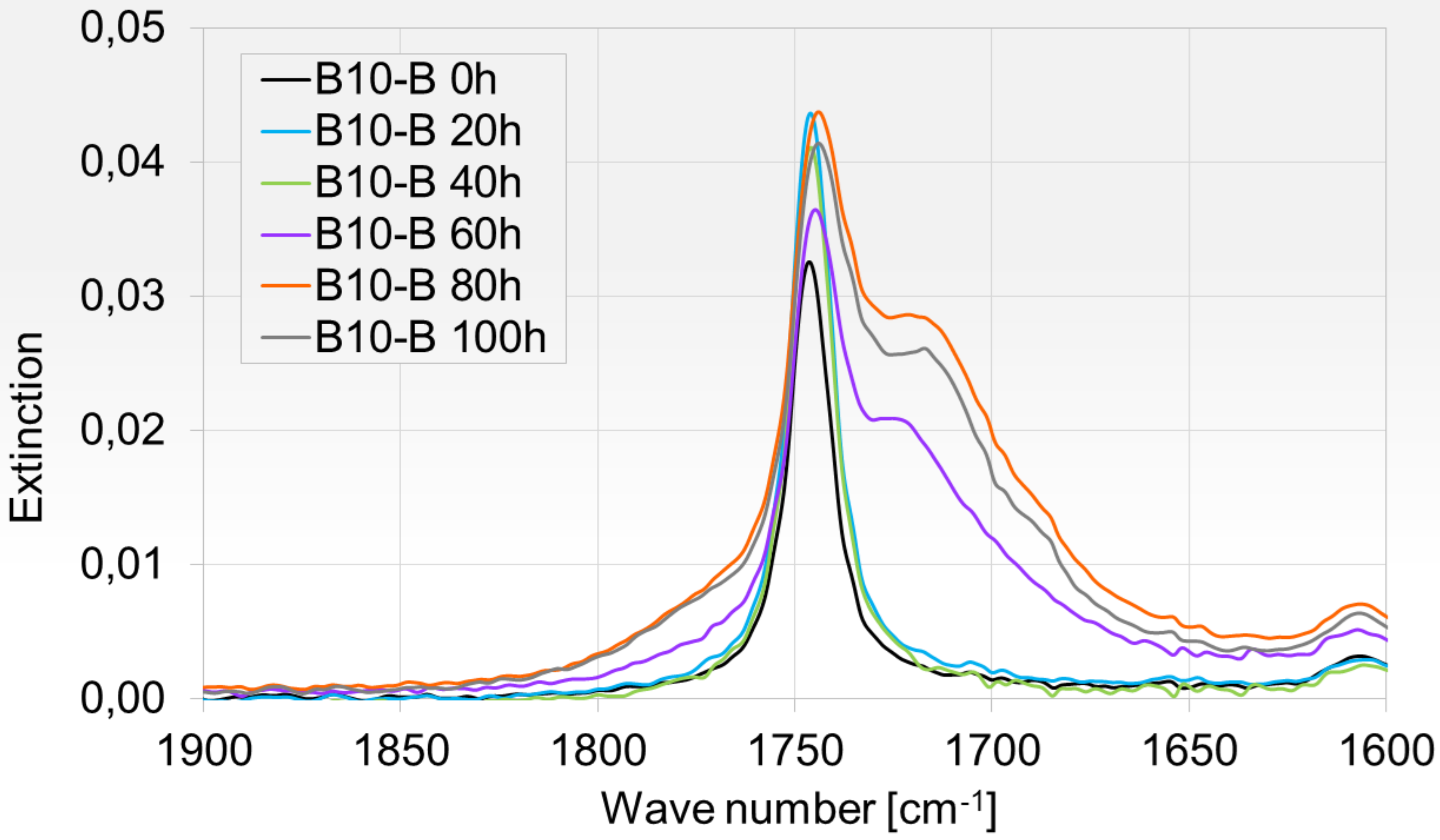
Task A4: FTIR spectrum of B10 from barrel (w/o sediments)

Illustration	Description
	○ The FTIR spectrum shows a carbonyl bond between 1600 cm^{-1} and 1900 cm^{-1}. ○ In the carbonyl area, the esters of fresh fuel are detected. ○ Carbonyl compounds are formed during aging and are also detected in this area.



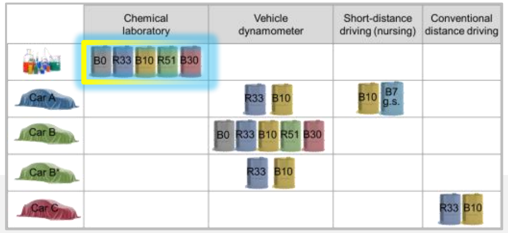
Task A4: Zoom in the carbonyl area of B10 from barrel (w/o sediments)

Illustration



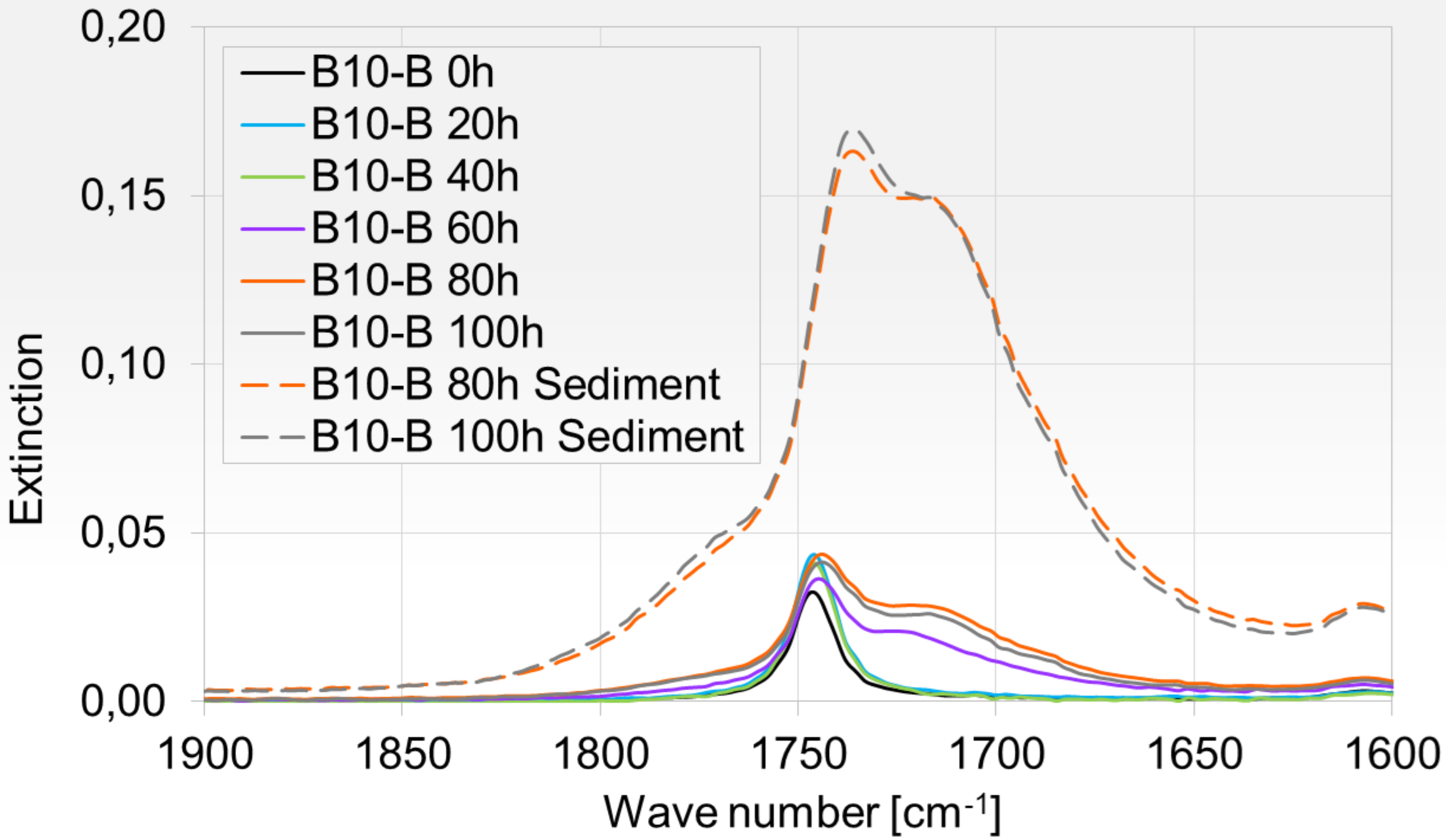
Description

- The fuel B10 from barrel is stable up to an aging time of 40 hours and shows little changes in the carbonyl area.
- From an aging time of 60 hours, band broadening and the formation of shoulders can be seen, which can be attributed to the formation of aging products.



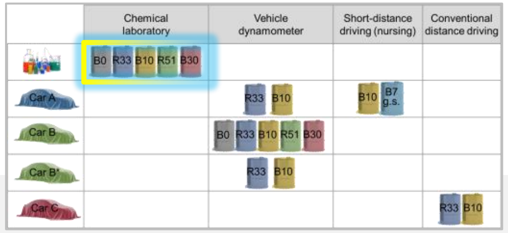
Task A4: Zoom in the carbonyl area of B10 from barrel (w/ sediments)

Illustration



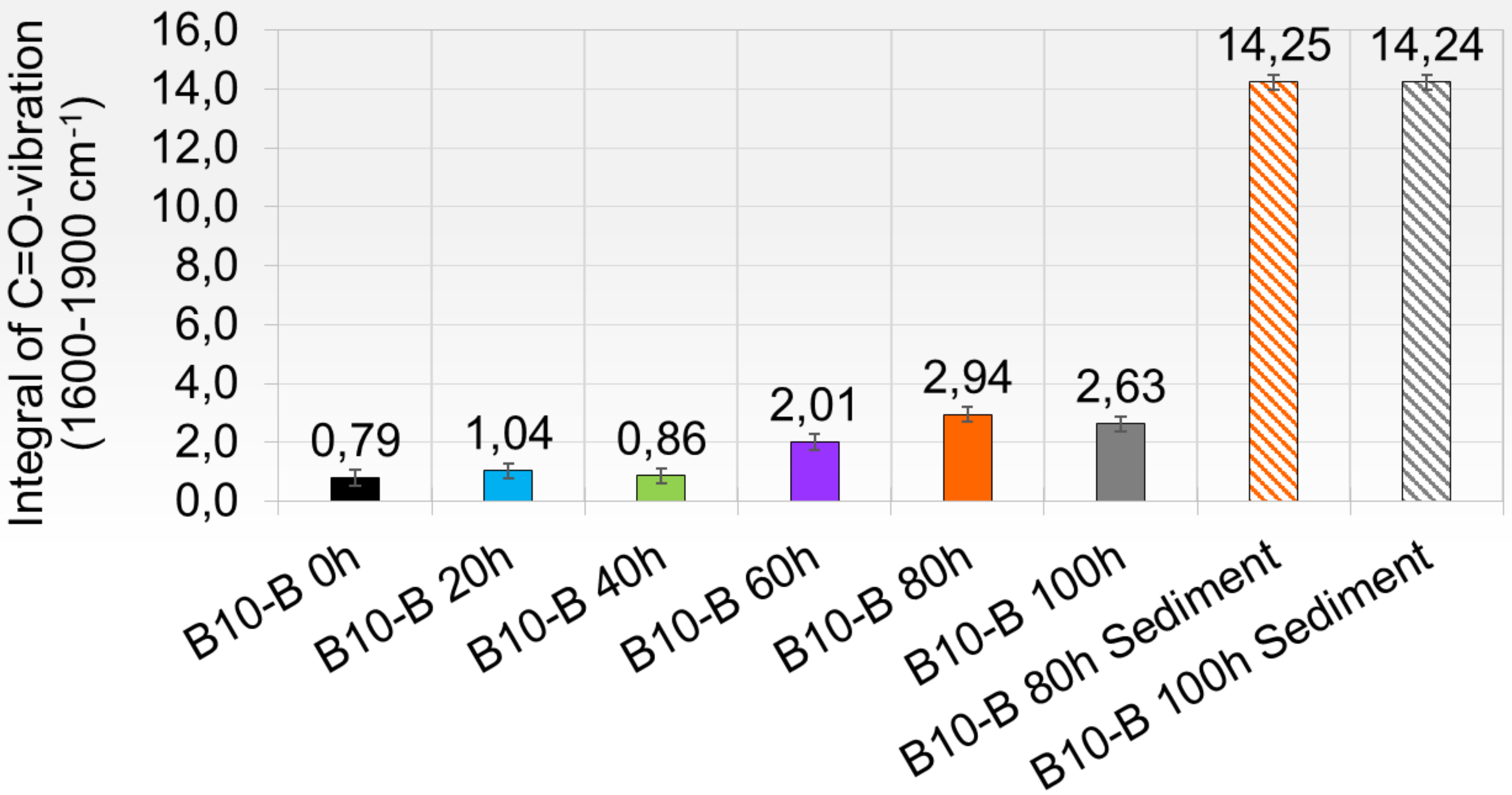
Description

- After 80 and 100 hours of aging, sediments are formed.
- The sediments show a carbonyl vibration with an extinction almost four times higher than that of the liquid phase.
- The area below the carbonyl bond can be integrated for better comparability.



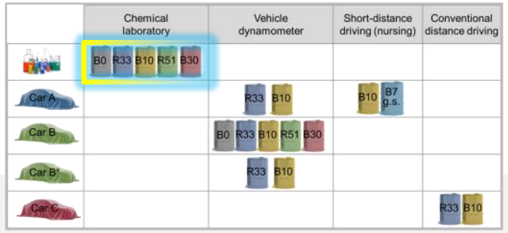
Task A4: Integral of carbonyl vibrations of B10 aging from barrel

Illustration

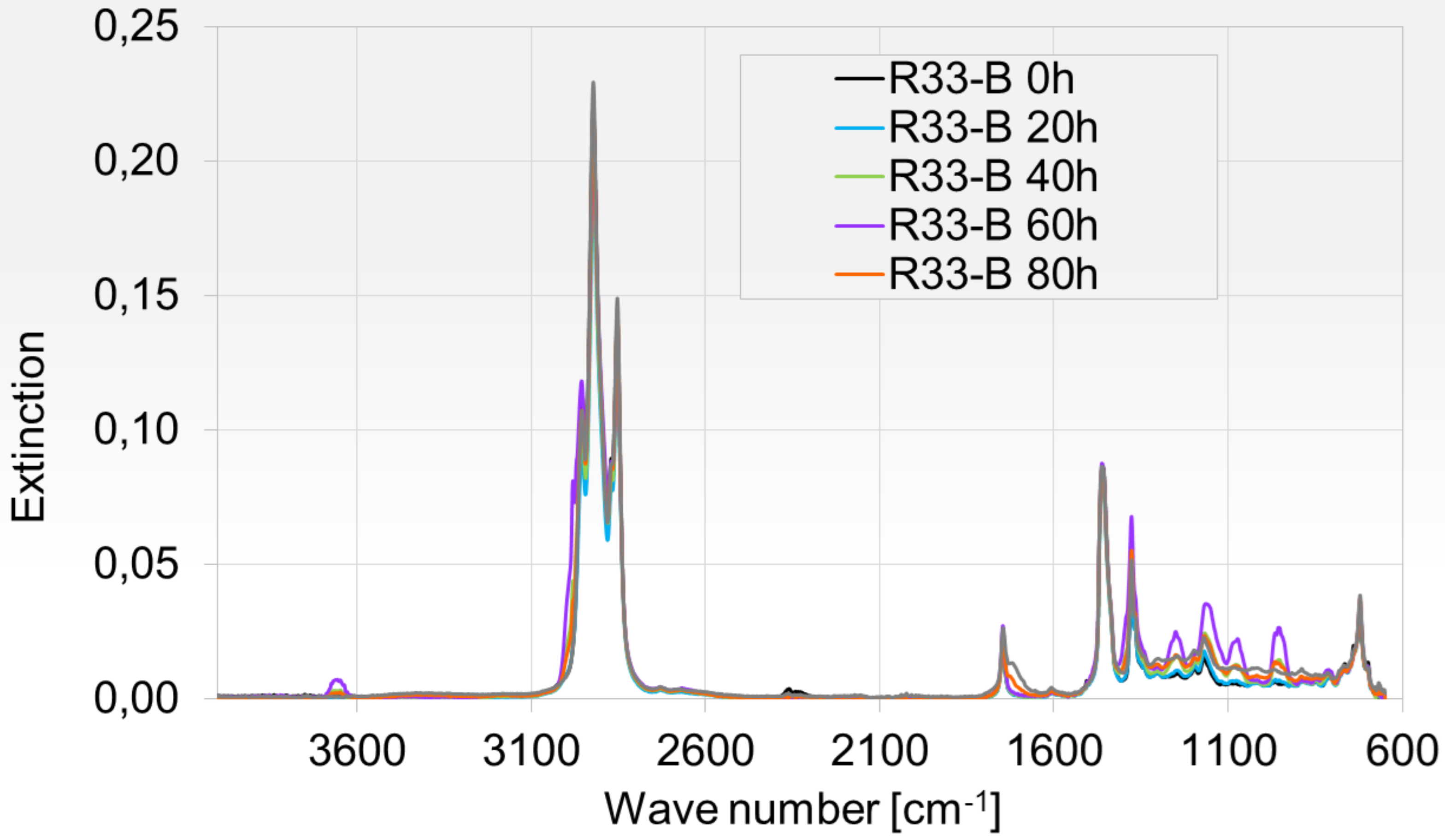


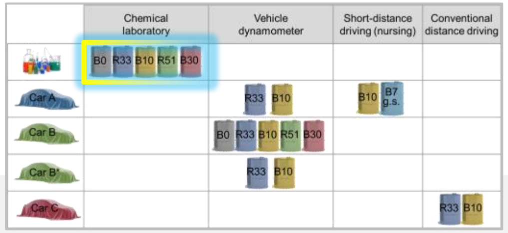
Description

- The integral shows the same values up to an aging time of 40 hours.
- After an aging period of 60 hours, the integral of the carbonyls increases.
- The area of 80 and 100 hours has continued to increase.
- The sediments from the 80 and 100 hour aging show an area that is almost fife times larger.



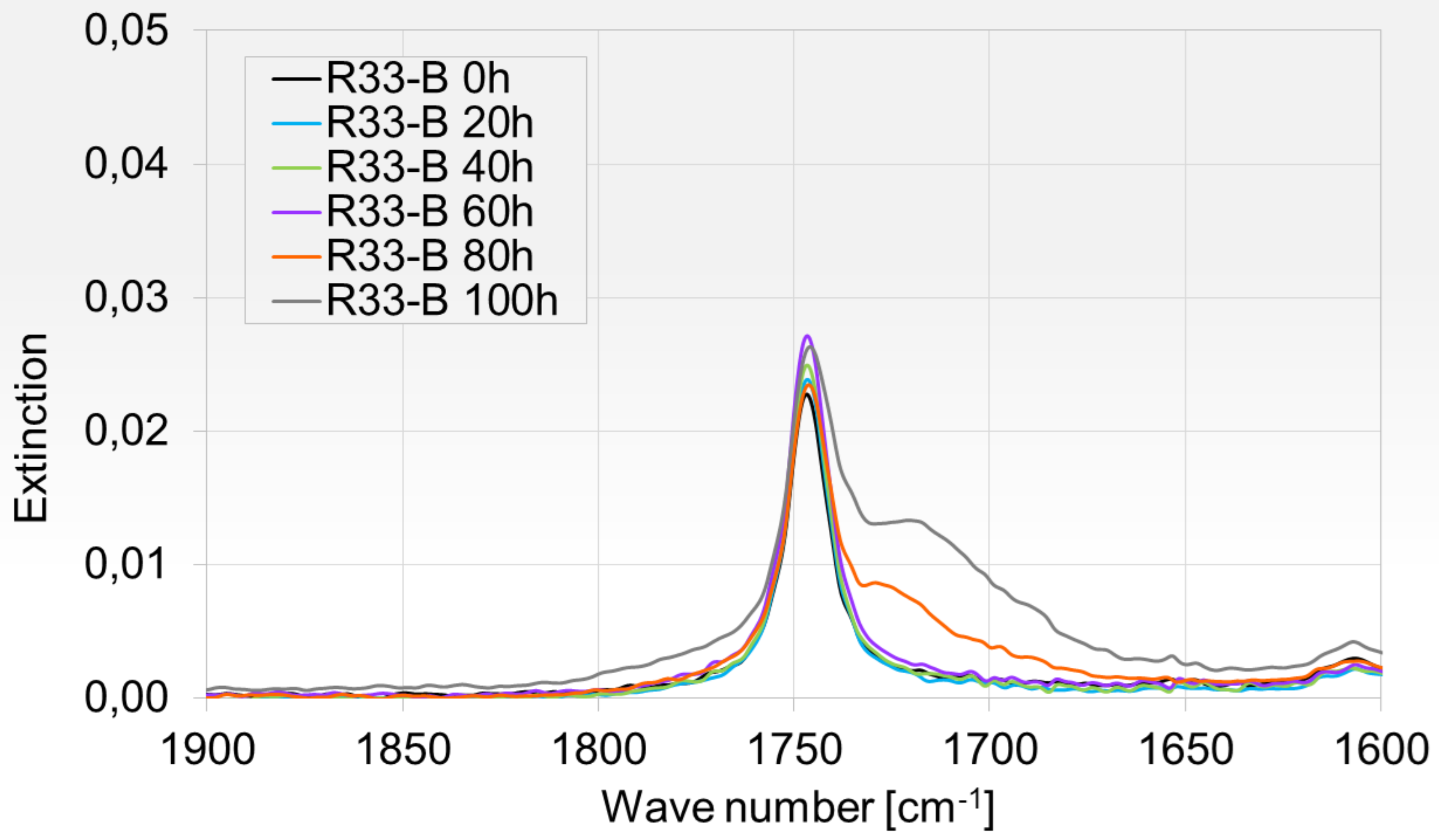
Task A4: FTIR spectrum of R33 from barrel

Illustration	Description
	○ The FTIR spectrum shows a carbonyl bond between 1600 cm^{-1} and 1900 cm^{-1}. ○ In the carbonyl area, the esters of fresh fuel are detected. ○ Carbonyl compounds are formed during aging and are also detected in this area.



Task A4: Zoom in the carbonyl area of R33 from barrel

Illustration



Description

- The fuel R33 from barrel is stable up to an aging period of 60 hours and shows little changes in the carbonyl area.
- From an aging time of 80 hours, band broadening and the formation of shoulders can be seen, which can be attributed to the formation of aging products.

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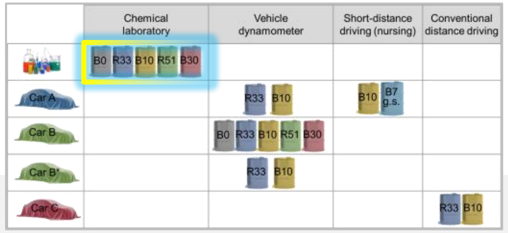
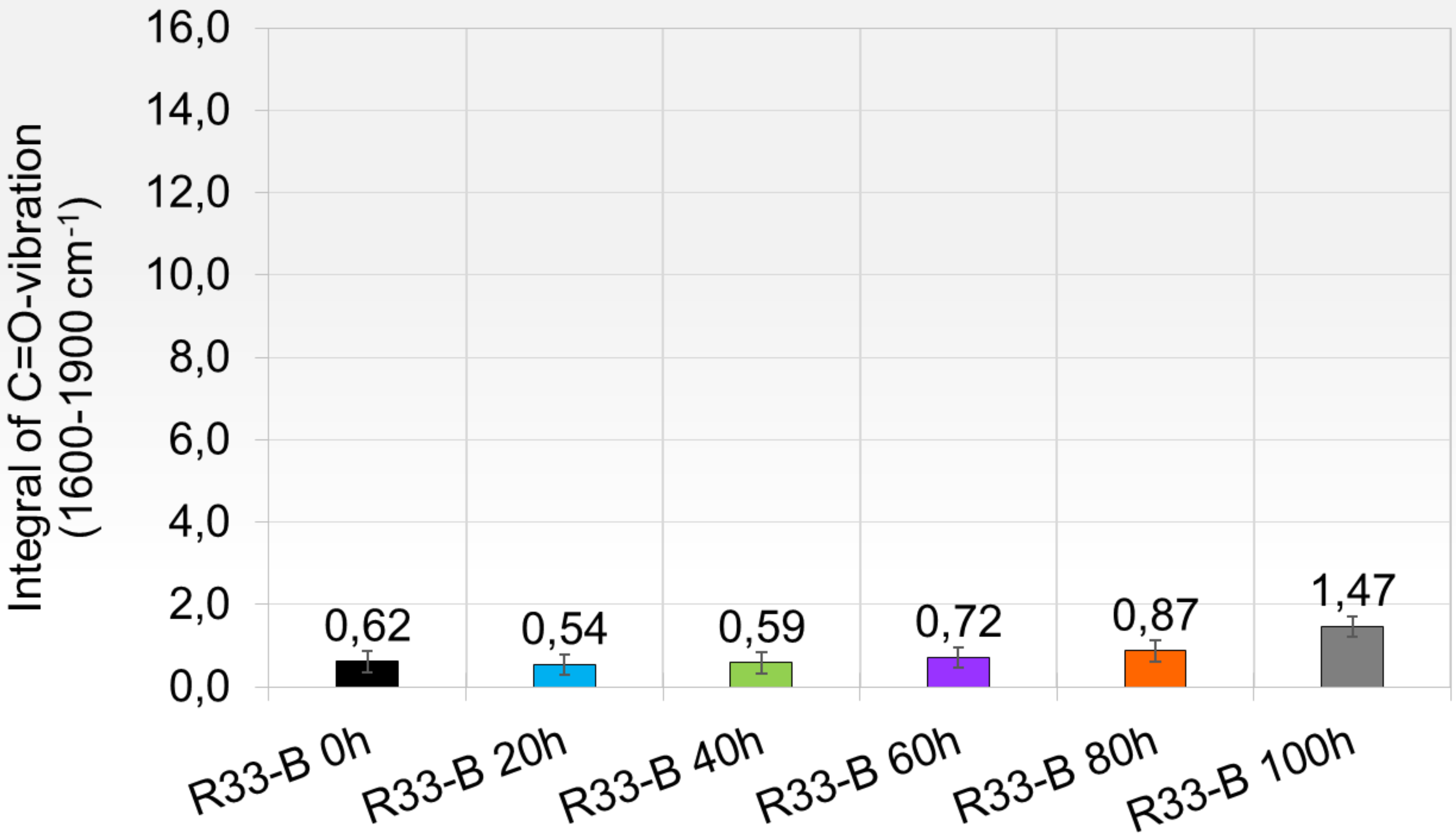


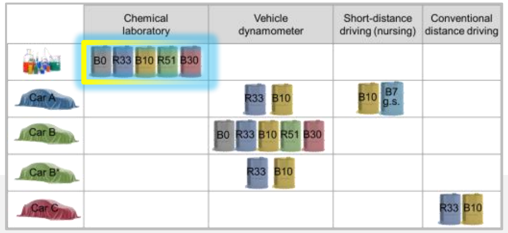
Task A4: Integral of carbonyl vibrations of R33 aging from barrel

Illustration

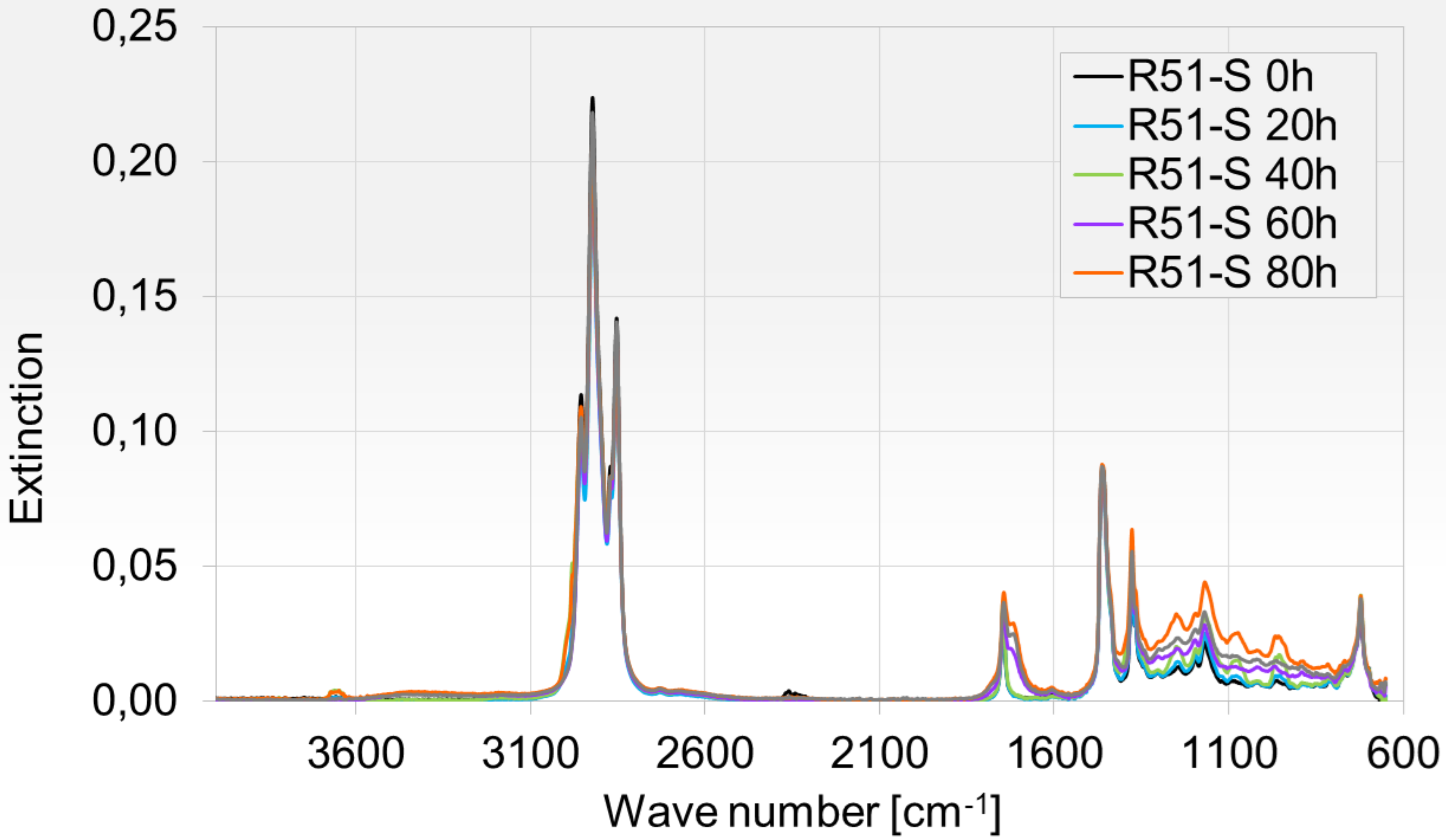


Description

- The integral shows the same values up to an aging time of 80 hours.
- After an aging period of 100 hours, the integral of the carbonyls increases.
- That the precipitates are not deposited in the R33 from the drum might be attributed to the additives.



Task A4: FTIR spectrum of self mixed R51 (w/o sediments)

Illustration	Description
	○ The FTIR spectrum shows a carbonyl bond between 1600 cm^{-1} and 1900 cm^{-1}. ○ In the carbonyl area, the esters of fresh fuel are detected. ○ Carbonyl compounds are formed during aging and are also detected in this area.

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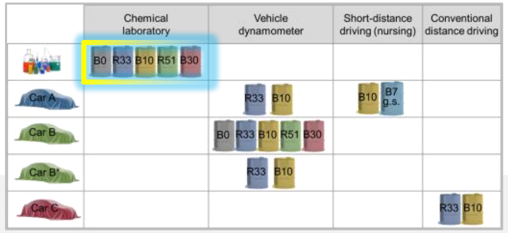
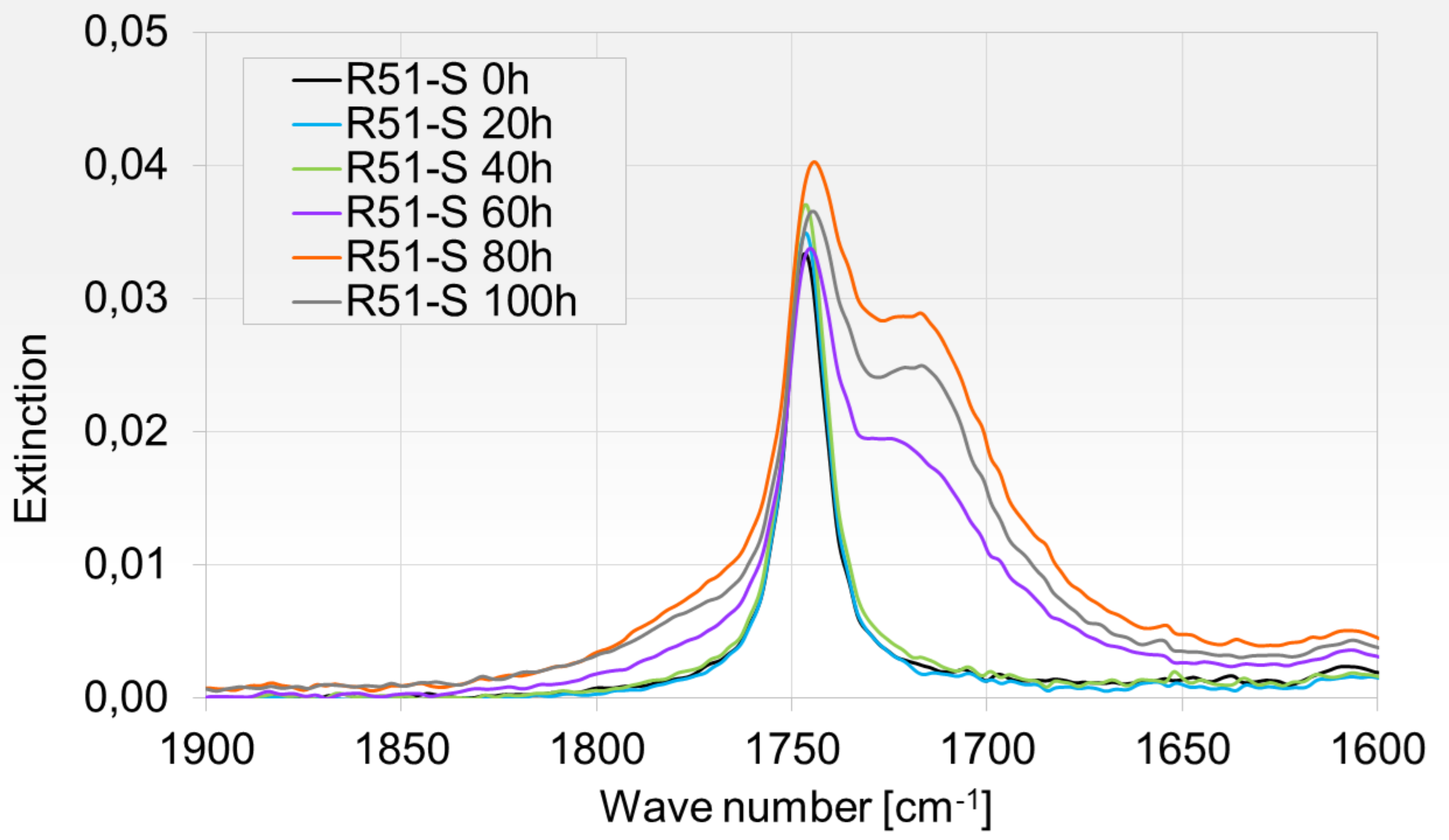
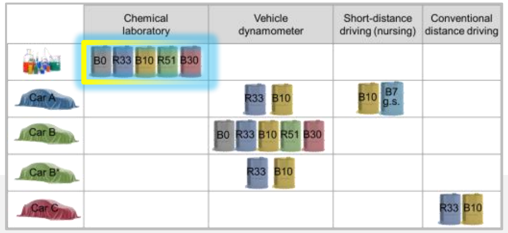


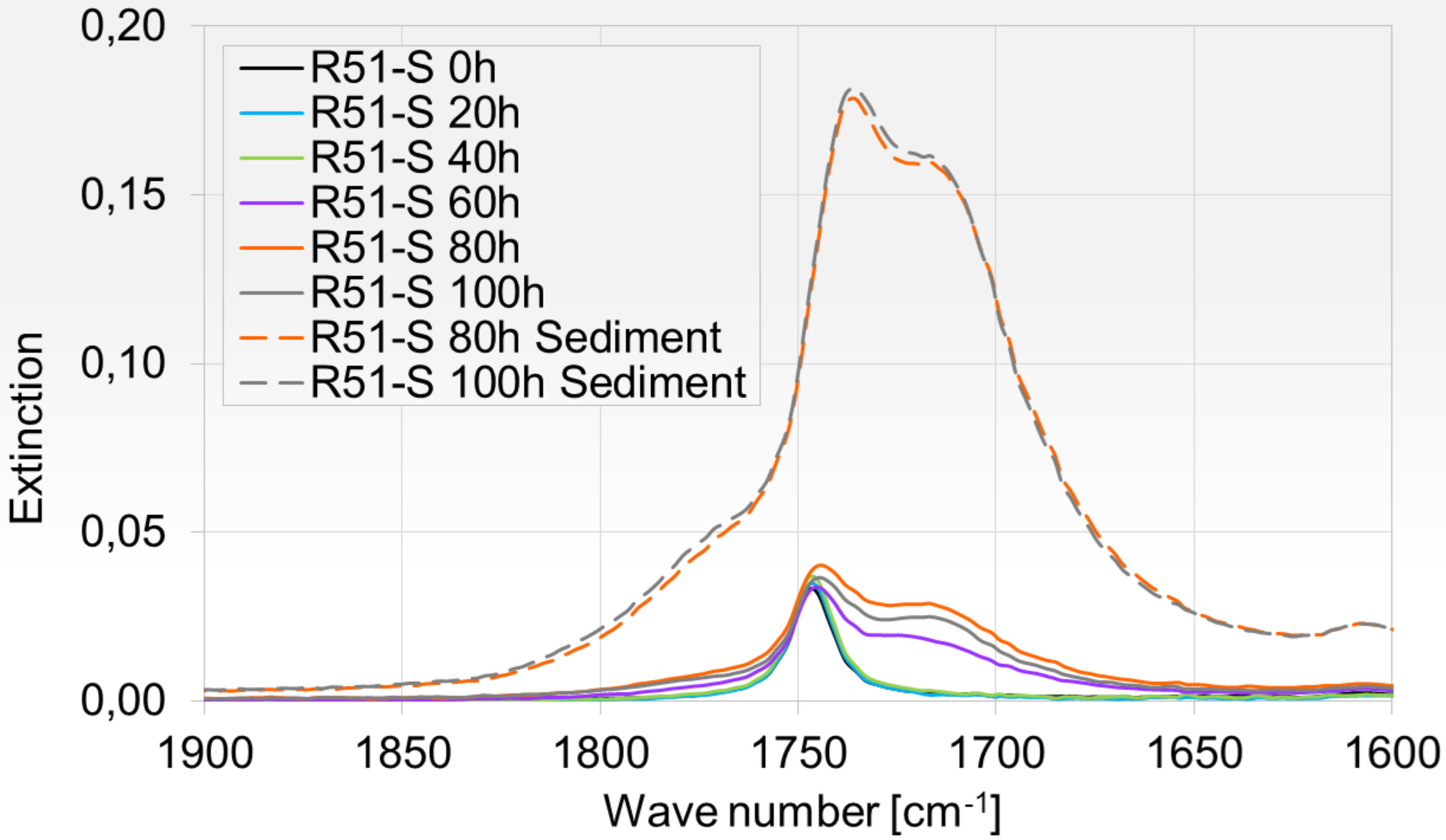
Task A4: Zoom in the carbonyl area of self mixed R51 (w/o sediments)

Illustration	Description
	○ The self mixed fuel R51 is stable up to an aging period of 40 hours and shows little changes in the carbonyl area. ○ From an aging time of 60 hours, band broadening and the formation of shoulders can be seen, which can be attributed to the formation of aging products.



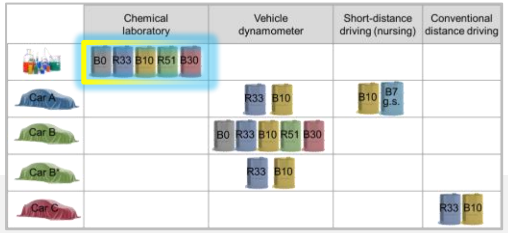
Task A4: Zoom in the carbonyl area of self mixed R51 (w/ sediments)

Illustration



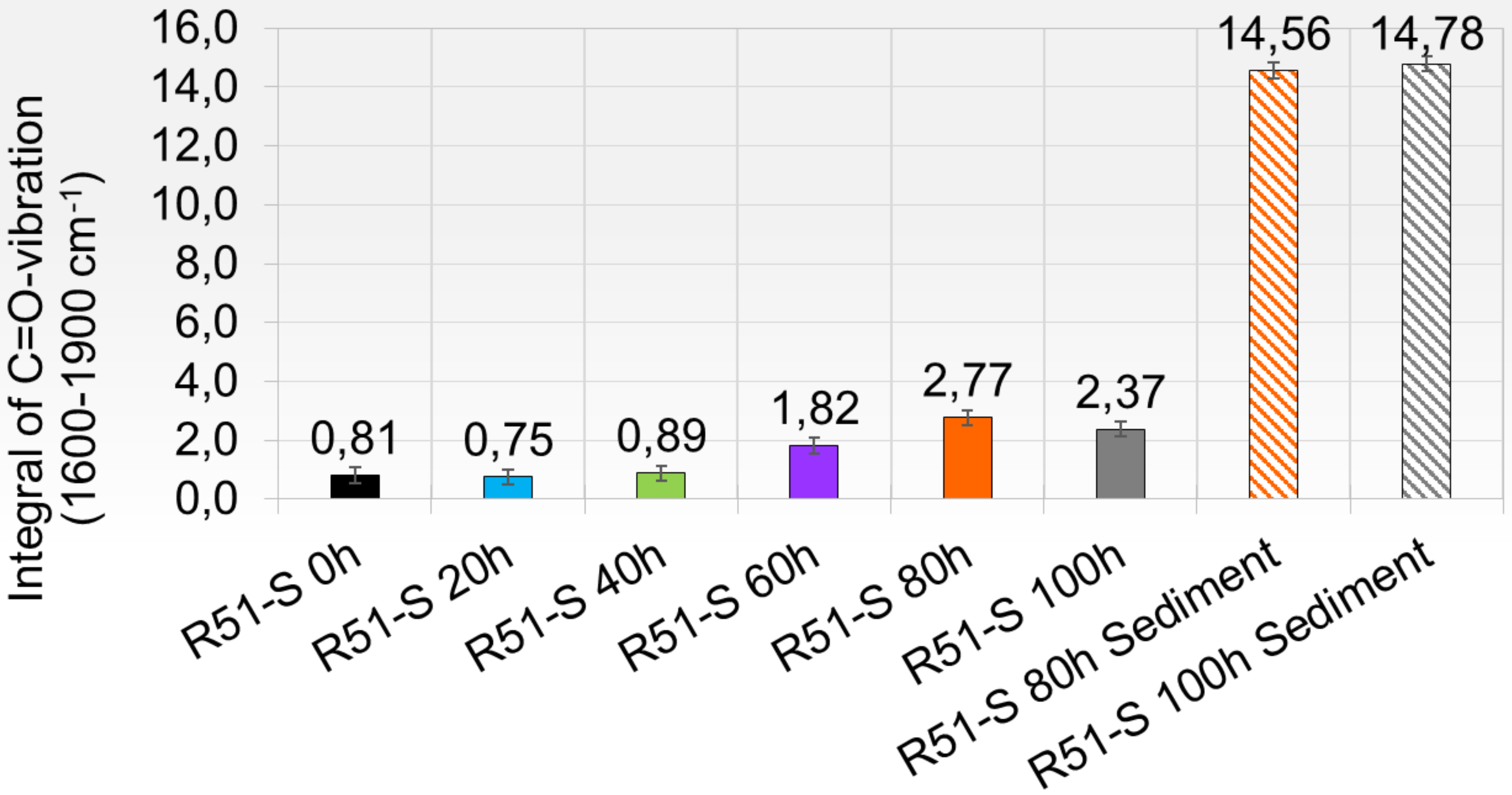
Description

- After 80 and 100 hours of aging, sediments are formed.
- The sediments show a carbonyl vibration with an extinction almost four times higher than that of the liquid phase.
- The area below the carbonyl bond can be integrated for better comparability.



Task A4: Integral of carbonyl vibrations of self mixed R51 aging

Illustration



Description

- The integral shows the same values up to an aging time of 40 hours.
- After an aging period of 60 hours, the integral of the carbonyls increases.
- The area of 80 and 100 hours has continued to increase.
- The sediments from the 80 and 100 hour aging show an area that is almost fife times larger.

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    - Aging experiments
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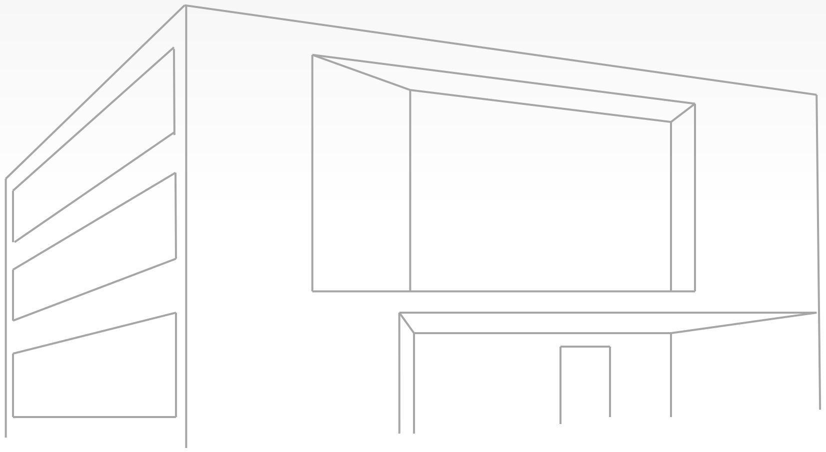
    - GPC analysis
    - GCMS analysis

- Task B: Reception of test vehicles
- Task C: WLTC emission testing



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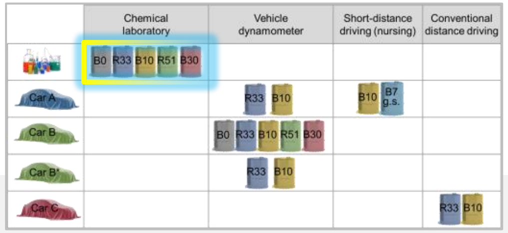
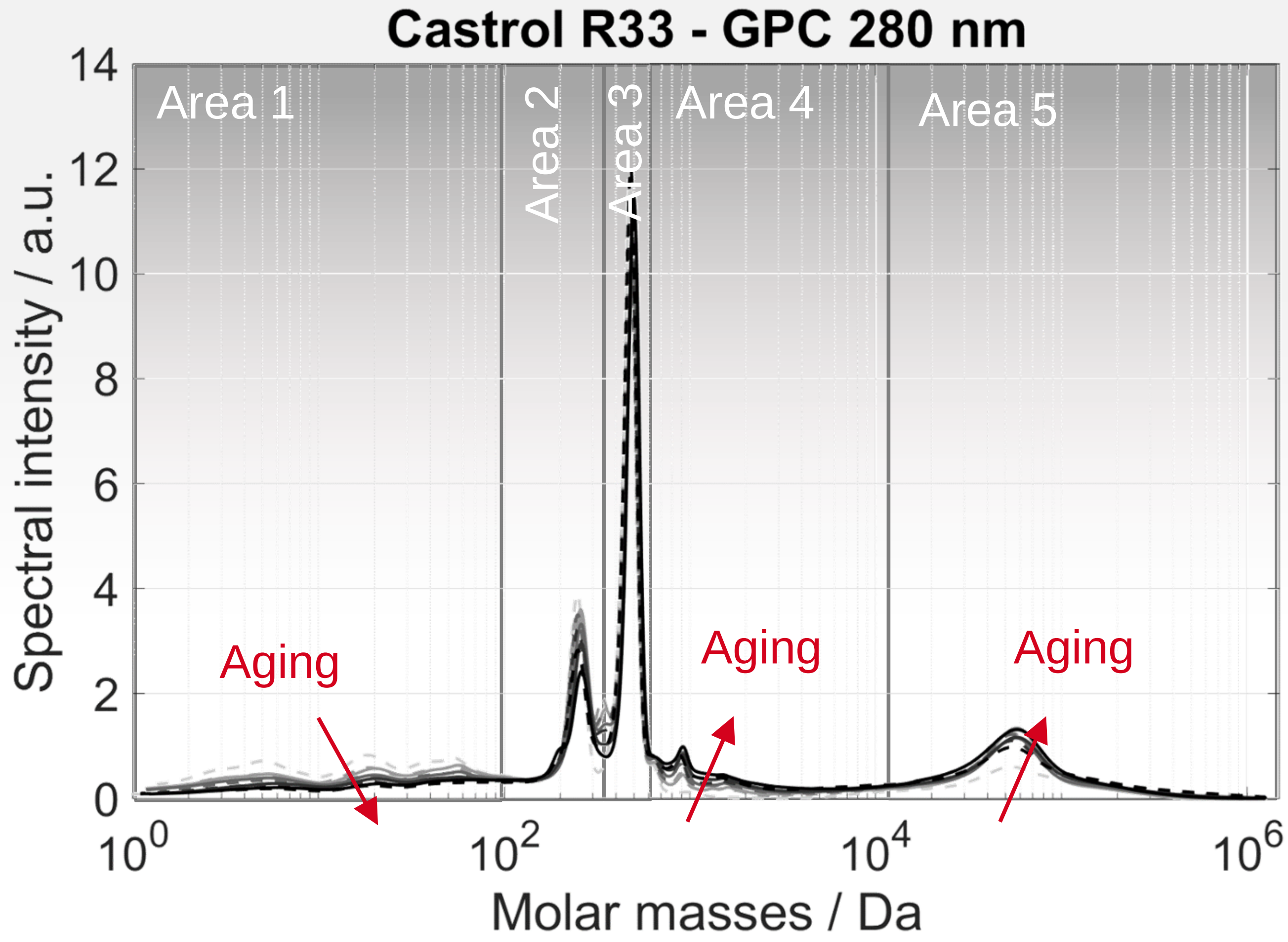


Task A4: GPC Analysis of Castrol + R33 aging

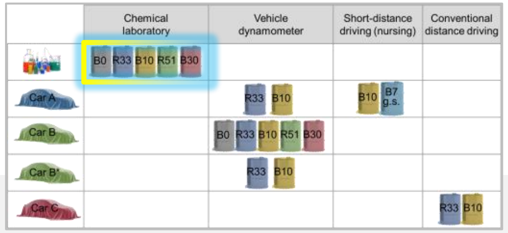
Illustration



Description

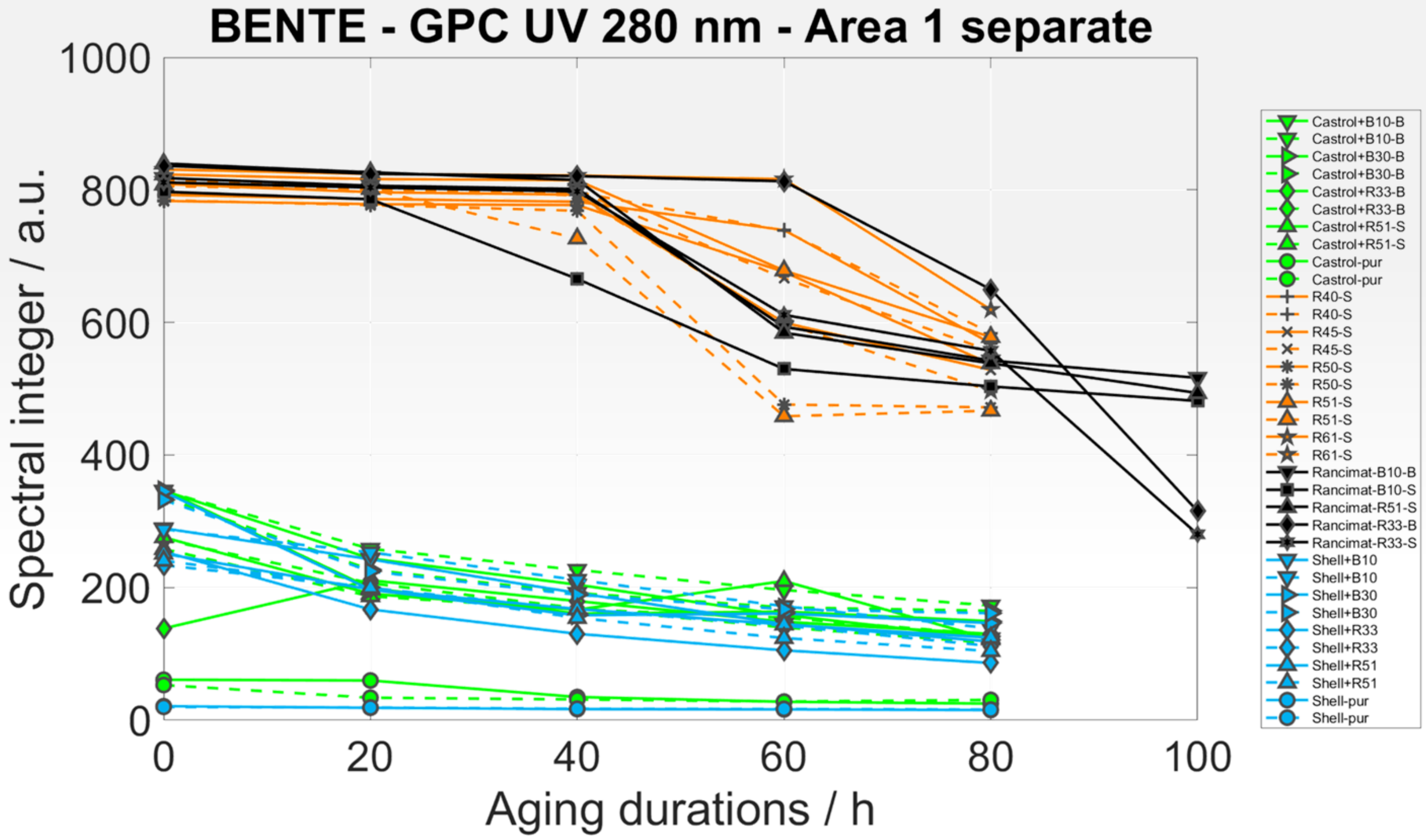
- The same logic applies for the oil and fuel samples with area 3 dominated by the oil peak
  - 1: smallest mol. decreasing
  - 2: small mol. increasing
  - 3: oil peak
  - 4 large mol. increasing
  - 5 largest mol. increasing

Legend:
- bright-line: fresh sample
- dark-line: aged sample
- solid-line: bucket 1
- dashed-line: bucket 2



Task A4: GPC Analysis data summary

Illustration

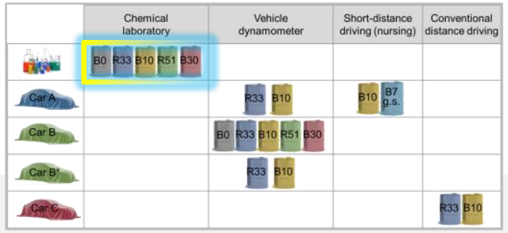


Legend

- Area 1 allows for a clear differentiation between the test samples.

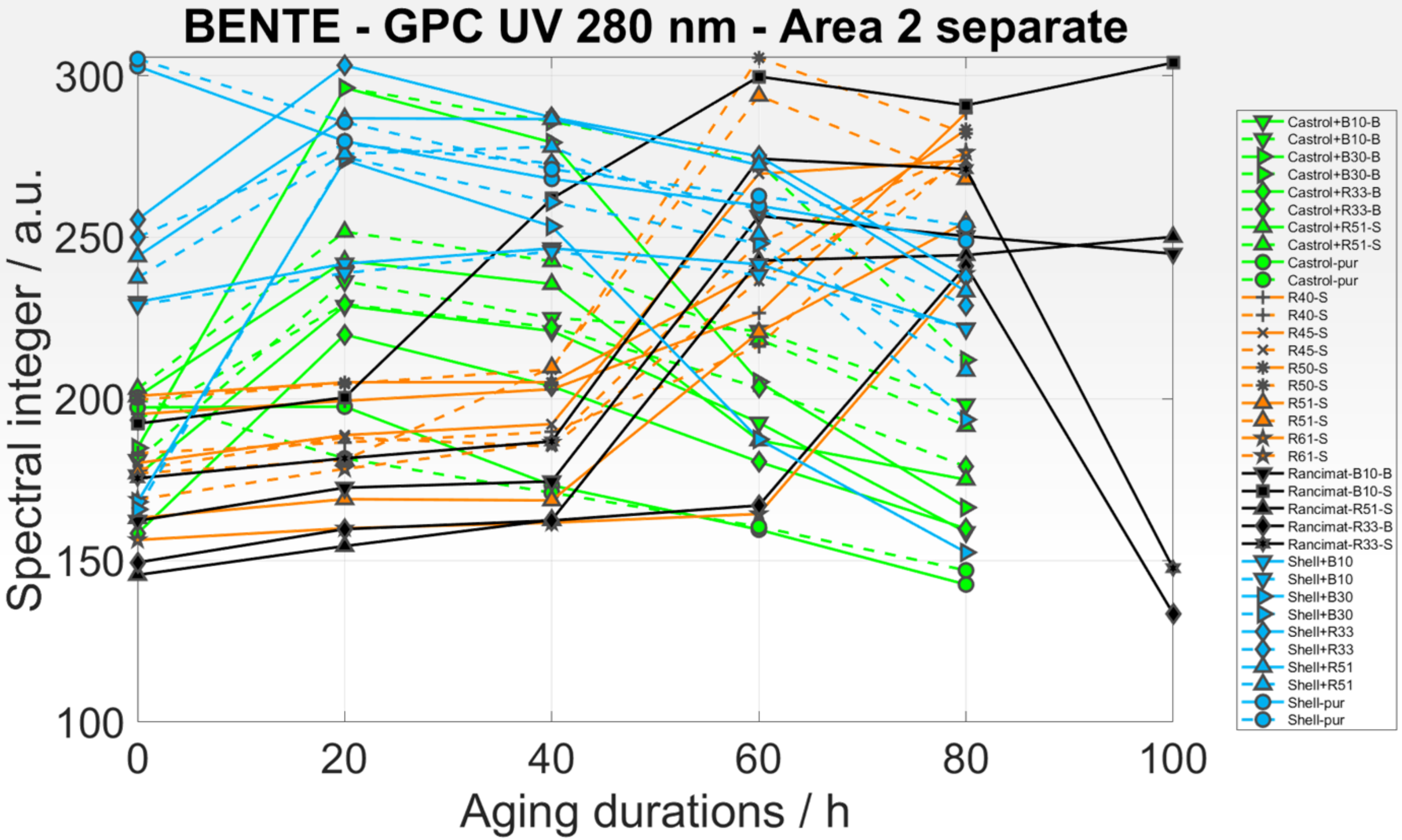
  - black: Racimat fuel only
  - orange: aperture fuel only
  - green: aperture castrol+fuel
  - blue: aperture shell+fuel

  - green circles: Castrol oil
  - blue circles: Shell oil (bottom of the diagram)



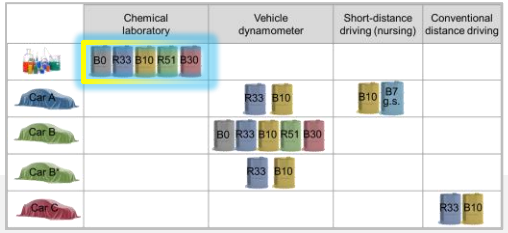
Task A4: GPC Analysis data summary

Illustration



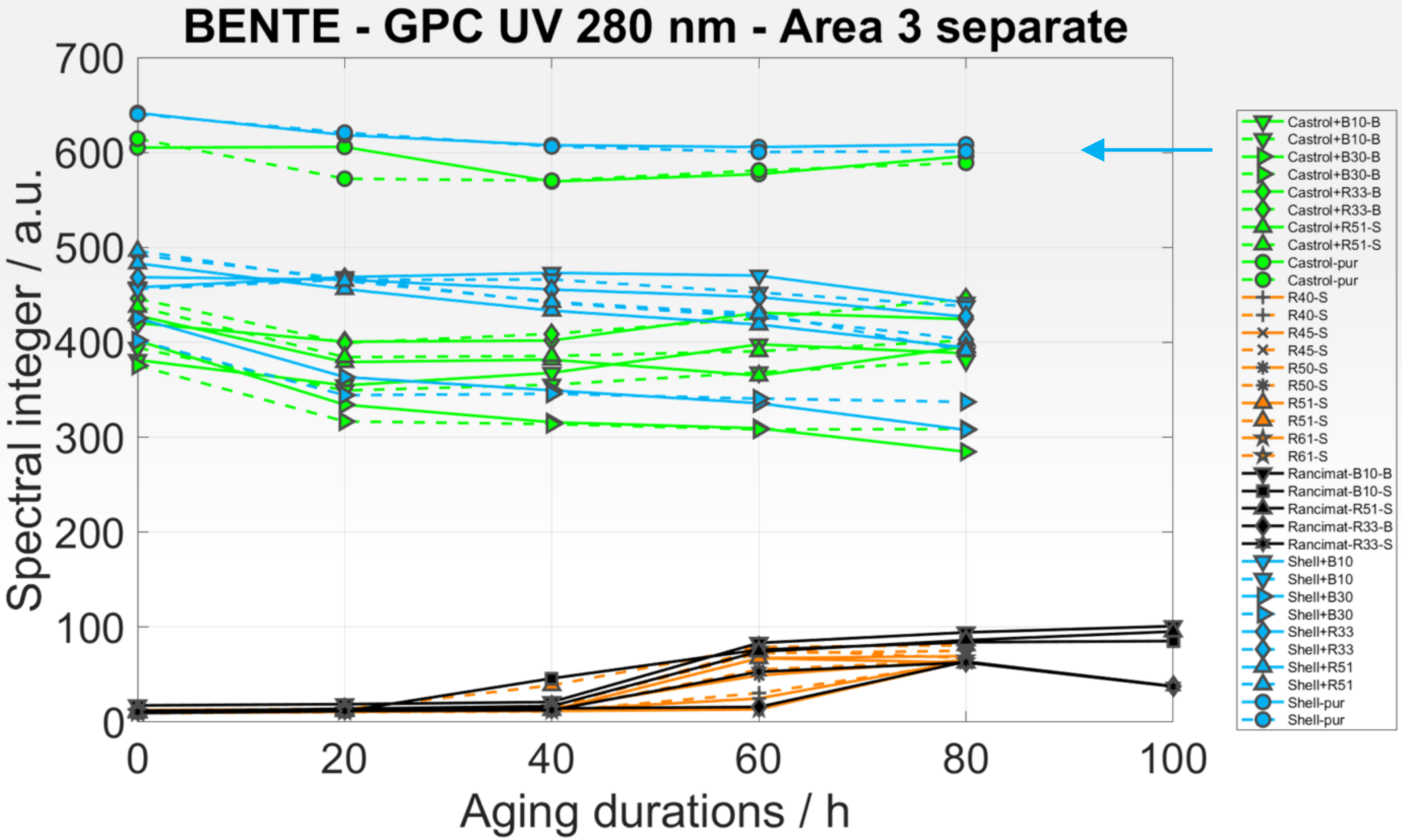
Legend

- Area 2 shows an overlap between the signals.
- Here, the change between increasing and decreasing steps could be an indication for the built-up and break-up of intermediates. (not verified)



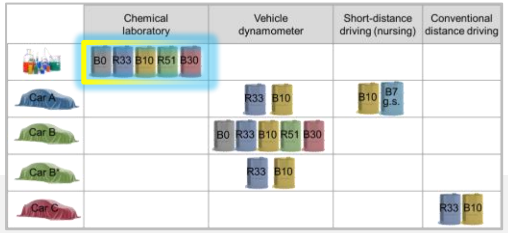
Task A4: GPC Analysis data summary

Illustration



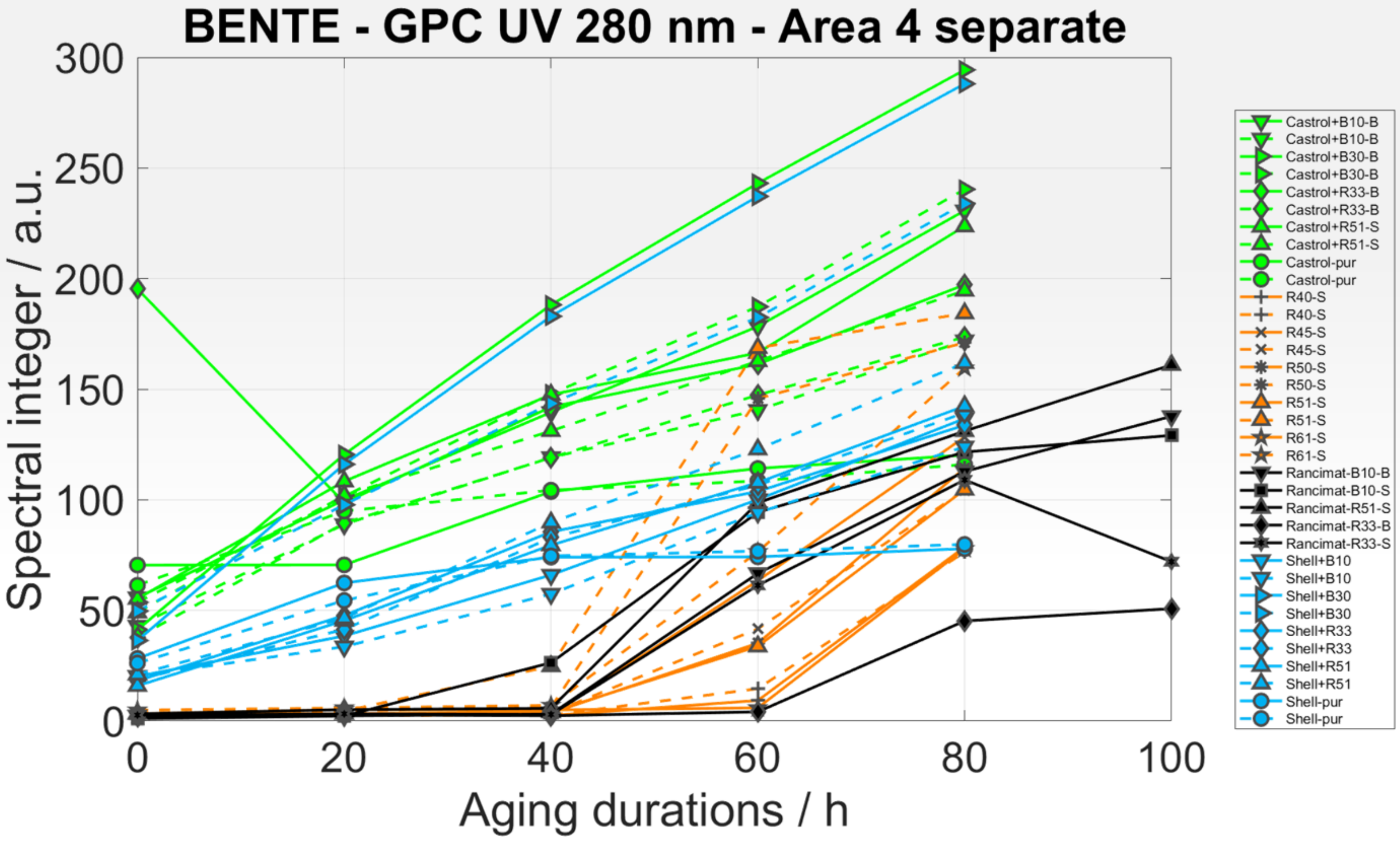
Legend

- Area 3 shows again a cleaner separation between the tests.
- Firstly, the oil-only tests show the highest signal indicating the highest concentration of the middle-sized molecules with slightly higher values for the Shell oils (blue) and minor tendency for decrease (blue).



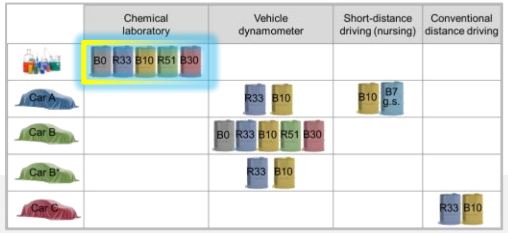
Task A4: GPC Analysis data summary

Illustration



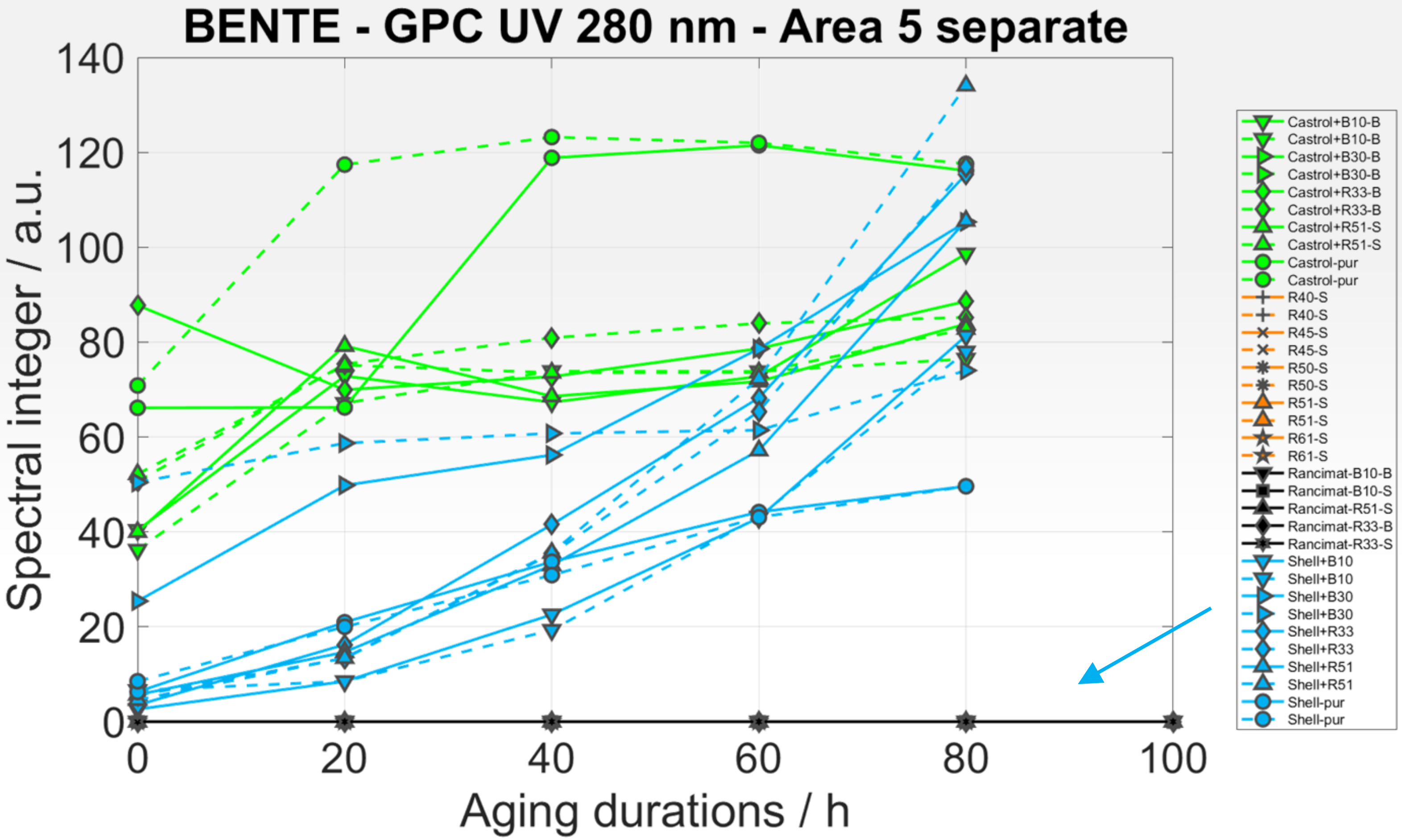
Legend

- Area 4 shows one outlier of Castrol R33 with 0 hours, which is also seen in the raw-data.
- Despite of the outlier, Area 4 shows an overall increase of signal intensity, which indicates an increase of large molecules with all tested samples.
- The delayed signal increase of the fuels-only samples might show a delayed start of aging.



Task A4: GPC Analysis data summary

Illustration



Legend

- Area 5 also shows a clear separation of the samples.
- The fuel-oil blends show noticeable signal intensities, which indicates the appearance of molecules or polymers with > 10.000 Da with slightly higher values for the castrol samples (green).
- The fuels-only samples show no signals for such large molecules, which indicates that such molecules correlate to oil aging processes.

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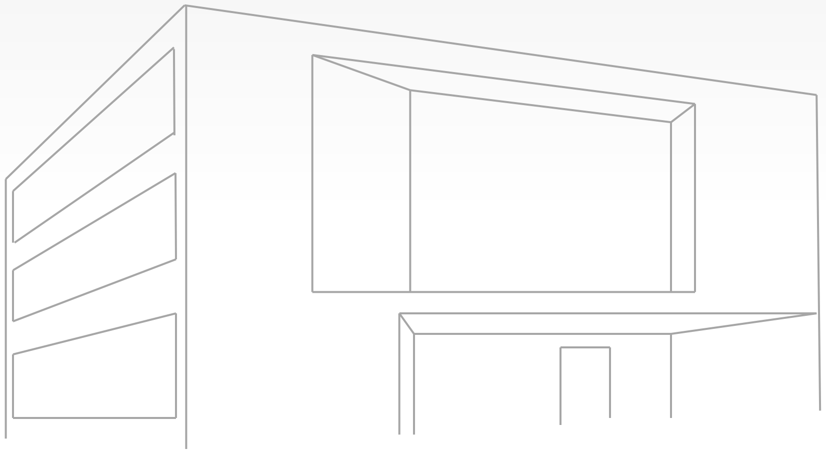
Agenda:

- Executive summary
- Theoretical introduction
- Methods and Materials
- Experimental results
  - Task A: Chemical analysis of fuels and oils
  - Task B: Reception of test vehicles
  - Task C: WLTC emission testing
  - Task D: WLTC oil dilution tests
  - Task E: Real-driving oil dilution testing
  - Task X: Thermodynamic raw-emissions
- Executive summary and outlook
- Acknowledgment
- Contact information



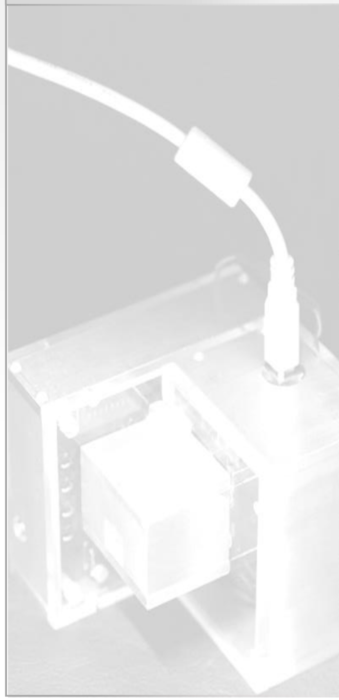
	Chemical laboratory	Vehicle dynamometer	Short-distance driving (nursing)	Conventional distance driving
	B0 R33 B10 R51 B30			
Car A		R33 B10	B10 B7 g.s.	
Car B		B0 R33 B10 R51 B30		
Car B*		R33 B10		
Car C				R33 B10

Fuel research at Coburg University

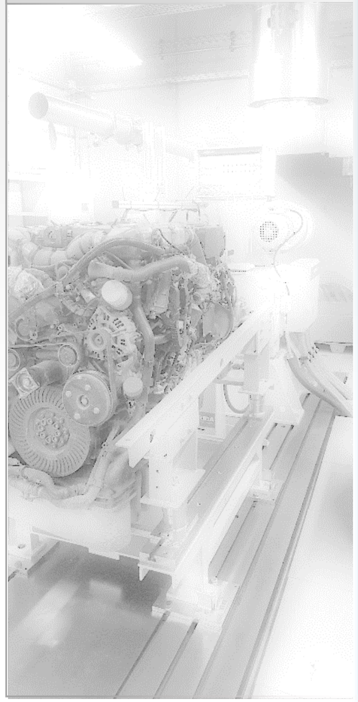
Fuel synthesis

Chemical laboratories

Sensor development



Multi-cylinder engine testing



Vehicle dynamometer

Real-life test driving

Fuel fleet testing

Customer use

	Chemical laboratory	Vehicle dynamometer	Short-distance driving (nursing)	Conventional distance driving
	B0 R33 B10 R51 B30			
Car A		R33 B10	B10 B7 g.s.	
Car B		B0 R33 B10 R51 B30		
Car B'		R33 B10		
Car C				R33 B10

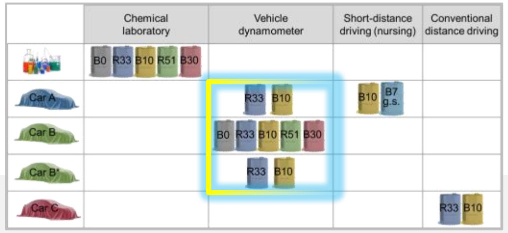
Methods and Materials – Test car: Vehicle A

Vehicle dynamometer

Illustration

Description

- Transmission: DQ381 (DSG/FWD)
- Emissioning: Euro 6d (EA288 EVO)
- Engine: 2.0l TDI SCR
  - 400 Nm @ 1750 - 3500 rpm
  - 147 kW @ 3500 - 4000 rpm
- Certified consumption:
  - 4,7 l/100 km
  - 124 g/km
- Model year: 2021



HOCHSCHULE COBURG

Methods and Materials – Test car: Vehicle B

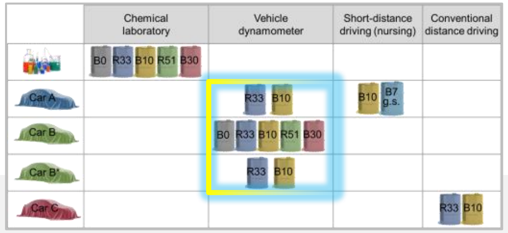
Vehicle dynamometer

Illustration

Description

- Transmission: DQ381 (DSG/FWD)
- Emissioning: Euro 6d (EA288 EVO)
- Engine: 2.0l TDI SCR
  - 400 Nm @ 1750 - 3500 rpm
  - 147 kW @ 3500 - 4000 rpm
- Certified consumption:
  - 4,7 l/100 km
  - 124 g/km
- Model year: 2019

Data source: VW configurator
Date: 28.06.2024



Results of vehicle emission tests

Vehicle A

R33: achieved 3 valid tests
B10: achieved 3 valid tests

Vehicle B

B0: achieved 3 valid tests
R33: achieved 3 valid tests
B10: achieved 3 valid tests
R51: achieved 3 valid tests
B30: achieved 3 valid tests

Description

- Coburg conducted the tests with vehicle A and vehicle B by using the summer tires of vehicle B (daily tire switches)
- Vehicle A finalized the tests with B10 and R33
- Vehicle B finalized the tests with B0, R33, B10, R51 and B30

Agenda:

Executive summary

Theoretical introduction

Methods and Materials

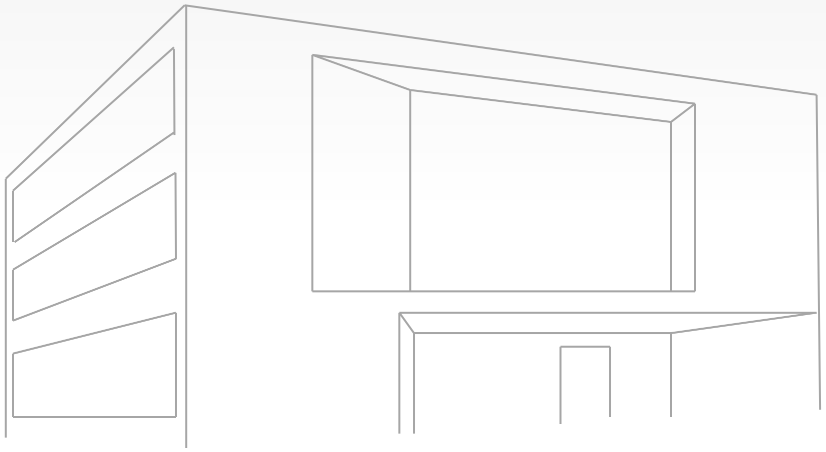
Experimental results

- Task A: Chemical analysis of fuels and oils
- Task B: Reception of test vehicles
- **Task C: WLTC emission testing**
- Task D: WLTC oil dilution tests
- Task E: Real-driving oil dilution testing
- Task X: Thermodynamic raw-emissions

Executive summary and outlook

Acknowledgment

Contact information



Agenda:

Executive summary

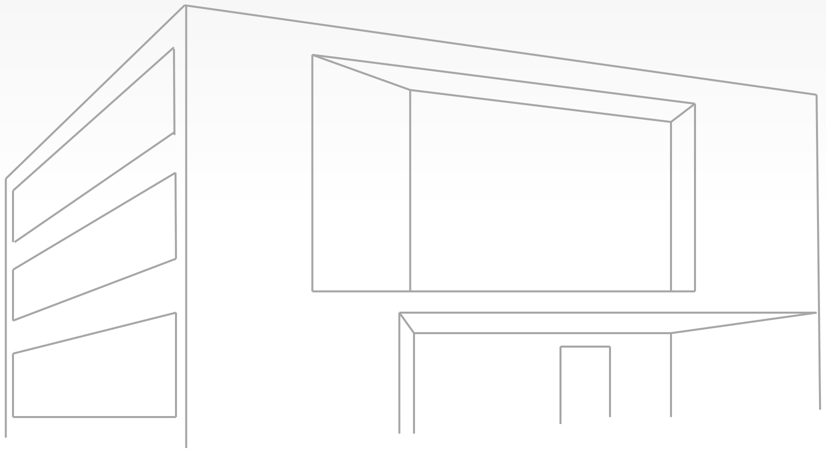
Theoretical introduction

Methods and Materials

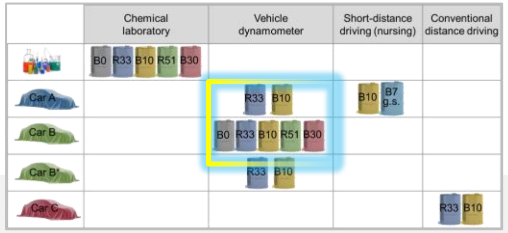
Experimental results

- Task A: Chemical analysis of fuels and oils
- Task B: Reception of test vehicles
- Task C: WLTC emission testing
  - Comparison between vehicle A and B
  - Comparison of fuels with vehicle B

- Task D: WLTC oil dilution tests
- Task E: Real-driving oil dilution testing
- …



All tests fulfill the
Euro 6 emission limits



Task C1: Comparison between vehicle A and B

Overview

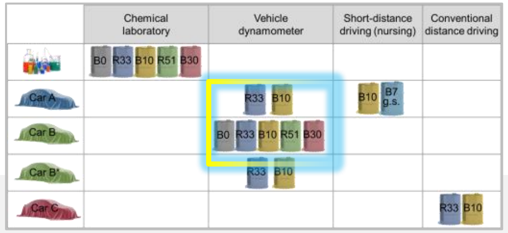
BENTE Vehicle A	CO2 (g/km)	CO (mg/km)	THC (mg/km)	NOx (mg/km)	HC+NOx (mg/km)	CH4 (mg/km)	NMHC (mg/km)	NMHC+NOx (mg/km)	PN (#/km)	Fuel Cons. (l/100km)	Distance (km)	
B10	124,72	24,8	8,5	20,9	29,4	4,3	4,7	25,6	7,08E+10	4,7441	23,265	Representative
B10	123,58	19,5	7,9	20,6	28,4	4,0	4,4	24,9	6,87E+10	4,7003	23,288	
B10	127,03	28,7	10,0	21,5	31,5	4,3	6,2	27,7	6,45E+10	4,8321	23,264	
Average	**125,11**	**24,33**	**8,78**	**20,99**	**29,77**	**4,22**	**5,09**	**26,08**	**6,80E+10**	**4,76**	**23,27**	

BENTE Vehicle A	CO2 (g/km)	CO (mg/km)	THC (mg/km)	NOx (mg/km)	HC+NOx (mg/km)	CH4 (mg/km)	NMHC (mg/km)	NMHC+NOx (mg/km)	PN (#/km)	Fuel Cons. (l/100km)	Distance (km)	
R33	120,72	19,7	6,2	20,7	26,9	2,9	3,7	24,4	6,02E+10	4,5914	23,283	Representative
R33	120,50	16,5	6,5	19,7	26,2	3,6	3,4	23,1	5,25E+10	4,5828	23,277	
R33	122,20	27,2	8,7	22,6	31,3	3,6	5,5	28,1	5,80E+10	4,6484	23,274	
Average	**121,14**	**21,14**	**7,13**	**21,00**	**28,14**	**3,34**	**4,21**	**25,21**	**5,69E+10**	**4,61**	**23,28**	

BENTE Vehicle B	CO2 (g/km)	CO (mg/km)	THC (mg/km)	NOx (mg/km)	HC+NOx (mg/km)	CH4 (mg/km)	NMHC (mg/km)	NMHC+NOx (mg/km)	PN (#/km)	Fuel Cons. (l/100km)	Distance (km)	
B10	123,73	25,4	10,1	16,0	26,1	4,3	6,3	22,3	1,65E+08	4,7067	23,272	
B10	125,01	34,1	11,9	16,7	28,7	4,4	8,1	24,8	1,74E+08	4,7561	23,273	
B10	124,53	25,9	10,1	18,1	28,1	3,5	7,0	25,1	3,09E+08	4,7371	23,269	Representative
Average	**124,43**	**28,49**	**10,72**	**16,93**	**27,64**	**4,08**	**7,14**	**24,07**	**2,16E+08**	**4,73**	**23,27**	

BENTE Vehicle B	CO2 (g/km)	CO (mg/km)	THC (mg/km)	NOx (mg/km)	HC+NOx (mg/km)	CH4 (mg/km)	NMHC (mg/km)	NMHC+NOx (mg/km)	PN (#/km)	Fuel Cons. (l/100km)	Distance (km)	
R33	123,64	24,8	8,2	16,7	25,0	3,3	5,3	22,1	1,33E+08	4,7031	23,260	
R33	123,50	24,9	8,8	16,7	25,5	3,5	5,7	22,4	1,88E+08	4,6976	23,269	Representative
R33	123,18	24,7	8,0	17,3	25,3	3,1	5,3	22,5	1,38E+08	4,6852	23,261	
Average	**123,44**	**24,82**	**8,35**	**16,88**	**25,23**	**3,33**	**5,44**	**22,32**	**1,53E+08**	**4,70**	**23,26**	

Representative tests chosen by medium carbon dioxide (CO_2) values



Vehicle A and B closely comparable
Only noticeable difference in PN

Task C1: Comparison between vehicle A and B

Overview

BENTE Vehicle A	CO2 (g/km)	CO (mg/km)	THC (mg/km)	NOx (mg/km)	HC+NOx (mg/km)	CH4 (mg/km)	NMHC (mg/km)	NMHC+NOx (mg/km)	PN (#/km)	Fuel Cons. (l/100km)	Distance (km)	
B10	124,72	24,8	8,5	20,9	29,4	4,3	4,7	25,6	7,08E+10	4,7441	23,265	Representative
B10	123,58	19,5	7,9	20,6	28,4	4,0	4,4	24,9	6,87E+10	4,7003	23,288	
B10	127,03	28,7	10,0	21,5	31,5	4,3	6,2	27,7	6,45E+10	4,8321	23,264	
Average	**125,11**	**24,33**	**8,78**	**20,99**	**29,77**	**4,22**	**5,09**	**26,08**	**6,80E+10**	**4,76**	**23,27**	

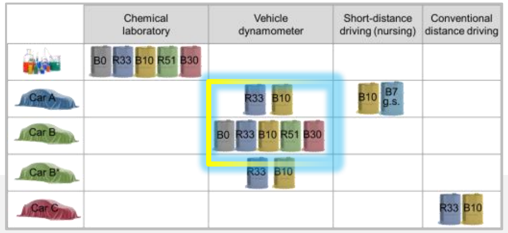
BENTE Vehicle A	CO2 (g/km)	CO (mg/km)	THC (mg/km)	NOx (mg/km)	HC+NOx (mg/km)	CH4 (mg/km)	NMHC (mg/km)	NMHC+NOx (mg/km)	PN (#/km)	Fuel Cons. (l/100km)	Distance (km)	
R33	120,72	19,7	6,2	20,7	26,9	2,9	3,7	24,4	6,02E+10	4,5914	23,283	Representative
R33	120,50	16,5	6,5	19,7	26,2	3,6	3,4	23,1	5,25E+10	4,5828	23,277	
R33	122,20	27,2	8,7	22,6	31,3	3,6	5,5	28,1	5,80E+10	4,6484	23,274	
Average	**121,14**	**21,14**	**7,13**	**21,00**	**28,14**	**3,34**	**4,21**	**25,21**	**5,69E+10**	**4,61**	**23,28**	

BENTE Vehicle B	CO2 (g/km)	CO (mg/km)	THC (mg/km)	NOx (mg/km)	HC+NOx (mg/km)	CH4 (mg/km)	NMHC (mg/km)	NMHC+NOx (mg/km)	PN (#/km)	Fuel Cons. (l/100km)	Distance (km)	
B10	123,73	25,4	10,1	16,0	26,1	4,3	6,3	22,3	1,65E+08	4,7067	23,272	
B10	125,01	34,1	11,9	16,7	28,7	4,4	8,1	24,8	1,74E+08	4,7561	23,273	
B10	124,53	25,9	10,1	18,1	28,1	3,5	7,0	25,1	3,09E+08	4,7371	23,269	Representative
Average	**124,43**	**28,49**	**10,72**	**16,93**	**27,64**	**4,08**	**7,14**	**24,07**	**2,16E+08**	**4,73**	**23,27**	

BENTE Vehicle B	CO2 (g/km)	CO (mg/km)	THC (mg/km)	NOx (mg/km)	HC+NOx (mg/km)	CH4 (mg/km)	NMHC (mg/km)	NMHC+NOx (mg/km)	PN (#/km)	Fuel Cons. (l/100km)	Distance (km)	
R33	123,64	24,8	8,2	16,7	25,0	3,3	5,3	22,1	1,33E+08	4,7031	23,260	
R33	123,50	24,9	8,8	16,7	25,5	3,5	5,7	22,4	1,88E+08	4,6976	23,269	Representative
R33	123,18	24,7	8,0	17,3	25,3	3,1	5,3	22,5	1,38E+08	4,6852	23,261	
Average	**123,44**	**24,82**	**8,35**	**16,88**	**25,23**	**3,33**	**5,44**	**22,32**	**1,53E+08**	**4,70**	**23,26**	

Representative tests chosen by medium carbon dioxide (CO_2) values

Representative tests are selected due to the medium CO_2 values



Task C1: Comparison between vehicle A and B

Overview

BENTE Vehicle A	CO2 (g/km)	CO (mg/km)	THC (mg/km)	NOx (mg/km)	HC+NOx (mg/km)	CH4 (mg/km)	NMHC (mg/km)	NMHC+NOx (mg/km)	PN (#/km)	Fuel Cons. (l/100km)	Distance (km)	
B10	124,72	24,8	8,5	20,9	29,4	4,3	4,7	25,6	7,08E+10	4,7441	23,265	Representative
B10	123,58	19,5	7,9	20,6	28,4	4,0	4,4	24,9	6,87E+10	4,7003	23,288	
B10	127,03	28,7	10,0	21,5	31,5	4,3	6,2	27,7	6,45E+10	4,8321	23,264	
Average	**125,11**	**24,33**	**8,78**	**20,99**	**29,77**	**4,22**	**5,09**	**26,08**	**6,80E+10**	**4,76**	**23,27**	

BENTE Vehicle A	CO2 (g/km)	CO (mg/km)	THC (mg/km)	NOx (mg/km)	HC+NOx (mg/km)	CH4 (mg/km)	NMHC (mg/km)	NMHC+NOx (mg/km)	PN (#/km)	Fuel Cons. (l/100km)	Distance (km)	
R33	120,72	19,7	6,2	20,7	26,9	2,9	3,7	24,4	6,02E+10	4,5914	23,283	Representative
R33	120,50	16,5	6,5	19,7	26,2	3,6	3,4	23,1	5,25E+10	4,5828	23,277	
R33	122,20	27,2	8,7	22,6	31,3	3,6	5,5	28,1	5,80E+10	4,6484	23,274	
Average	**121,14**	**21,14**	**7,13**	**21,00**	**28,14**	**3,34**	**4,21**	**25,21**	**5,69E+10**	**4,61**	**23,28**	

BENTE Vehicle B	CO2 (g/km)	CO (mg/km)	THC (mg/km)	NOx (mg/km)	HC+NOx (mg/km)	CH4 (mg/km)	NMHC (mg/km)	NMHC+NOx (mg/km)	PN (#/km)	Fuel Cons. (l/100km)	Distance (km)	
B10	123,73	25,4	10,1	16,0	26,1	4,3	6,3	22,3	1,65E+08	4,7067	23,272	
B10	125,01	34,1	11,9	16,7	28,7	4,4	8,1	24,8	1,74E+08	4,7561	23,273	
B10	124,53	25,9	10,1	18,1	28,1	3,5	7,0	25,1	3,09E+08	4,7371	23,269	Representative
Average	**124,43**	**28,49**	**10,72**	**16,93**	**27,64**	**4,08**	**7,14**	**24,07**	**2,16E+08**	**4,73**	**23,27**	

BENTE Vehicle B	CO2 (g/km)	CO (mg/km)	THC (mg/km)	NOx (mg/km)	HC+NOx (mg/km)	CH4 (mg/km)	NMHC (mg/km)	NMHC+NOx (mg/km)	PN (#/km)	Fuel Cons. (l/100km)	Distance (km)	
R33	123,64	24,8	8,2	16,7	25,0	3,3	5,3	22,1	1,33E+08	4,7031	23,260	
R33	123,50	24,9	8,8	16,7	25,5	3,5	5,7	22,4	1,88E+08	4,6976	23,269	Representative
R33	123,18	24,7	8,0	17,3	25,3	3,1	5,3	22,5	1,38E+08	4,6852	23,261	
Average	**123,44**	**24,82**	**8,35**	**16,88**	**25,23**	**3,33**	**5,44**	**22,32**	**1,53E+08**	**4,70**	**23,26**	

Agenda:

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  - Task A: Chemical analysis of fuels and oils
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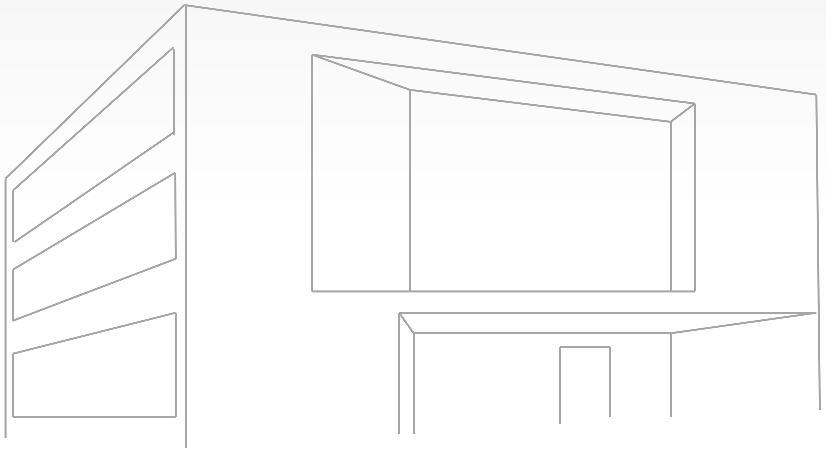
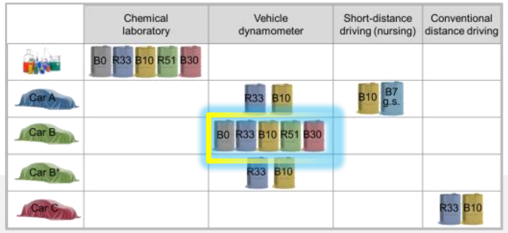
  - Task C: WLTC emission testing
    - Comparison between vehicle A and B
    - Comparison of fuels with vehicle B
  - Task D: WLTC oil dilution tests
  - Task E: Real-driving oil dilution testing
  - …





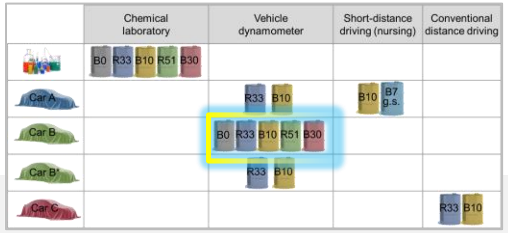
Methods and Materials – Test car: Vehicle B

Vehicle dynamometer

Illustration

Description

- Transmission: DQ381 (DSG/FWD)
- Emissioning: Euro 6d (EA288 EVO)
- Engine: 2.0l TDI SCR
  - 400 Nm @ 1750 - 3500 rpm
  - 147 kW @ 3500 - 4000 rpm
- Certified consumption:
  - 4,7 l/100 km
  - 124 g/km
- Used in task C and task D



Vehicle B fulfills the Euro 6 emission limits with all fuels

Task C2: Vehicle B – B0, B30, R51, B10, R33, data

Overview – Bag results

BENTE Vehicle B	CO2 (g/km)	CO (mg/km)	THC (mg/km)	NOx (mg/km)	HC+NOx (mg/km)	CH4 (mg/km)	NMHC (mg/km)	NMHC+NOx (mg/km)	PN (#/km)	Fuel Cons. (l/100km)	Distance (km)	
B10	123,73	25,4	10,1	16,0	26,1	4,3	6,3	22,3	1,65E+08	4,7067	23,272	
B10	125,01	34,1	11,9	16,7	28,7	4,4	8,1	24,8	1,74E+08	4,7561	23,273	
B10	124,53	25,9	10,1	18,1	28,1	3,5	7,0	25,1	3,09E+08	4,7371	23,269	Representative
Average	**124,43**	**28,49**	**10,72**	**16,93**	**27,64**	**4,08**	**7,14**	**24,07**	**2,16E+08**	**4,73**	**23,27**	
R33	123,64	24,8	8,2	16,7	25,0	3,3	5,3	22,1	1,33E+08	4,7031	23,260	
R33	123,50	24,9	8,8	16,7	25,5	3,5	5,7	22,4	1,88E+08	4,6976	23,269	Representative
R33	123,18	24,7	8,0	17,3	25,3	3,1	5,3	22,5	1,38E+08	4,6852	23,261	
Average	**123,44**	**24,82**	**8,35**	**16,88**	**25,23**	**3,33**	**5,44**	**22,32**	**1,53E+08**	**4,70**	**23,26**	
B0	123,37	20,1	7,0	19,9	26,8	2,7	4,6	24,4	6,40E+08	4,6921	23,279	
B0	123,76	27,5	8,2	19,1	27,3	3,0	5,6	24,7	3,09E+08	4,7076	23,266	
B0	123,21	26,6	7,9	20,9	28,8	3,2	5,1	26,0	9,96E+07	4,6866	23,263	Representative
Average	**123,45**	**24,74**	**7,68**	**19,98**	**27,66**	**2,96**	**5,09**	**25,07**	**3,49E+08**	**4,70**	**23,27**	
R51	122,16	20,8	7,2	18,7	26,0	2,3	5,3	24,0	6,03E+07	4,7460	23,305	Representative
R51	122,82	23,7	7,3	18,0	25,4	2,7	5,0	23,0	1,07E+08	4,7717	23,269	
R51	121,03	15,6	5,3	16,5	21,8	2,5	3,1	19,6	3,81E+08	4,7015	23,305	
Average	**122,00**	**20,03**	**6,60**	**17,73**	**24,40**	**2,50**	**4,47**	**22,20**	**1,83E+08**	**4,74**	**23,29**	
B30	123,80	23,9	8,3	17,3	25,5	3,1	5,6	22,8	9,45E+07	4,7088	23,258	
B30	124,47	25,0	8,8	16,9	25,7	3,0	6,2	23,1	5,79E+07	4,7345	23,270	Representative
B30	125,47	24,3	7,4	17,3	24,7	2,8	5,0	22,3	8,97E+07	4,7722	23,279	
Average	**124,58**	**24,40**	**8,17**	**17,17**	**25,30**	**2,97**	**5,60**	**22,73**	**8,07E+07**	**4,74**	**23,27**	

Representative tests chosen by CO2

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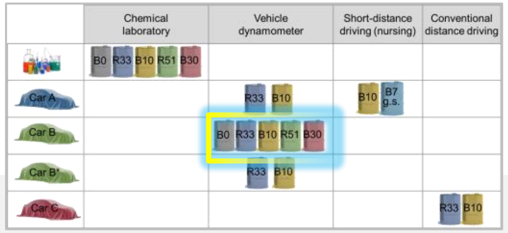

Representative tests are selected due to the medium CO_2 values

Task C2: Vehicle B – B0, B30, R51, B10, R33, data

Overview – Bag results

BENTE Vehicle B	CO2 (g/km)	CO (mg/km)	THC (mg/km)	NOx (mg/km)	HC+NOx (mg/km)	CH4 (mg/km)	NMHC (mg/km)	NMHC+NOx (mg/km)	PN (#/km)	Fuel Cons. (l/100km)	Distance (km)	
B10	123,73	25,4	10,1	16,0	26,1	4,3	6,3	22,3	1,65E+08	4,7067	23,272	
B10	125,01	34,1	11,9	16,7	28,7	4,4	8,1	24,8	1,74E+08	4,7561	23,273	
B10	124,53	25,9	10,1	18,1	28,1	3,5	7,0	25,1	3,09E+08	4,7371	23,269	Representative
Average	**124,43**	**28,49**	**10,72**	**16,93**	**27,64**	**4,08**	**7,14**	**24,07**	**2,16E+08**	**4,73**	**23,27**	
R33	123,64	24,8	8,2	16,7	25,0	3,3	5,3	22,1	1,33E+08	4,7031	23,260	
R33	123,50	24,9	8,8	16,7	25,5	3,5	5,7	22,4	1,88E+08	4,6976	23,269	Representative
R33	123,18	24,7	8,0	17,3	25,3	3,1	5,3	22,5	1,38E+08	4,6852	23,261	
Average	**123,44**	**24,82**	**8,35**	**16,88**	**25,23**	**3,33**	**5,44**	**22,32**	**1,53E+08**	**4,70**	**23,26**	
B0	123,37	20,1	7,0	19,9	26,8	2,7	4,6	24,4	6,40E+08	4,6921	23,279	
B0	123,76	27,5	8,2	19,1	27,3	3,0	5,6	24,7	3,09E+08	4,7076	23,266	
B0	123,21	26,6	7,9	20,9	28,8	3,2	5,1	26,0	9,96E+07	4,6866	23,263	Representative
Average	**123,45**	**24,74**	**7,68**	**19,98**	**27,66**	**2,96**	**5,09**	**25,07**	**3,49E+08**	**4,70**	**23,27**	
R51	122,16	20,8	7,2	18,7	26,0	2,3	5,3	24,0	6,03E+07	4,7460	23,305	Representative
R51	122,82	23,7	7,3	18,0	25,4	2,7	5,0	23,0	1,07E+08	4,7717	23,269	
R51	121,03	15,6	5,3	16,5	21,8	2,5	3,1	19,6	3,81E+08	4,7015	23,305	
Average	**122,00**	**20,03**	**6,60**	**17,73**	**24,40**	**2,50**	**4,47**	**22,20**	**1,83E+08**	**4,74**	**23,29**	
B30	123,80	23,9	8,3	17,3	25,5	3,1	5,6	22,8	9,45E+07	4,7088	23,258	
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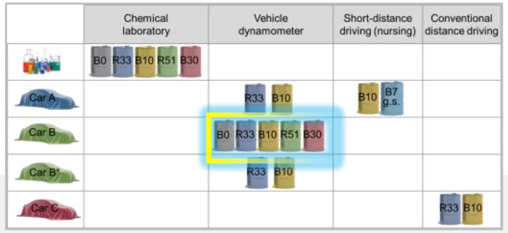
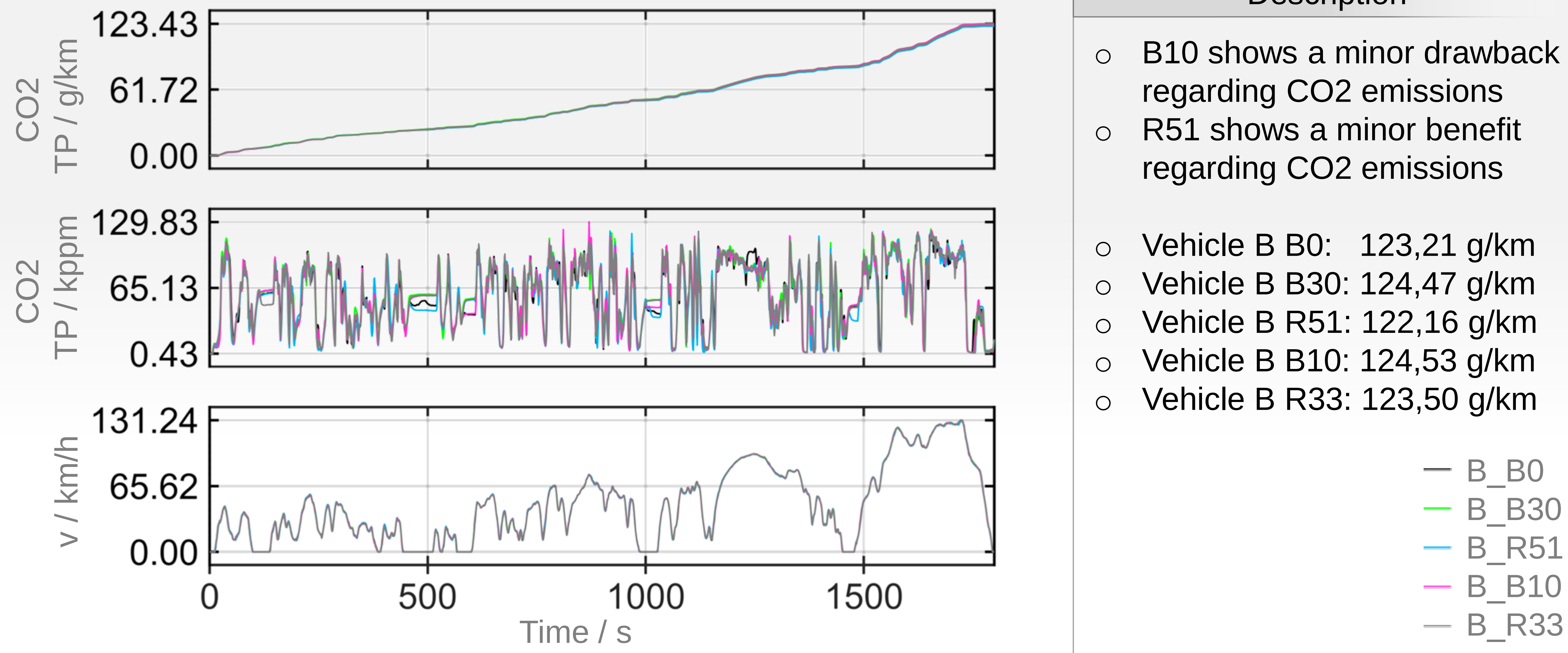
B30	125,47	24,3	7,4	17,3	24,7	2,8	5,0	22,3	8,97E+07	4,7722	23,279	
Average	**124,58**	**24,40**	**8,17**	**17,17**	**25,30**	**2,97**	**5,60**	**22,73**	**8,07E+07**	**4,74**	**23,27**	



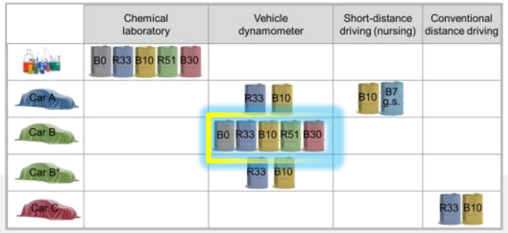
Task C2: Vehicle B – B0, B30, R51, B10, R33, data



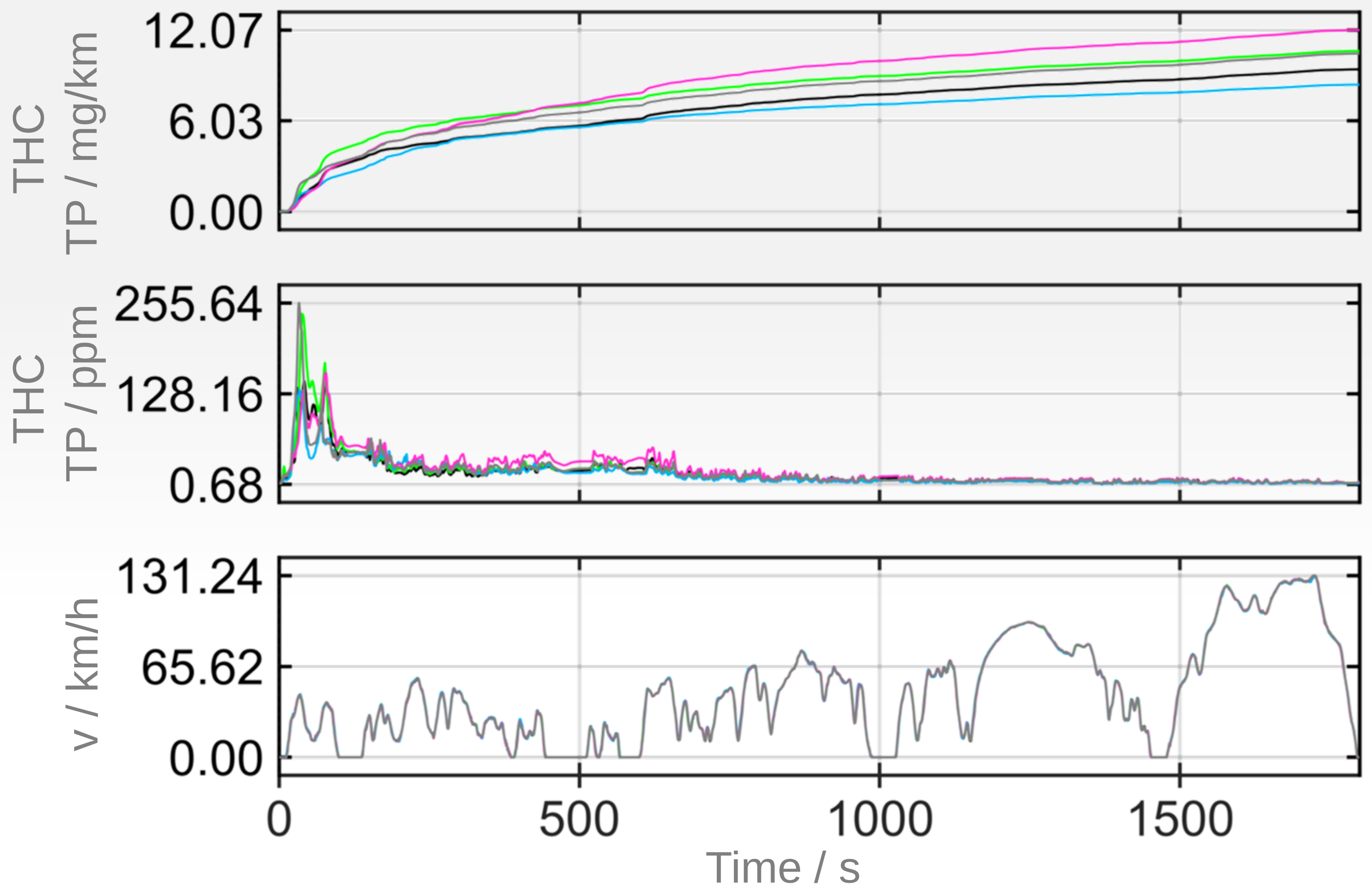
Description

- B10 shows a minor drawback regarding CO_2 emissions
- R51 shows a minor benefit regarding CO_2 emissions

- Vehicle B B0: 123,21 g/km
- Vehicle B B30: 124,47 g/km
- Vehicle B R51: 122,16 g/km
- Vehicle B B10: 124,53 g/km
- Vehicle B R33: 123,50 g/km



Task C2: Vehicle B – B0, B30, R51, B10, R33, data

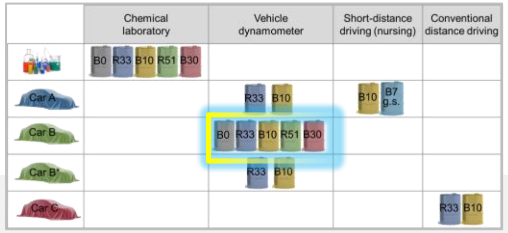


Description

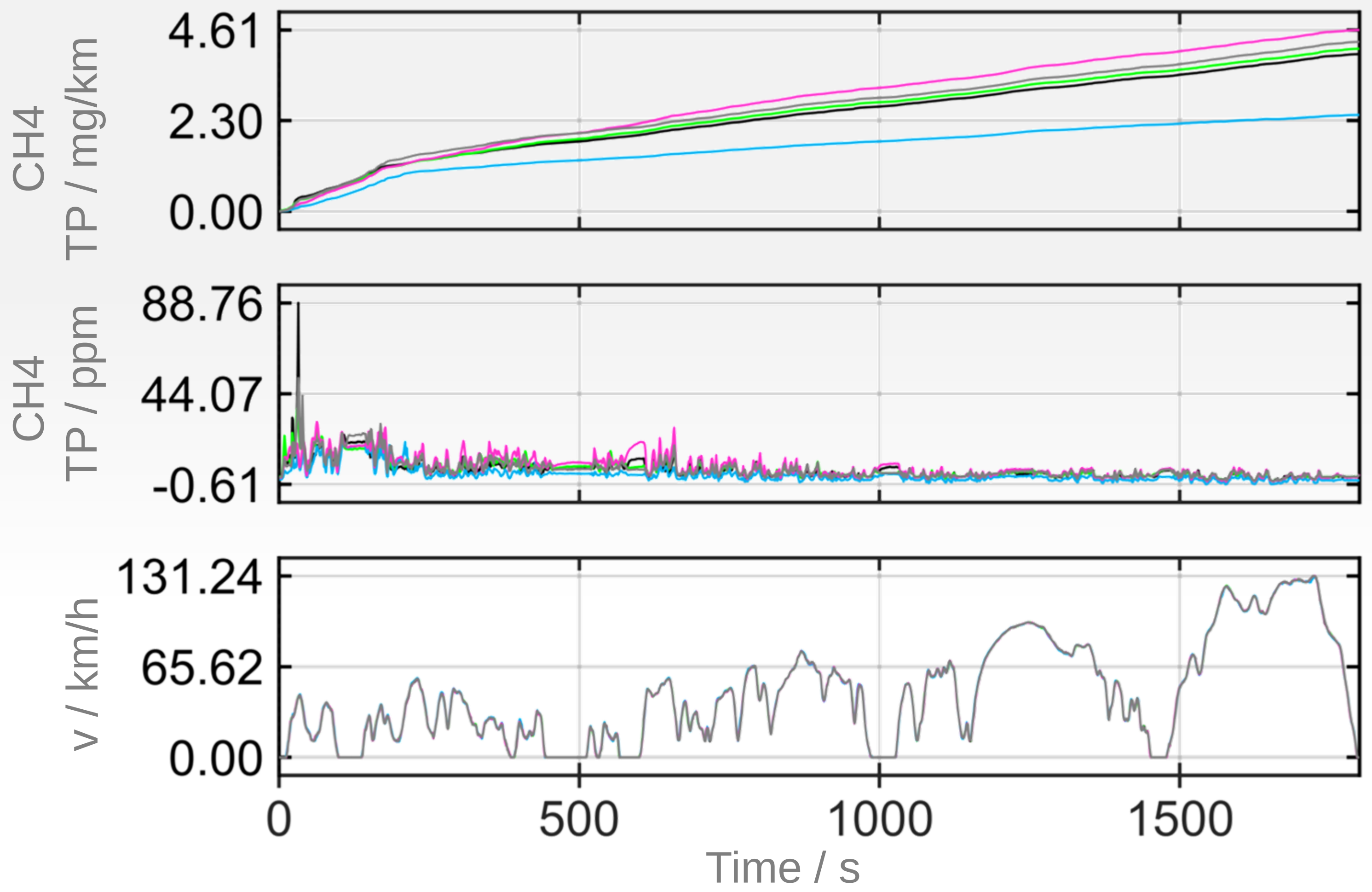
- B10 shows slightly higher THC emissions.
- R51 shows a minor benefit regarding THC emissions
- B30 and R33 show similar results.

- Vehicle B B0 : 7,9 mg/km
- Vehicle B B30: 8,8 mg/km
- Vehicle B R51: 7,2 mg/km
- Vehicle B B10: 10,1 mg/km
- Vehicle B R33: 8,8 mg/km
- Limit: 100 mg/km

B_R51
B_B0
B_B10
B_B30
B_R33



Task C2: Vehicle B – B0, B30, R51, B10, R33, data



Description

- B10 and R33 show slightly higher CH4 emissions.
- R51 shows a minor benefit regarding CH4 emissions

- Vehicle B B0: 3,2 mg/km
- Vehicle B B30: 3,0 mg/km
- Vehicle B R51: 2,3 mg/km
- Vehicle B B10: 3,5 mg/km
- Vehicle B R33: 3,5 mg/km

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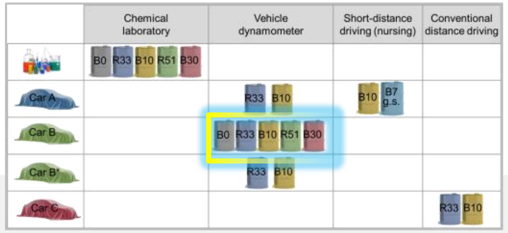
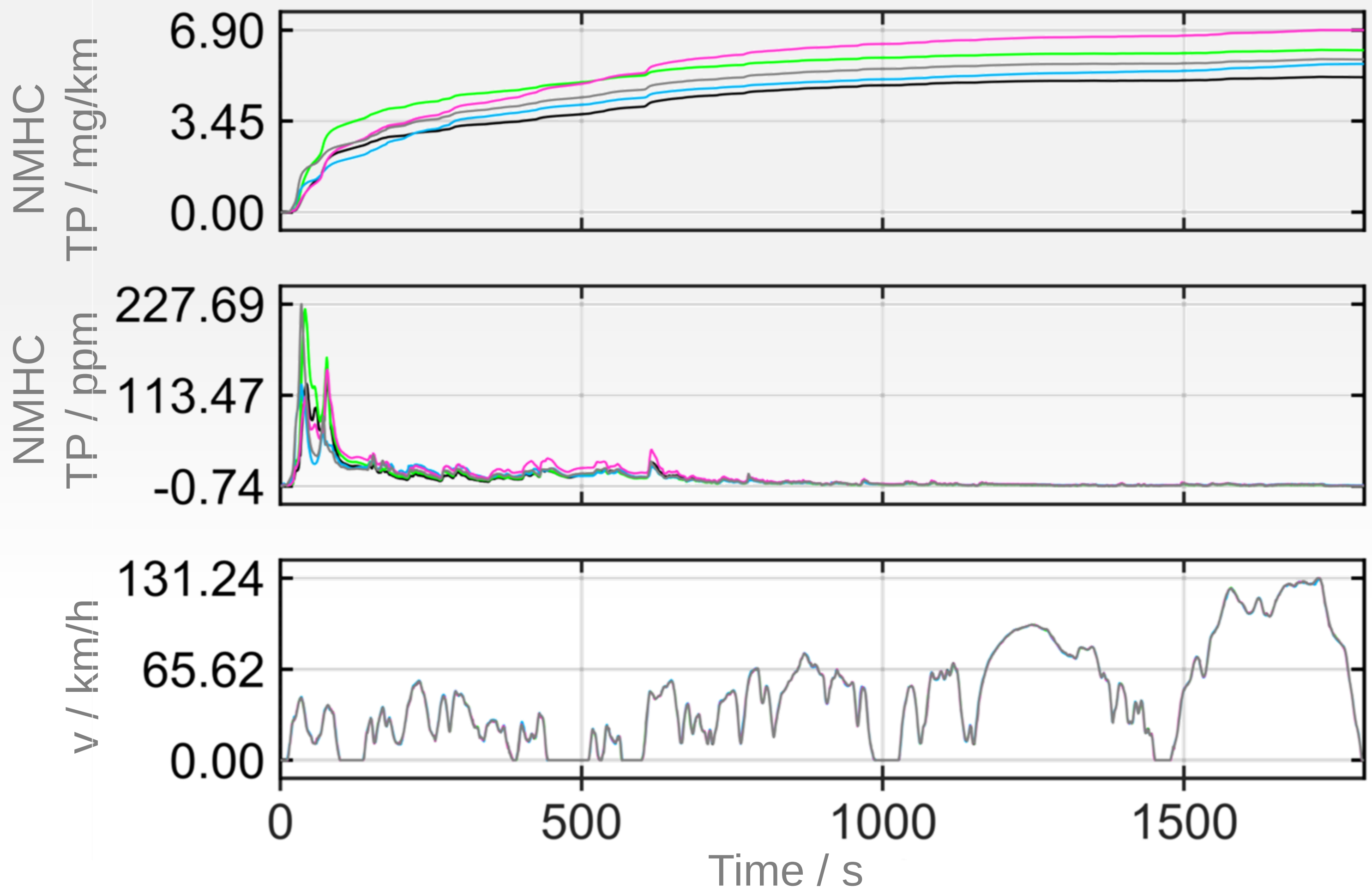


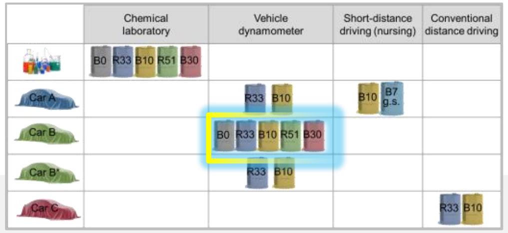
Task C2: Vehicle B – B0, B30, R51, B10, R33, data



Description

- B10 shows slightly higher NMHC emissions
- B0 shows a minor benefit regarding NMHC emissions

- Vehicle B B0: 5,1 mg/km
- Vehicle B B30: 6,2 mg/km
- Vehicle B R51: 5,3 mg/km
- Vehicle B B10: 7,0 mg/km
- Vehicle B R33: 5,7 mg/km
- Limit: 68 mg/km



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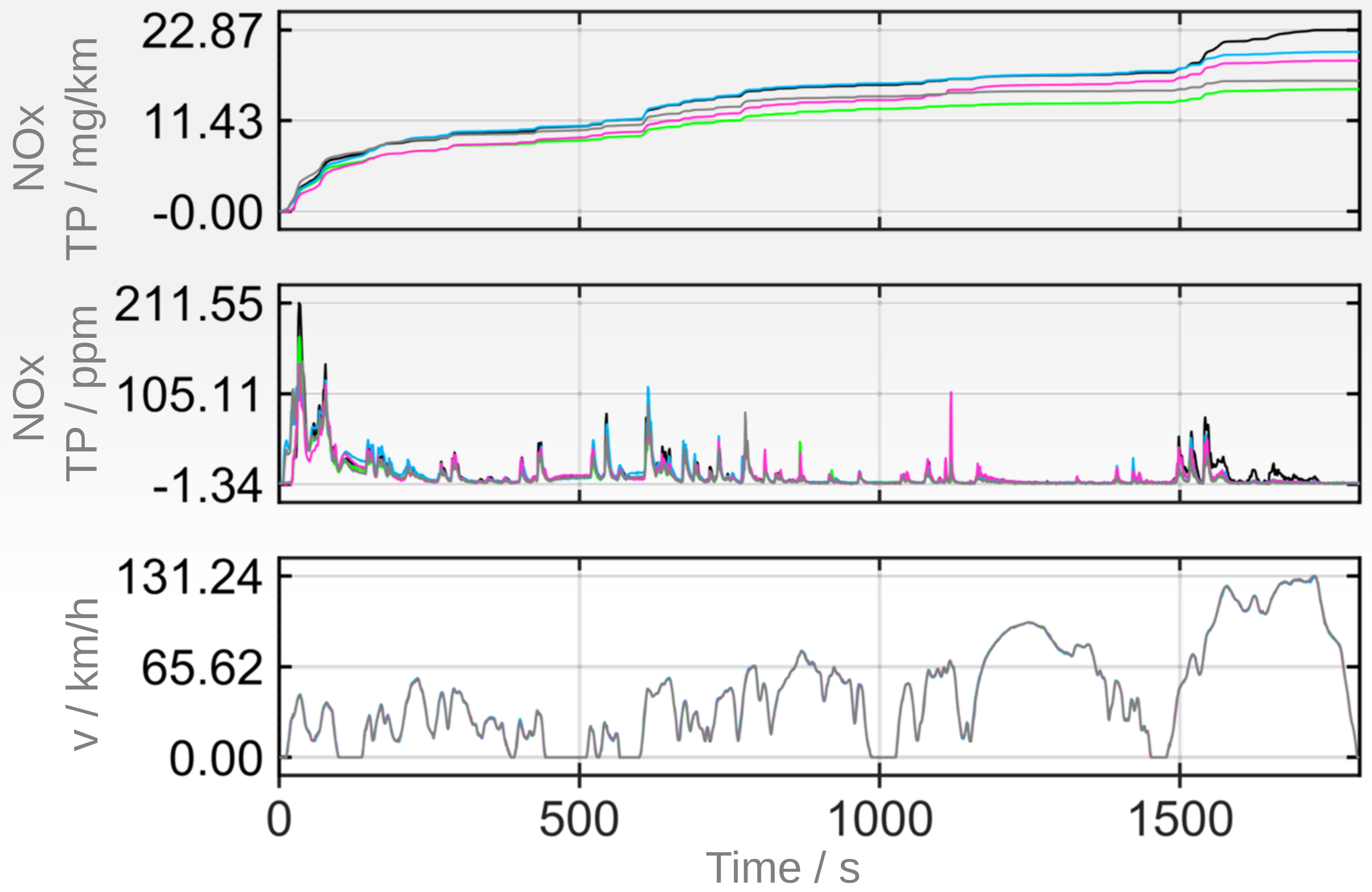
Task C2: Vehicle B – B0, B30, R51, B10, R33, data



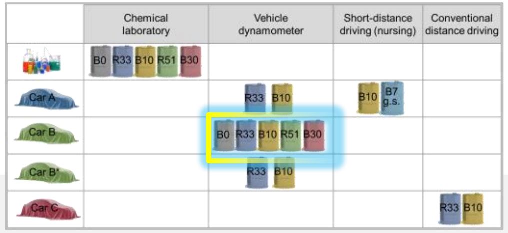
Description

- B0 shows slightly higher NOx emissions
- R33 and B30 show best NOx emissions

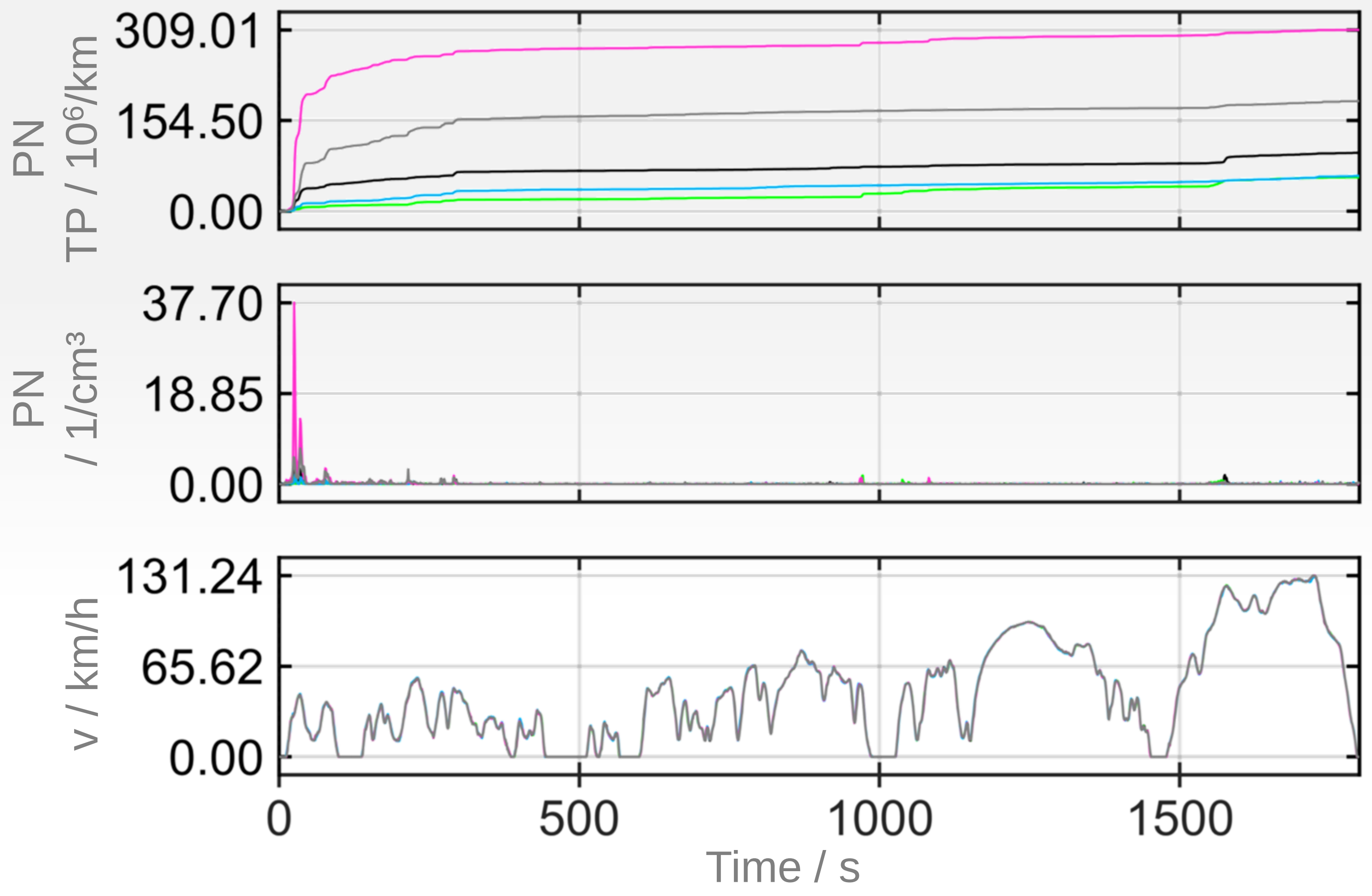
- Vehicle B B0: 20,9 mg/km
- Vehicle B B30: 16,9 mg/km
- Vehicle B R51: 18,7 mg/km
- Vehicle B B10: 18,1 mg/km
- Vehicle B R33: 16,7 mg/km
- Limit: 60 mg/km

B_B0
B_B30
B_R51
B_B10
B_R33

Representative tests chosen by CO2
Nox: nitrogen oxids (NO1 + NO2)



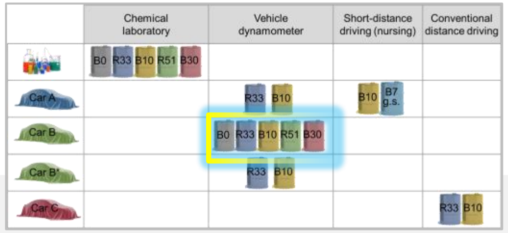
Task C2: Vehicle B – B0, B30, R51, B10, R33, data



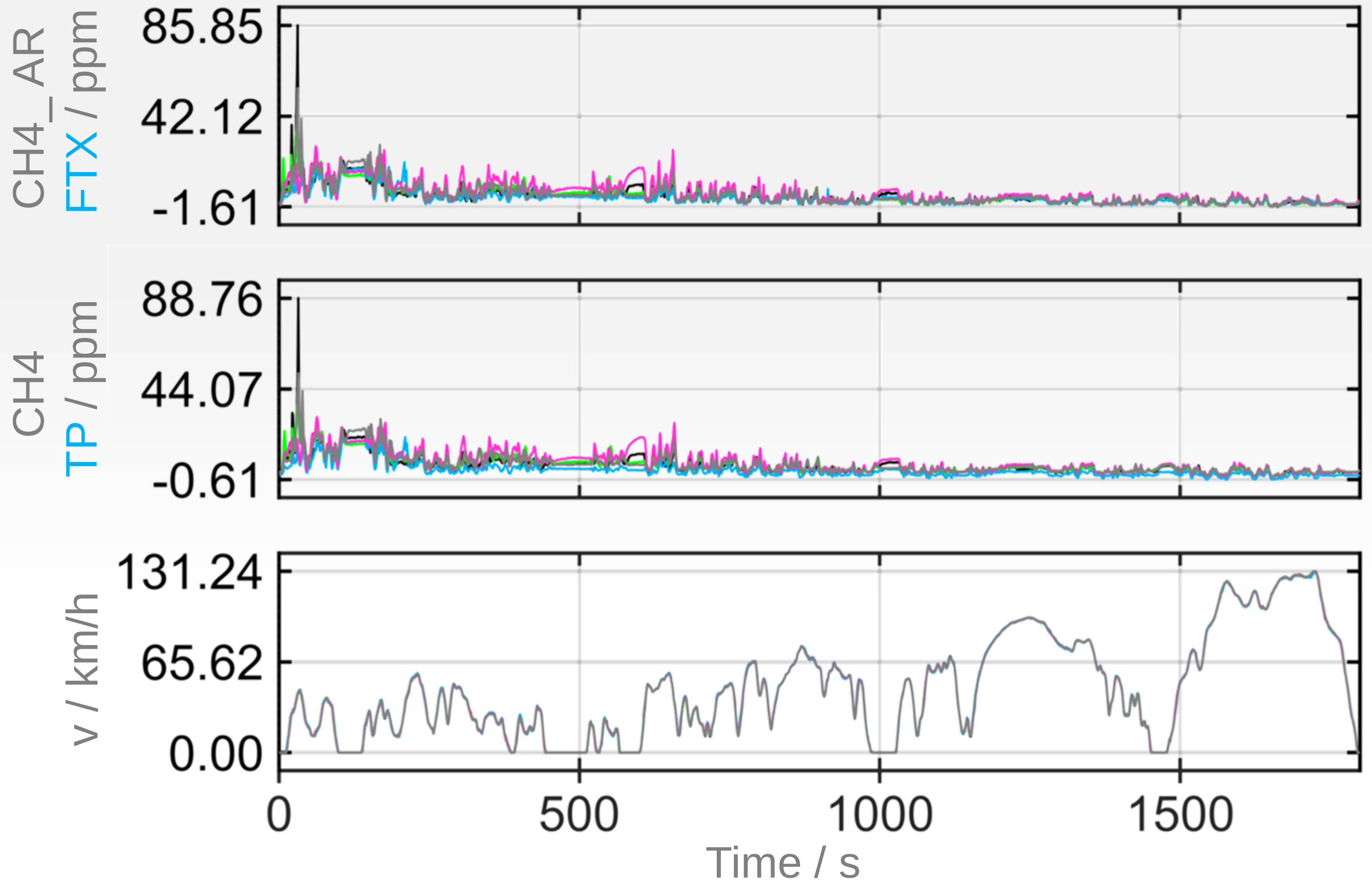
Description

- B10 and R33 show the highest PN emissions
- R51 and B30 show a minor benefits with PN emissions

- Vehicle B B0: $9*10^7$ /km
- Vehicle B B30: $6*10^7$ /km
- Vehicle B R51: $6*10^7$ /km
- Vehicle B B10: $3*10^8$ /km
- Vehicle B R33: $2*10^8$ /km
- Limit: $6*10^{11}$ /km

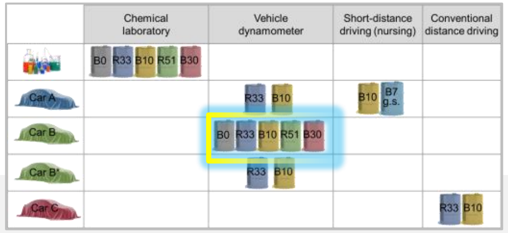


Task C2: Vehicle B – B0, B30, R51, B10, R33, data

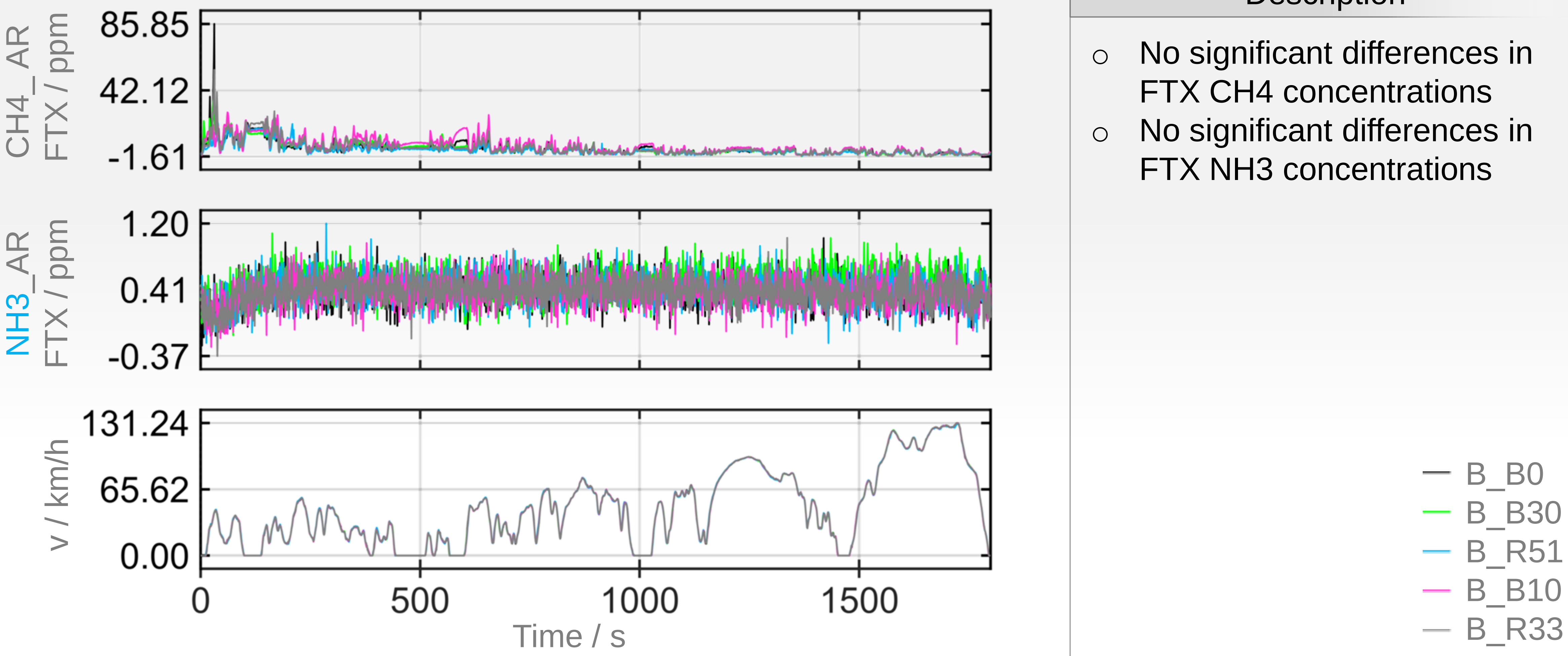


Description

- Tests also performed with FTX emission analysis
- CH4 detection of FTX and tailpipe nearly identical

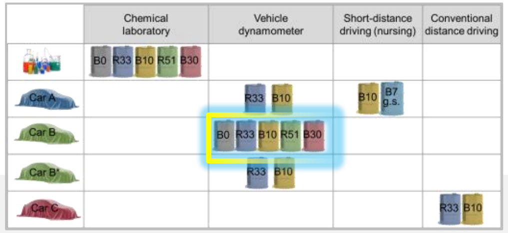


Task C2: Vehicle B – B0, B30, R51, B10, R33, data

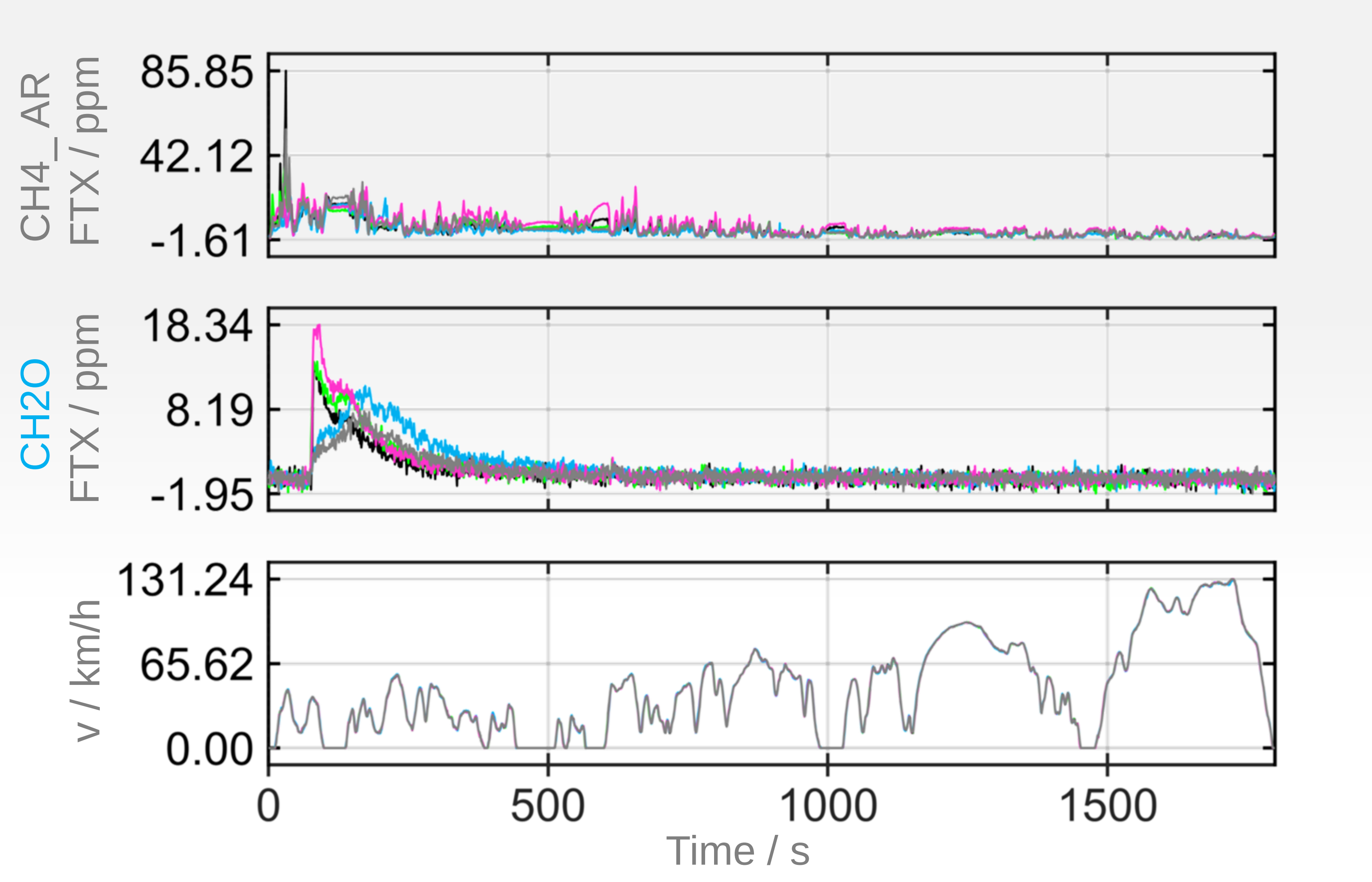


Description

- No significant differences in FTX CH4 concentrations
- No significant differences in FTX NH3 concentrations

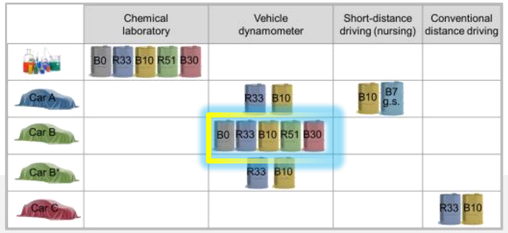


Task C2: Vehicle B – B0, B30, R51, B10, R33, data

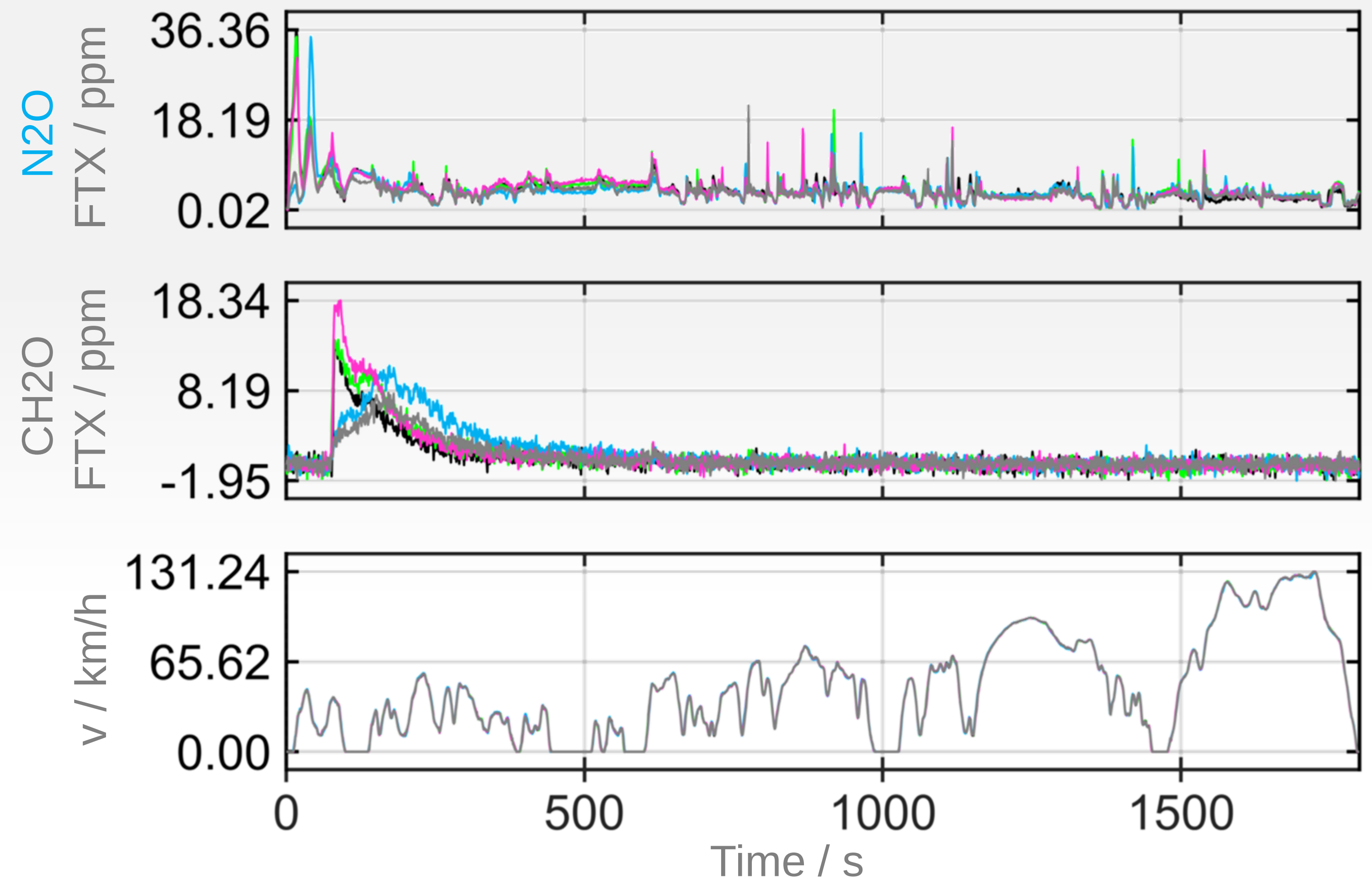


Description

- No significant differences in FTX CH4 concentrations
- Minor CH2O emissions, which decrease after catalyst light-off



Task C2: Vehicle B – B0, B30, R51, B10, R33, data



Description

- Minor N2O emissions on low concentrations with all fuels
- Minor CH2O emissions, which decrease after catalyst light-off

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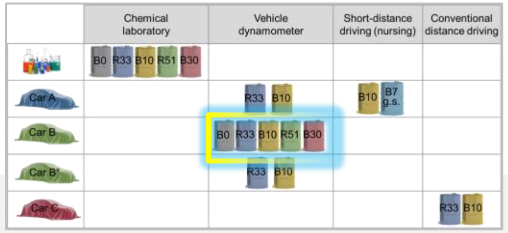

Vehicle B meets all limits with all tested fuels

Task C2: Vehicle B – B0, B30, R51, B10, R33, data

Overview – Bag results

BENTE Vehicle B	CO2 (g/km)	CO (mg/km)	THC (mg/km)	NOx (mg/km)	HC+NOx (mg/km)	CH4 (mg/km)	NMHC (mg/km)	NMHC+NOx (mg/km)	PN (#/km)	Fuel Cons. (l/100km)	Distance (km)	
B10	123,73	25,4	10,1	16,0	26,1	4,3	6,3	22,3	1,65E+08	4,7067	23,272	
B10	125,01	34,1	11,9	16,7	28,7	4,4	8,1	24,8	1,74E+08	4,7561	23,273	
B10	124,53	25,9	10,1	18,1	28,1	3,5	7,0	25,1	3,09E+08	4,7371	23,269	Representative
Average	**124,43**	**28,49**	**10,72**	**16,93**	**27,64**	**4,08**	**7,14**	**24,07**	**2,16E+08**	**4,73**	**23,27**	
R33	123,64	24,8	8,2	16,7	25,0	3,3	5,3	22,1	1,33E+08	4,7031	23,260	
R33	123,50	24,9	8,8	16,7	25,5	3,5	5,7	22,4	1,88E+08	4,6976	23,269	Representative
R33	123,18	24,7	8,0	17,3	25,3	3,1	5,3	22,5	1,38E+08	4,6852	23,261	
Average	**123,44**	**24,82**	**8,35**	**16,88**	**25,23**	**3,33**	**5,44**	**22,32**	**1,53E+08**	**4,70**	**23,26**	
B0	123,37	20,1	7,0	19,9	26,8	2,7	4,6	24,4	6,40E+08	4,6921	23,279	
B0	123,76	27,5	8,2	19,1	27,3	3,0	5,6	24,7	3,09E+08	4,7076	23,266	
B0	123,21	26,6	7,9	20,9	28,8	3,2	5,1	26,0	9,96E+07	4,6866	23,263	Representative
Average	**123,45**	**24,74**	**7,68**	**19,98**	**27,66**	**2,96**	**5,09**	**25,07**	**3,49E+08**	**4,70**	**23,27**	
R51	122,16	20,8	7,2	18,7	26,0	2,3	5,3	24,0	6,03E+07	4,7460	23,305	Representative
R51	122,82	23,7	7,3	18,0	25,4	2,7	5,0	23,0	1,07E+08	4,7717	23,269	
R51	121,03	15,6	5,3	16,5	21,8	2,5	3,1	19,6	3,81E+08	4,7015	23,305	
Average	**122,00**	**20,03**	**6,60**	**17,73**	**24,40**	**2,50**	**4,47**	**22,20**	**1,83E+08**	**4,74**	**23,29**	
B30	123,80	23,9	8,3	17,3	25,5	3,1	5,6	22,8	9,45E+07	4,7088	23,258	
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B30	125,47	24,3	7,4	17,3	24,7	2,8	5,0	22,3	8,97E+07	4,7722	23,279	
Average	**124,58**	**24,40**	**8,17**	**17,17**	**25,30**	**2,97**	**5,60**	**22,73**	**8,07E+07**	**4,74**	**23,27**	

Representative tests chosen by CO2

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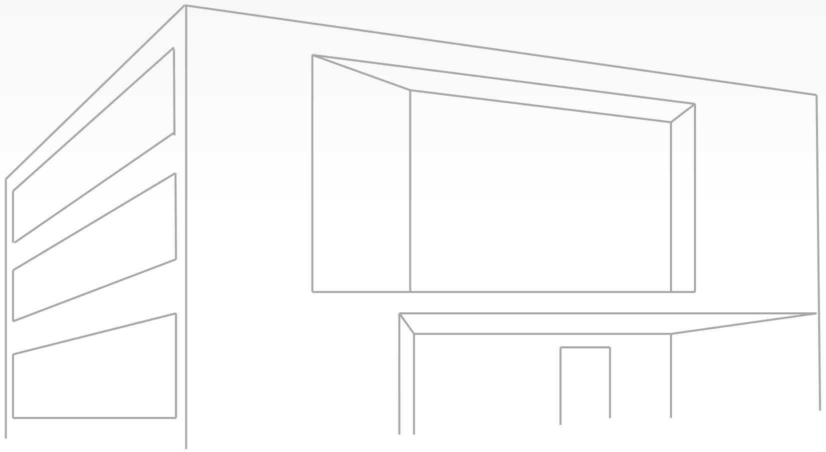
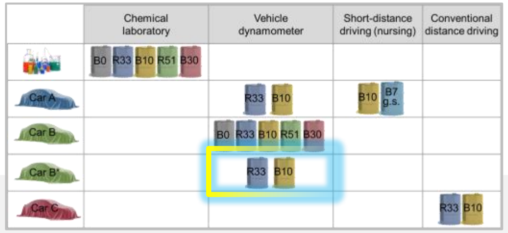
Agenda:

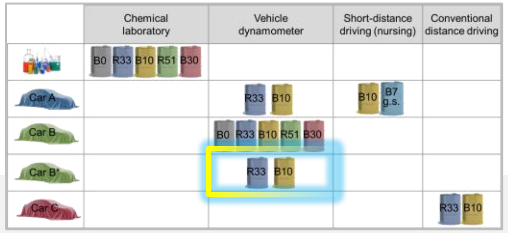
- Executive summary
- Theoretical introduction
- Methods and Materials
- Experimental results
  - Task A: Chemical analysis of fuels and oils
  - Task B: Reception of test vehicles
  - Task C: WLTC emission testing
  - Task D: WLTC oil dilution tests
  - Task E: Real-driving oil dilution testing
  - Task X: Thermodynamic raw-emissions
- Executive summary and outlook
- Acknowledgment
- Contact information





Task D2: Oil dilution tests

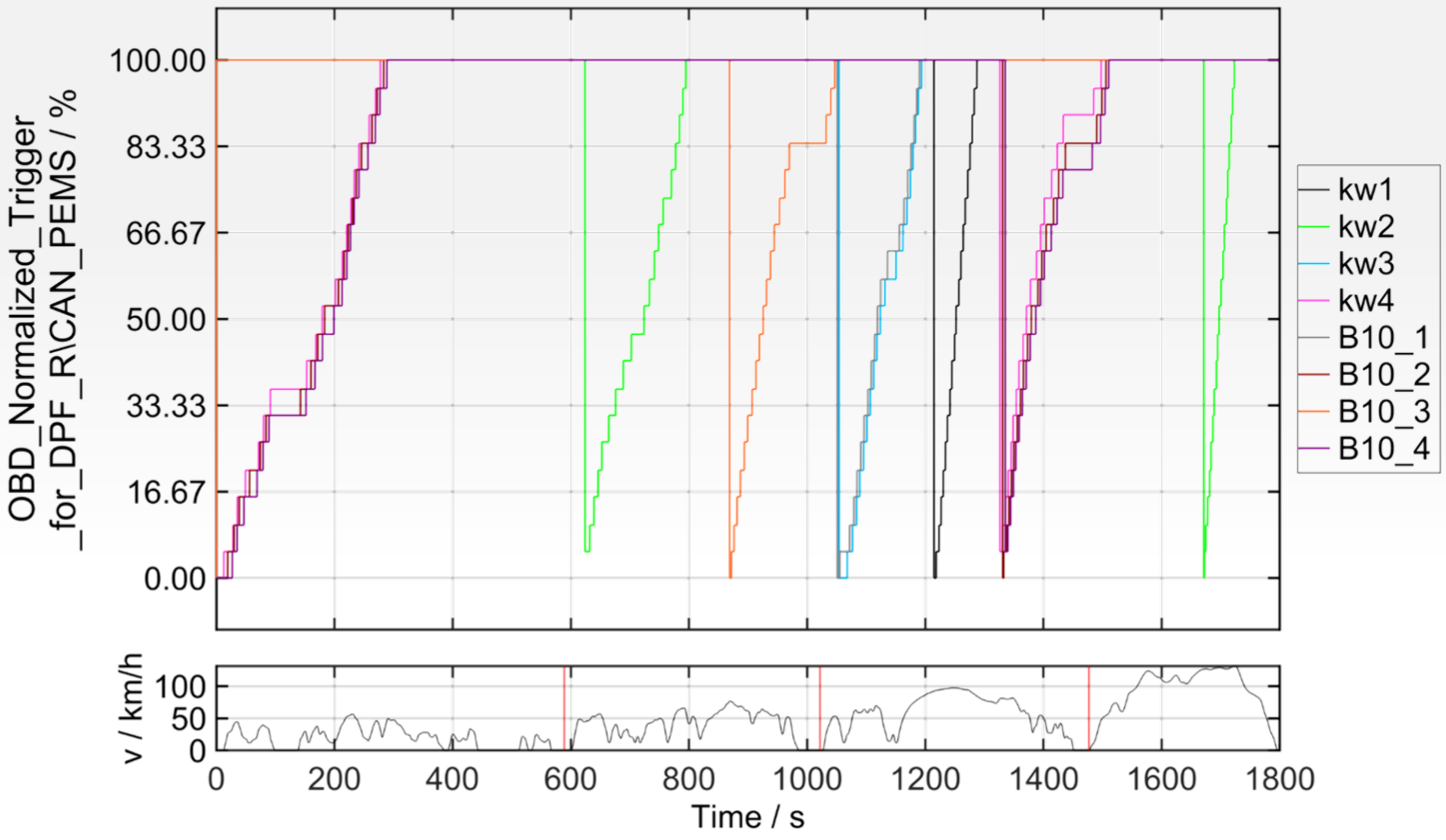
Illustration	Description
	○ The test-bench oil dilution tests are done at the vehicle chassis dynamometer with vehicle B equipped with an adapted ECU for continuous DPF regeneration. ○ There is a difference between the first and second oil dilution tests of each fuel. ○ However, the recorded data provides no indication for a changed vehicle operation



Task D2: Oil dilution tests – B10 (First run, Trigger, 1/2)

B10 - R33 - R33 - B10

Illustration



Description

- The following diagrams show
  - the trigger signal for DPF regeneration (OBD record)
  - the temperatures with the oxidation cat (CAN record)
  - the temperatures with the particle filter (CAN record)
- All signals show reproducible operation with the DPF regeneration mode
- No OBD on last day (B10/2)
- No CAN on B10/1 day 2&3
- CAN shows Reg. on last day

OBD: onboard diagnostics, CAN: controller area network,
DPF: diesel particle filter, PEMS: portable emission measurement system

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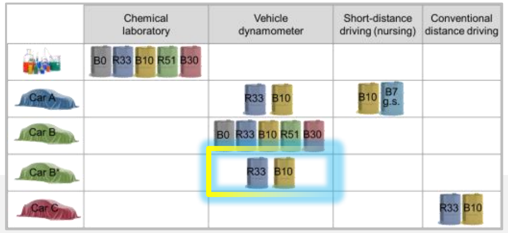
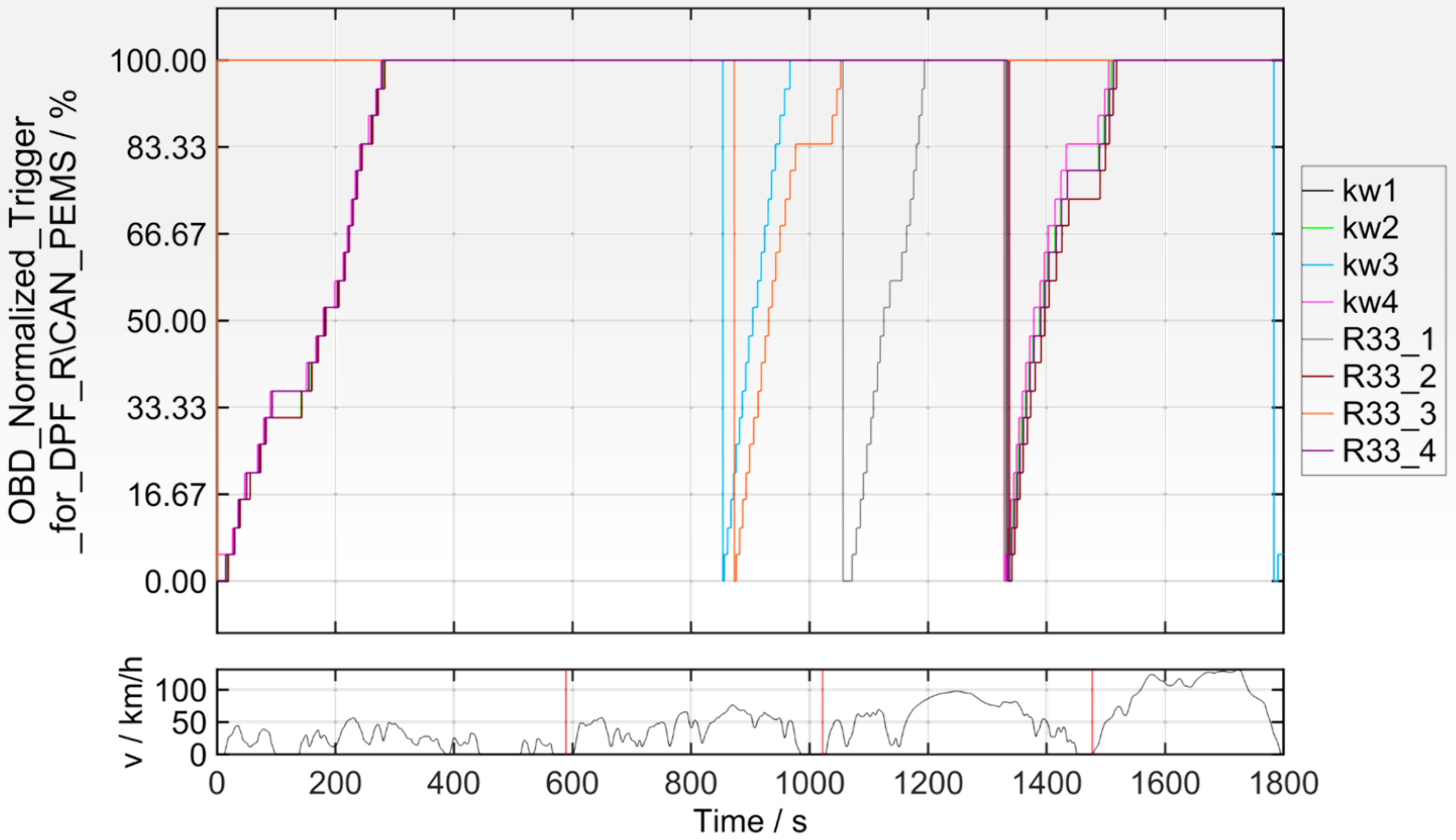


Task D2: Oil dilution tests – R33 (First run, Trigger, 1/2)

B10 - R33 - R33 - B10

Illustration



Description

- The following diagrams show
  - the trigger signal for DPF regeneration (OBD record)
  - the temperatures with the oxidation cat (CAN record)
  - the temperatures with the particle filter (CAN record)
- All signals show reproducible operation with the DPF regeneration mode
- No OBD on last day (B10/2)
- No CAN on B10/1 day 2&3
- CAN shows Reg. on last day

OBD: onboard diagnostics, CAN: controller area network,
DPF: diesel particle filter, PEMS: portable emission measurement system

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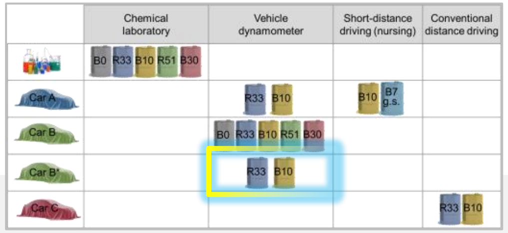


Task D2: Oil dilution tests

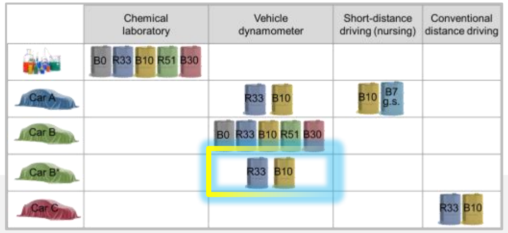
B10 - R33 - R33 - B10

Illustration

	B10	R33	R33	B10
Testday 1	✓	✓	✓	✓
Testday 2	✓	✓	✓	✓
Testday 3	✓	✓	✓	✓
Fuel-change day	✓	✓	✓	✓
Samples taken	7	7	7	7
Starting oil-mass	3531 g	3533 g	3532 g	3531 g
Scavenged oil-mass	3518,59 g	3526,06 g	3452,58 g	3500,14 g
Oil mass in Filter	188,96 g	190,39 g	190,23 g	189,76 g
Total final oil-mass	3707,55	3716,45 g	3642,81 g	3689,9 g
Delta oil-mass	+ 176,55 g	+ 183,45 g	+ 110,81 g	+ 158,9 g

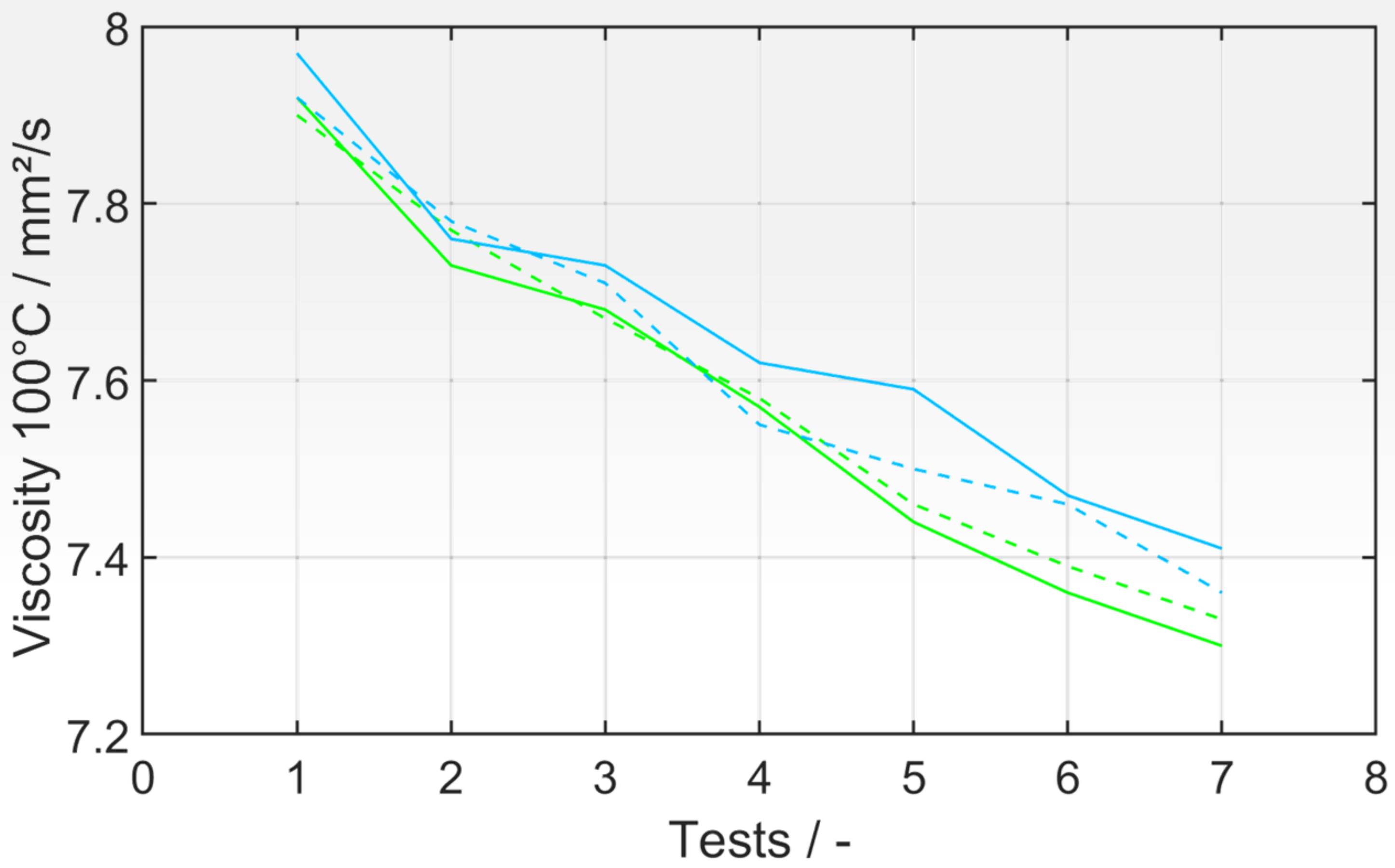
Description

- The oil dilution results are based on tests with vehicle B equipped with an adapted ECU for continuous DPF regeneration
- There is a difference between the first and second oil dilution tests of each fuel.
- However, the recorded data provides no indication for a changed vehicle operation



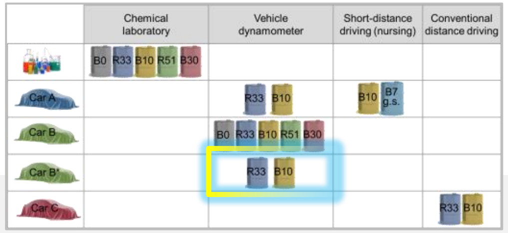
Task D2: ECU oil dilution analysis – results

Illustration



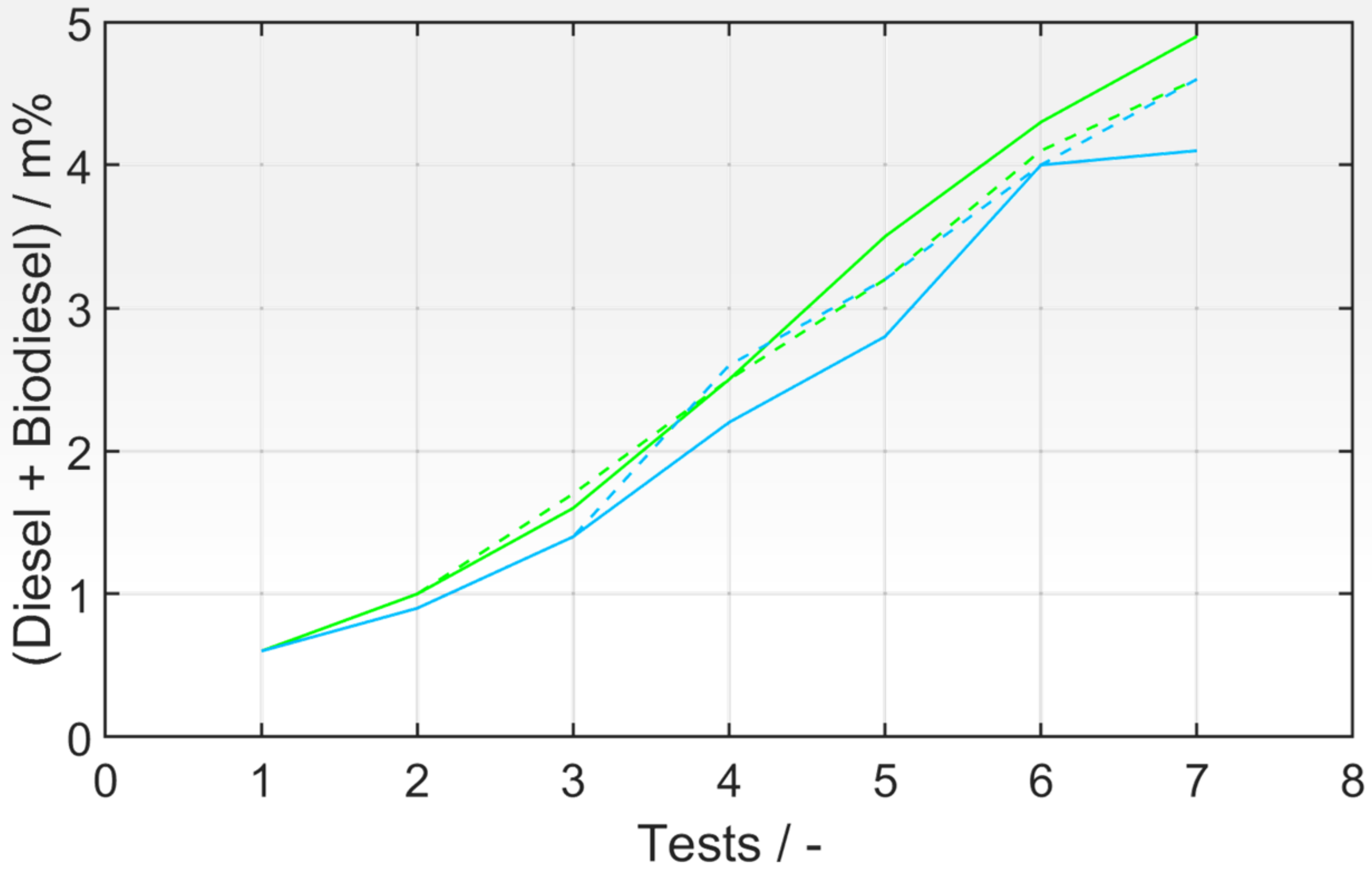
Description

- The viscosity data of the taken samples shows a continuous decrease of viscosity over the 7 samples taken during one oil dilution run.
- This result shows the viscosity effect of oil dilution outweighs the viscosity effect of oil aging, since the oil-fuel aging experiments show increasing viscosities with propagating accelerated aging in the chemical laboratory



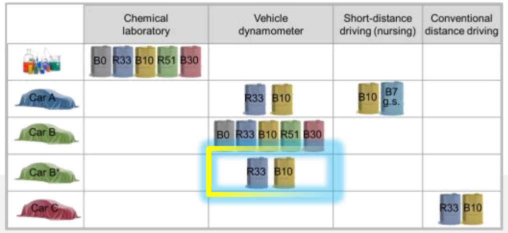
Task D2: ECU oil dilution analysis – results

Illustration



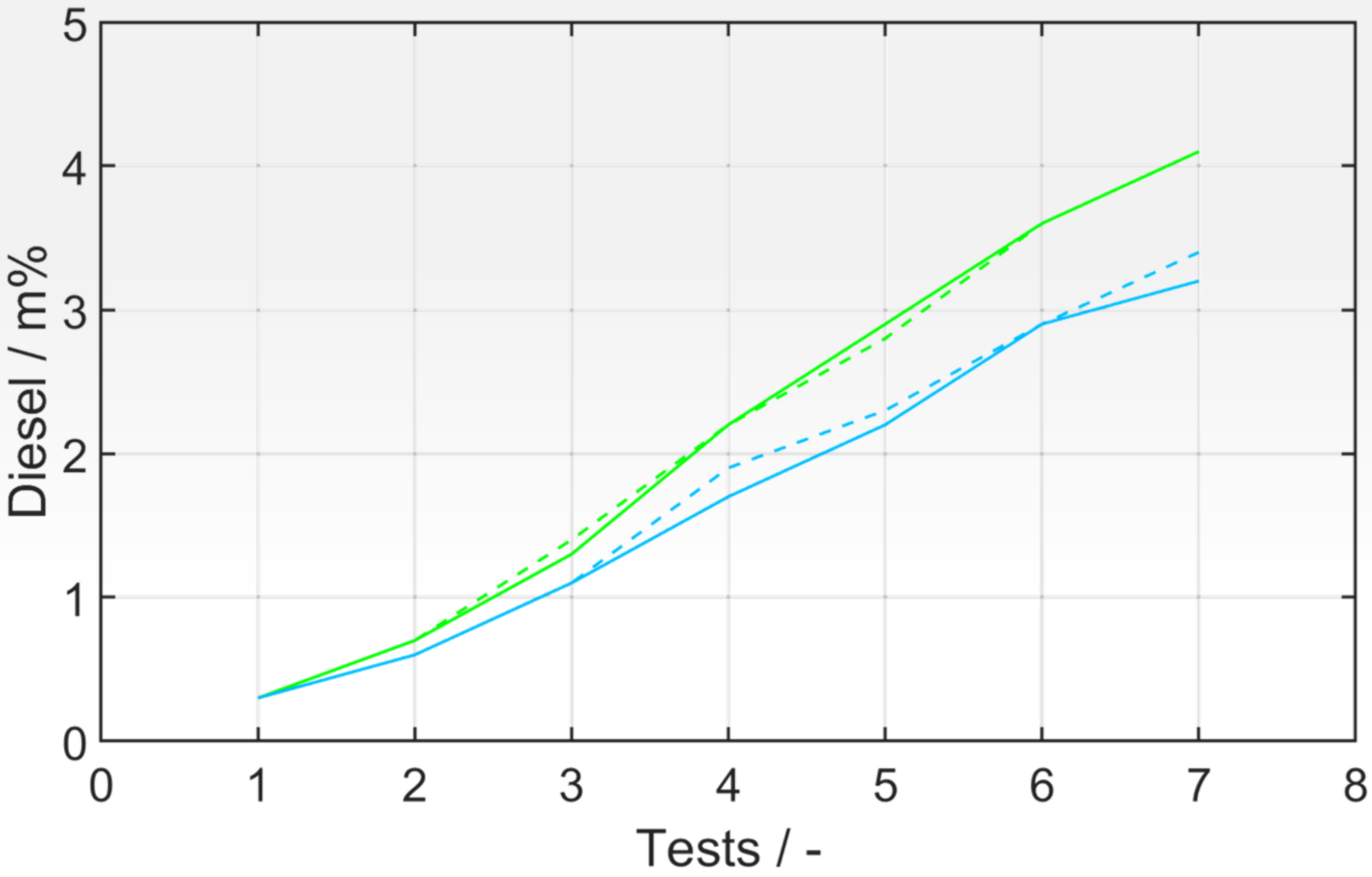
Description

- The total accumulated fuel mass of the taken samples shows a continuous increase during the oil dilution runs.
- This result shows the viscosity effect of oil dilution outweighs the viscosity effect of oil aging, since the oil-fuel aging experiments show increasing viscosities with propagating accelerated aging in the chemical laboratory



Task D2: ECU oil dilution analysis – results

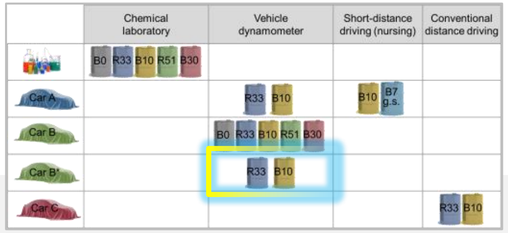
Illustration



Description

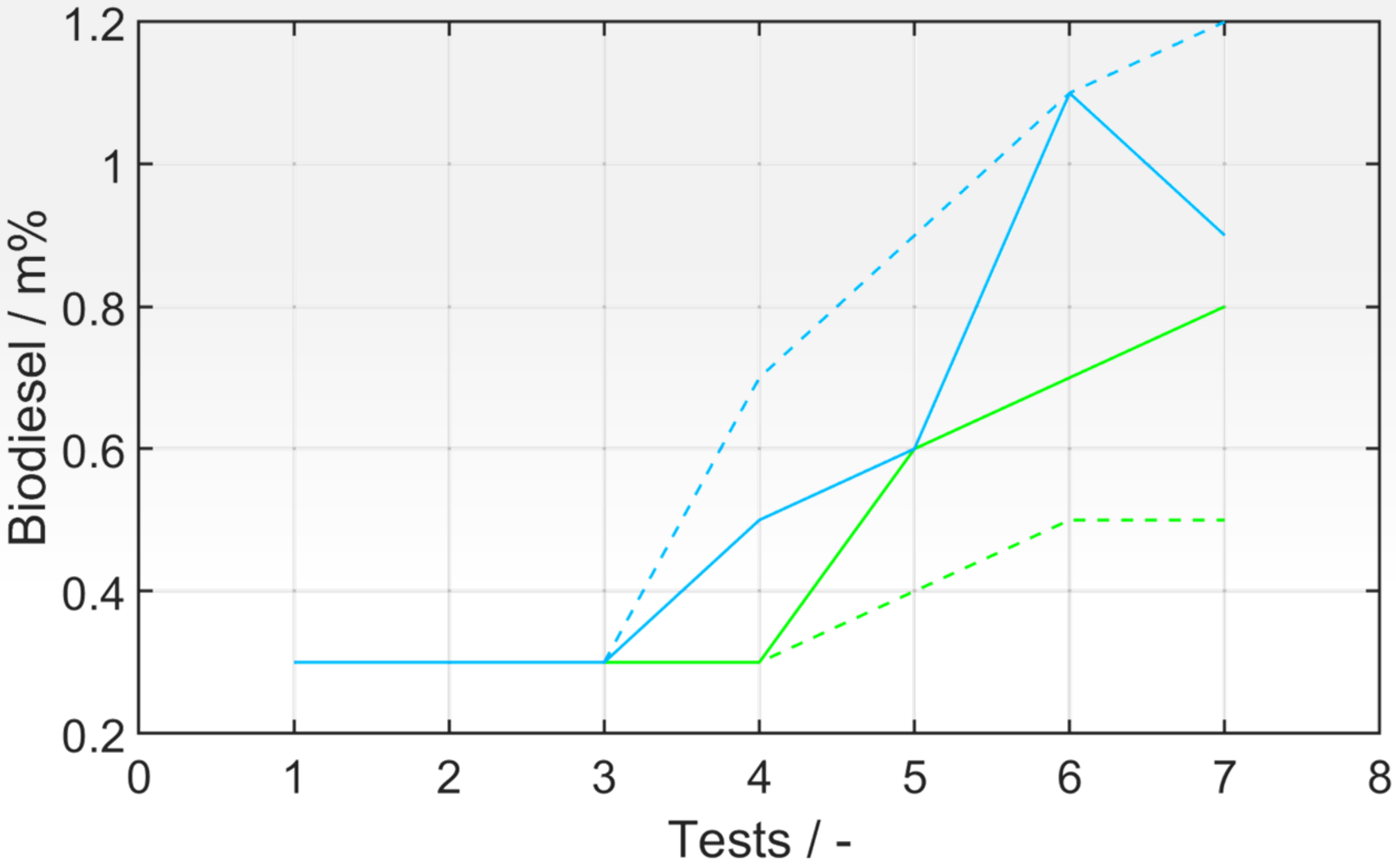
- The data of diesel content shows increasing diesel contents over the duration of the oil dilution tests.
- Here, the tests with R33 show higher masses of entrained diesel, despite of the point that Diesel R33 contains 67 vol% of fossil diesel, while B10 contains 90 vol%.

R33 run1 R33 run2
B10 run1 B10 run2



Task D2: ECU oil dilution analysis – results

Illustration



Description

- The data of the FAME content is influenced by two facts.

a) The system can only detect massfractions of > 0,3 m%. Thus, the first 3 values show the signal base-line

b) The B10_1_FAME values seem to have outliers.

- The data still shows that the content of Biodiesel oil dilution is larger with B10.

R33 run1 — R33 run2
B10 run1 — B10 run2

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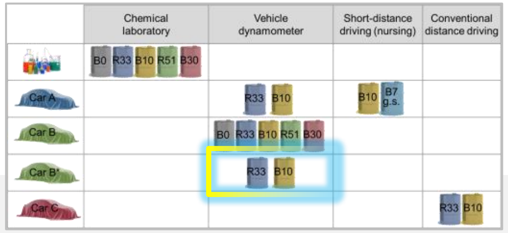
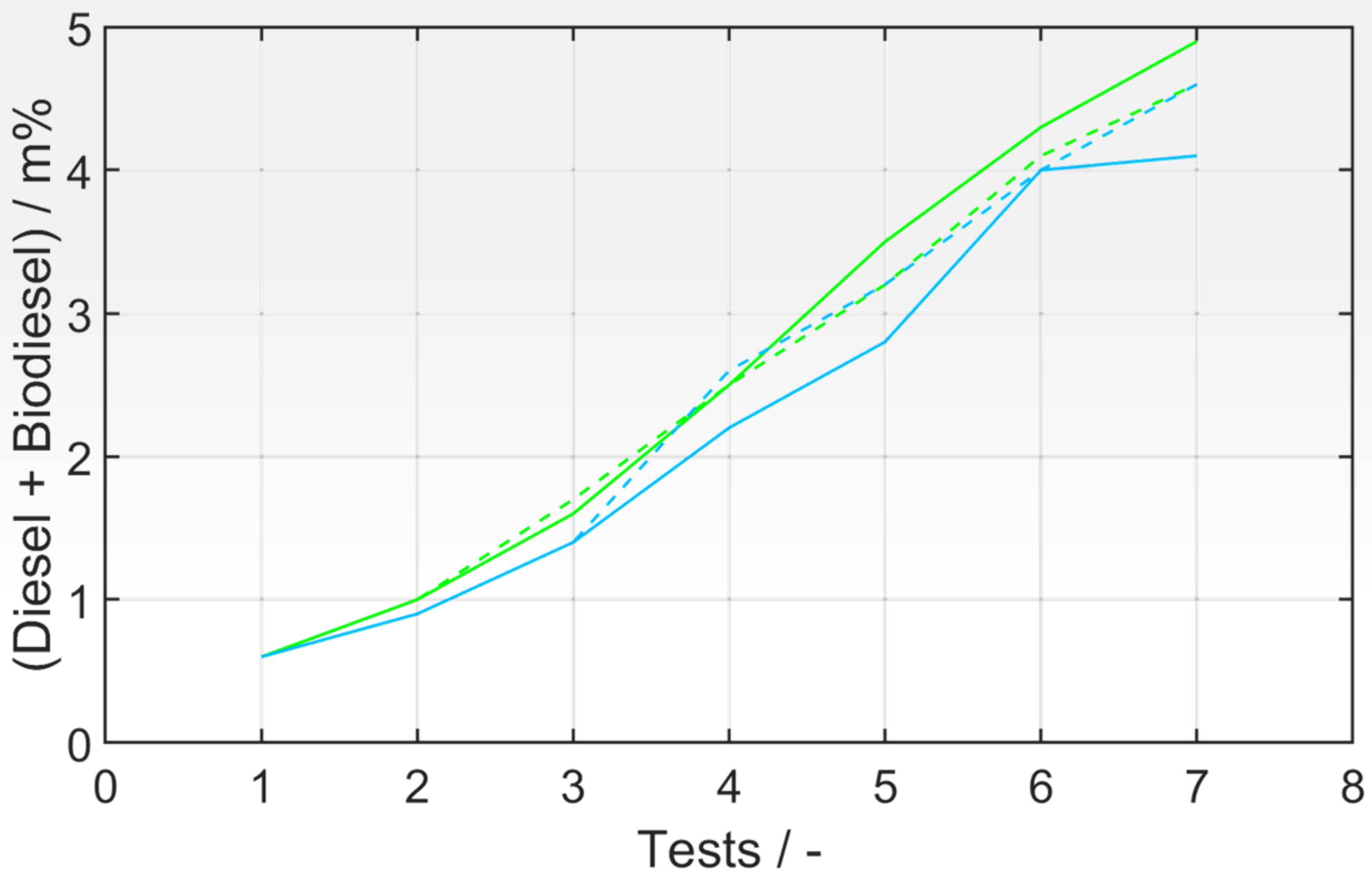
In total, the test-bench oil-dilution tests show slightly lower total oil dilutions during the operation with B10



Task D2: ECU oil dilution analysis – results

Illustration



Description

- The total accumulated fuel mass of the taken samples shows a continuous increase during the oil dilution runs.
- This result shows the viscosity effect of oil dilution outweighs the viscosity effect of oil aging, since the oil-fuel aging experiments show increasing viscosities with propagating accelerated aging in the chemical laboratory

Agenda:

- Executive summary
- Theoretical introduction
- Methods and Materials
- Experimental results
  - Task A: Chemical analysis of fuels and oils
  - Task B: Reception of test vehicles
  - Task C: WLTC emission testing
  - Task D: WLTC oil dilution tests
  - Task E: Real-driving oil dilution testing
  - Task X: Thermodynamic raw-emissions
- Executive summary and outlook
- Acknowledgment
- Contact information

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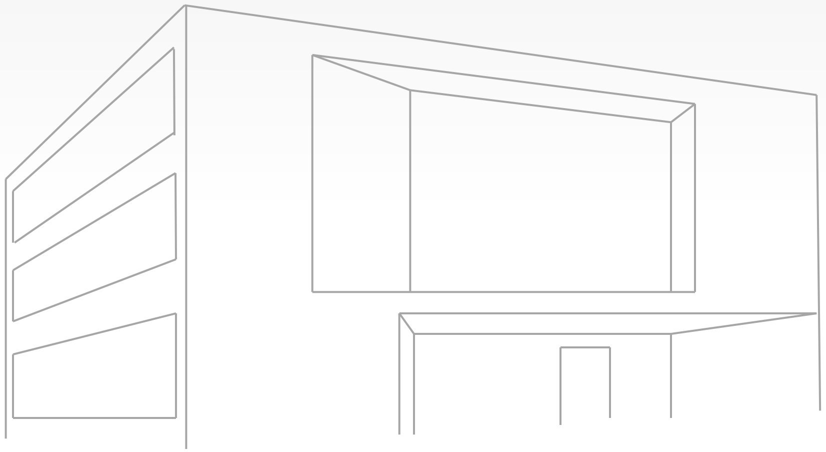
  - **Short-distance driving by AGQM**
  - Long-distance driving by VW
- Task X: Thermodynamic raw-emissions
- …



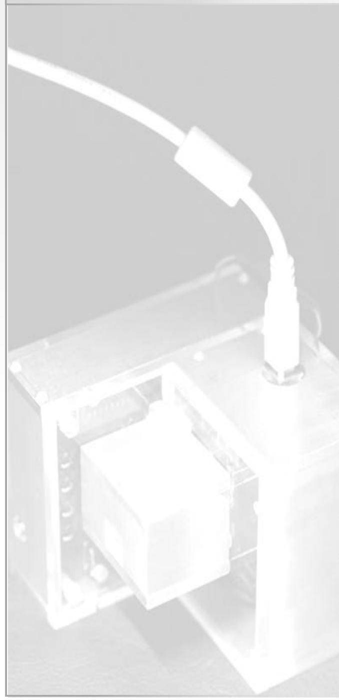
	Chemical laboratory	Vehicle dynamometer	Short-distance driving (nursing)	Conventional distance driving
	B0 R33 B10 R51 B30			
Car A		R33 B10	B10 B7 g.s.	
Car B		B0 R33 B10 R51 B30		
Car B'		R33 B10		
Car C				R33 B10

Fuel research at Coburg University

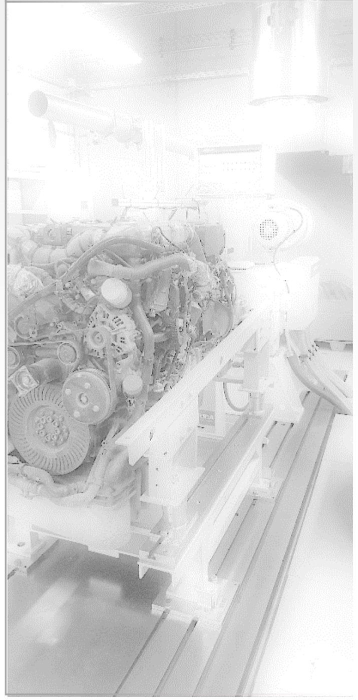
Fuel synthesis

Chemical laboratories

Sensor development



Multi-cylinder engine testing

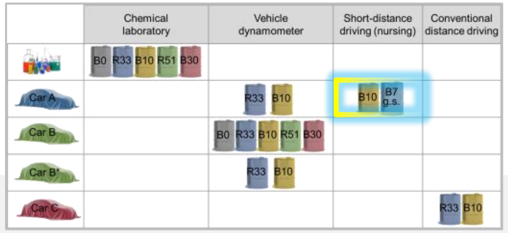


Vehicle dynamometer

Real-life test driving

Fuel fleet testing

Customer use



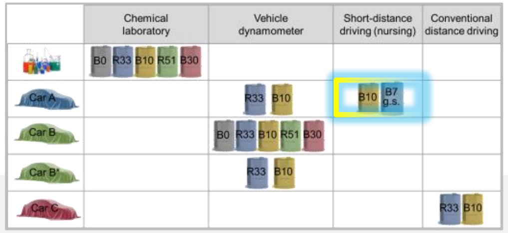
Methods and Materials – Test car: Vehicle A

Vehicle dynamometer	Illustration	Description

- Transmission: DQ381 (DSG/FWD)
- Emissioning: Euro 6d (EA288 EVO)
- Engine: 2.0l TDI SCR
    - 400 Nm @ 1750 - 3500 rpm
    - 147 kW @ 3500 - 4000 rpm
- Certified consumption:
    - 4,7 l/100 km
    - 124 g/km
- Used in task C and task E

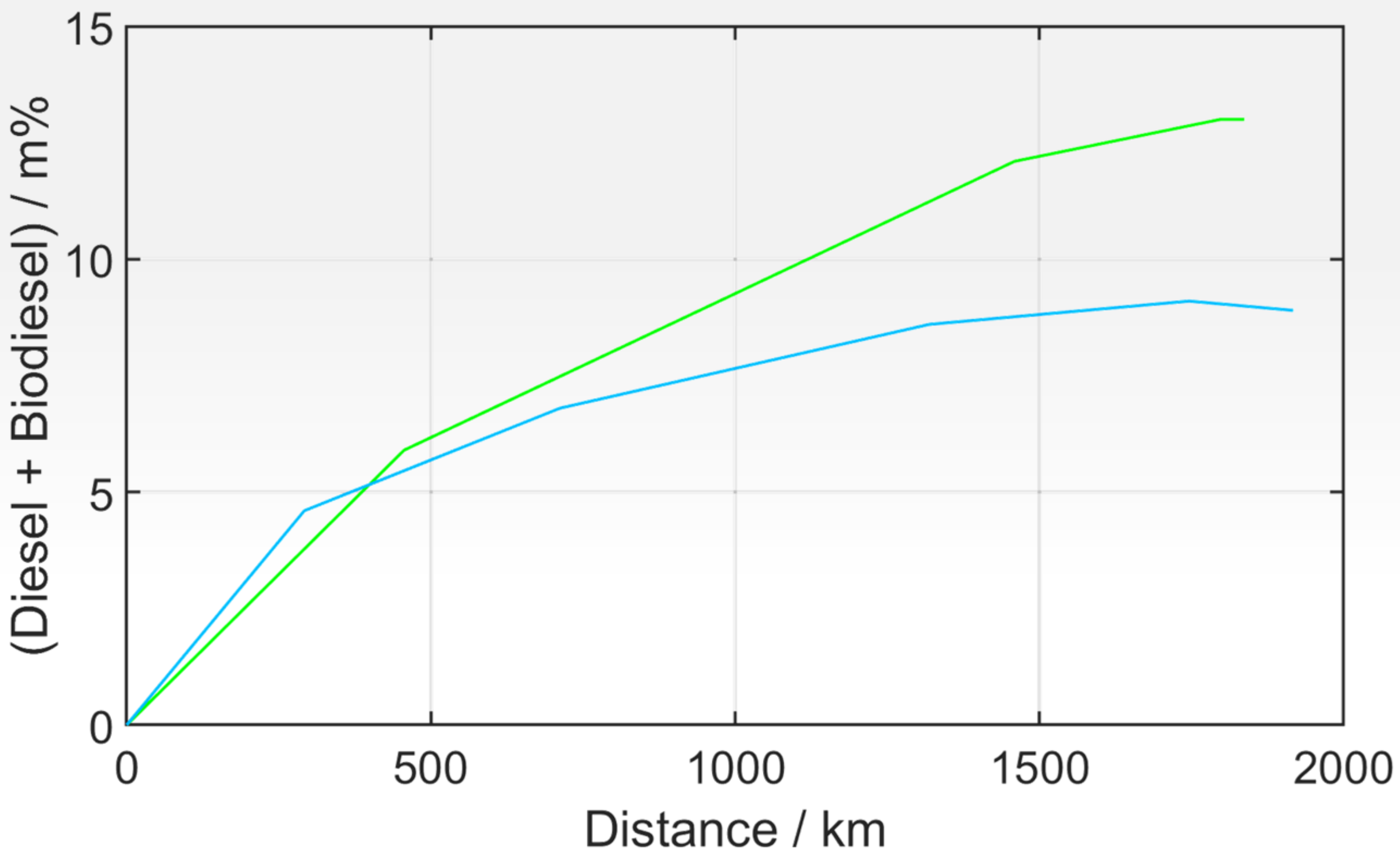
Data source: VW configurator
Date: 28.06.2024

In total, the oil-dilution with B10 in short-distance driving is slightly less present than the oil dilution with B7



Task E2: Short distance (sd) driving of vehicle A by AGQM

Illustration



Description

- The short-distance driving tests are done by nursery service running vehicle A with B7 from different public fuel stations and B10 for a total distance of ~ 2000 km each.
- The total mass of diesel and biodiesel oil dilution shows the higher oil dilution tendency of vehicle A during operation with B7.

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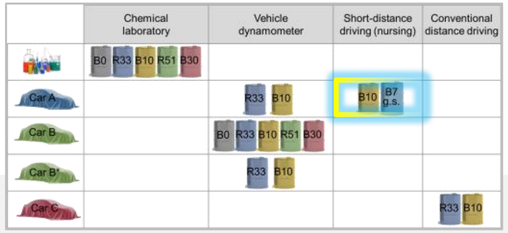
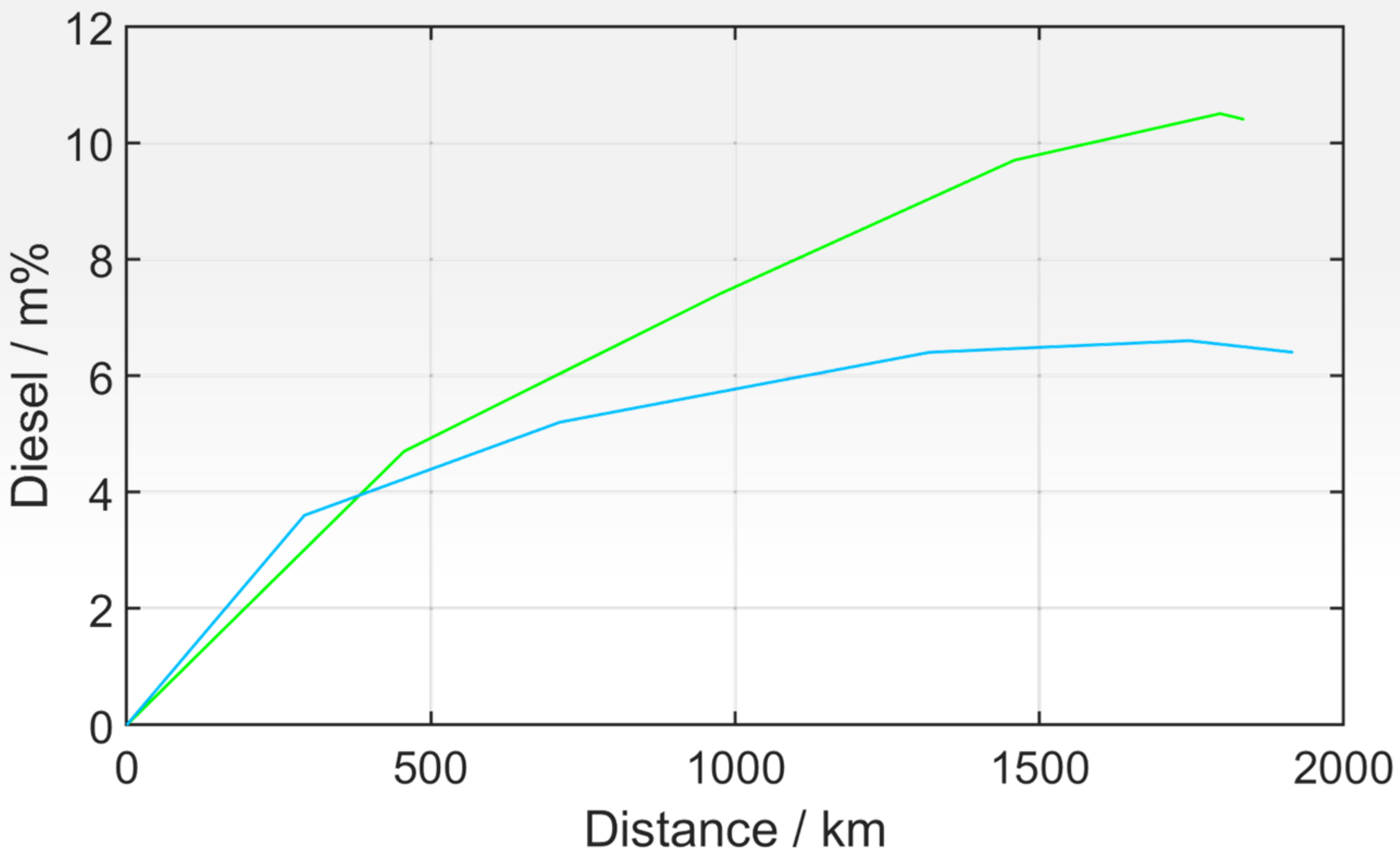


Task E2: Short distance (sd) driving of vehicle A by AGQM

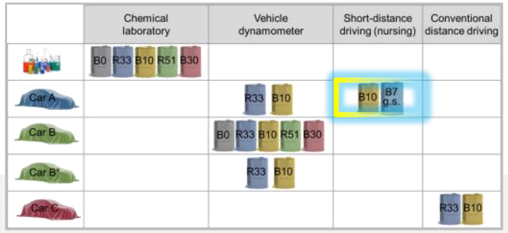
Illustration



Description

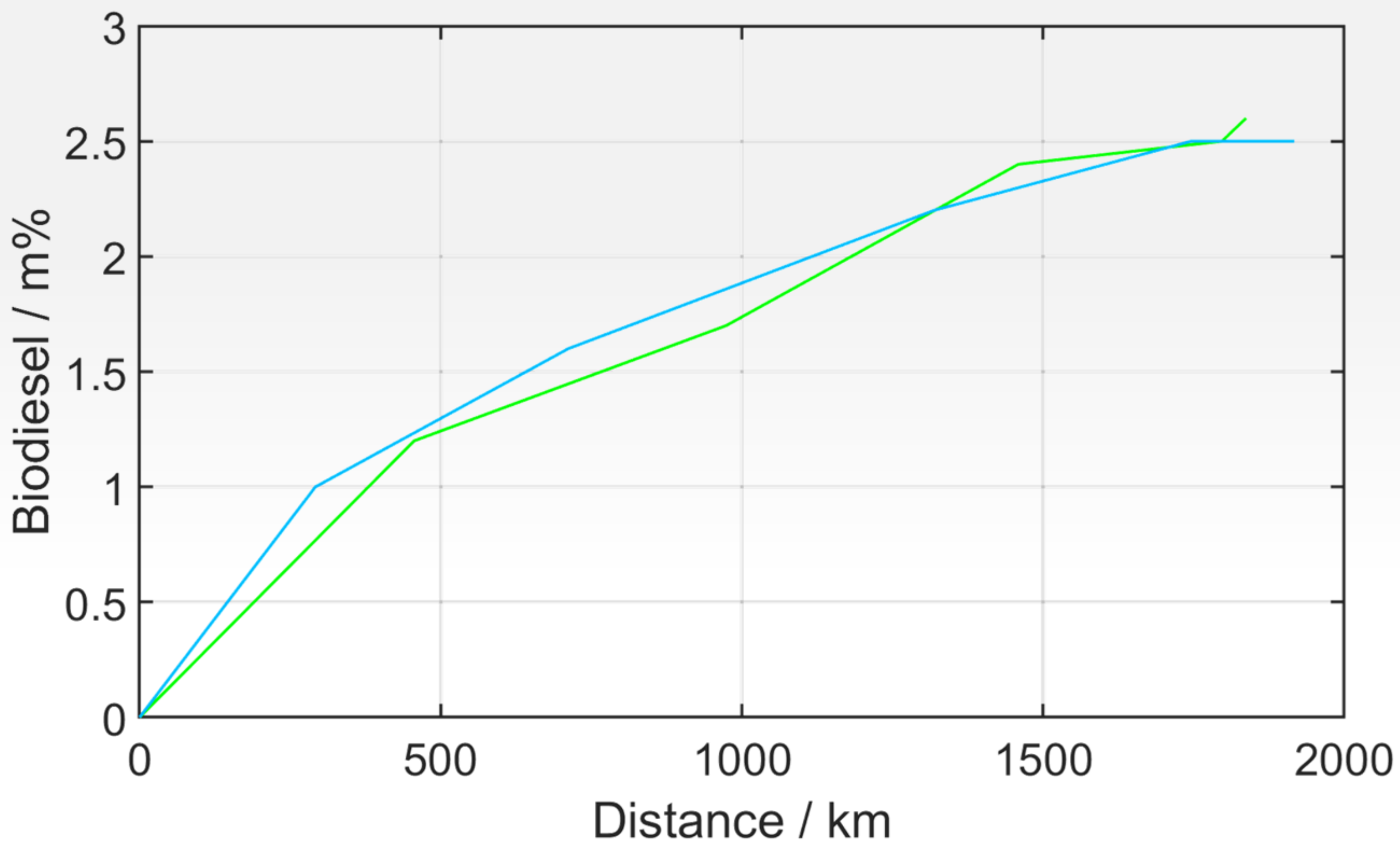
- The short-distance driving tests are done by nursery service running vehicle A with B7 from different public fuel stations and B10 for a total distance of ~ 2000 km each.
- The results show that the vehicle A has a stronger oil dilution caused by diesel fuel while operating with B7. Moreover, the vehicle didn't activate the MiL during the operation with B10.

MIL: malfunction indication lamp



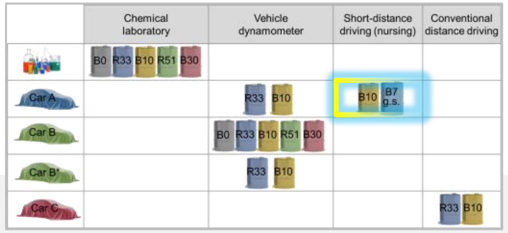
Task E2: Short distance (sd) driving of vehicle A by AGQM

Illustration

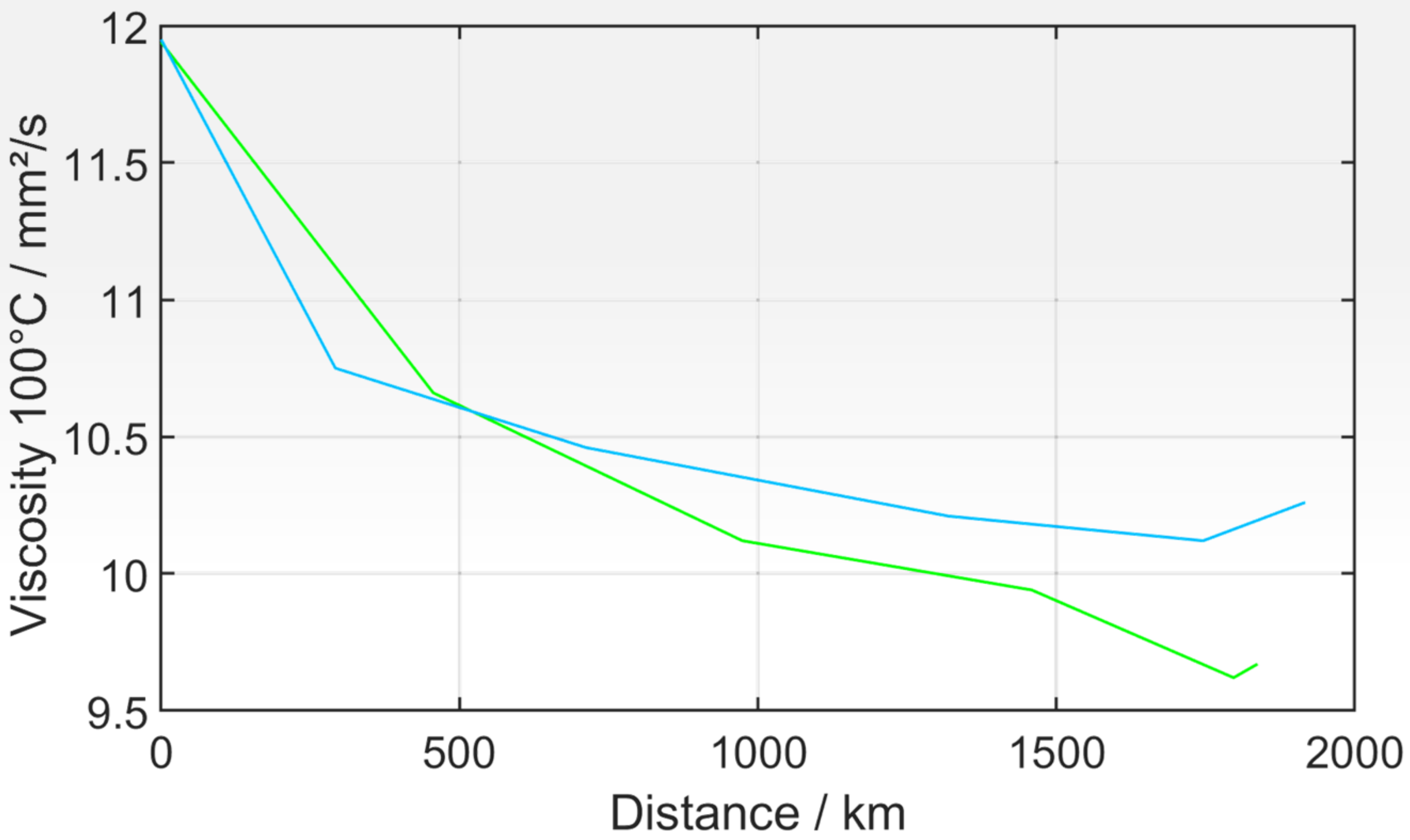


Description

- The short-distance driving tests are done by nursery service running vehicle A with B7 from different public fuel stations and B10 for a total distance of ~ 2000 km each.
- The total mass content of the oildilution caused by biodiesel is similar with B7 and B10, which could result from a balance between higher biodiesel content and lower oil dilution tendency.



Task E2: Short distance (sd) driving of vehicle A by AGQM

Illustration	Description
	○ The short-distance driving tests are done by nursery service running vehicle A with B7 from different public fuel stations and B10 for a total distance of ~ 2000 km each. ○ The overall oil dilution results in a decrease of the oil viscosity, which is on a comparable level for both tested fuels.

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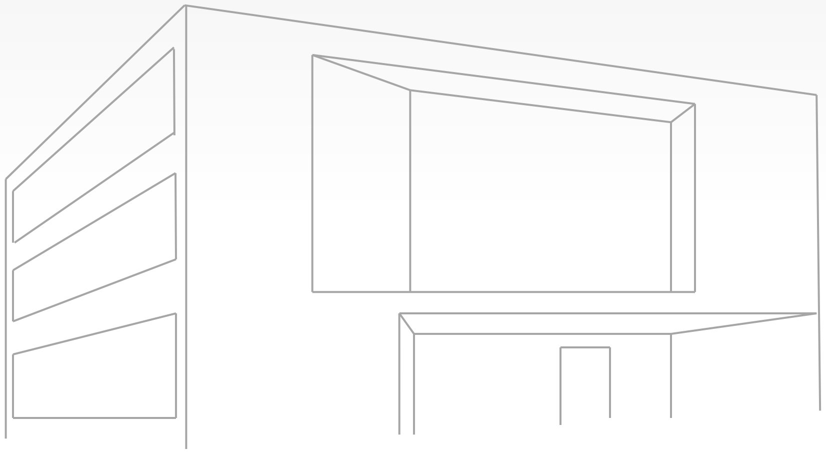
- Task E: Real-driving oil dilution testing
  - Short-distance driving by AGQM
  - Long-distance driving by VW
- Task X: Thermodynamic raw-emissions
- …

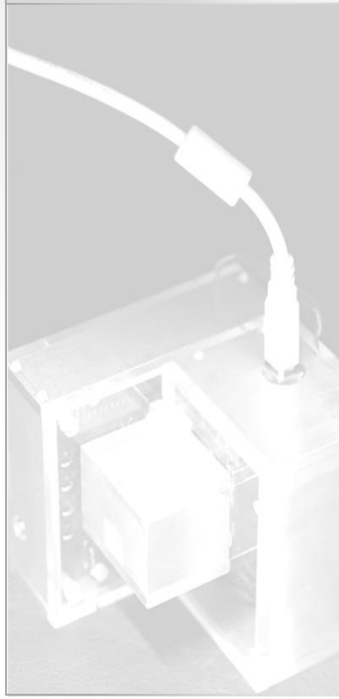
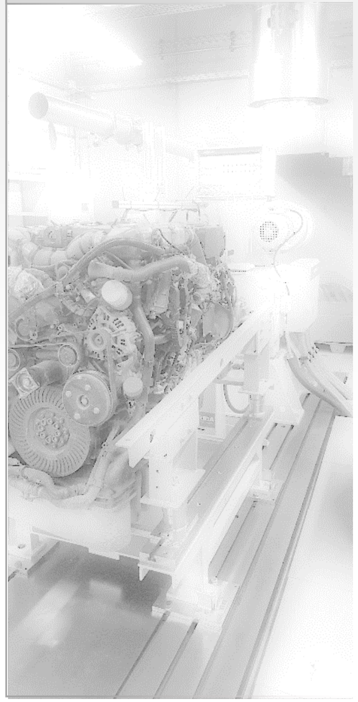


	Chemical laboratory	Vehicle dynamometer	Short-distance driving (nursing)	Conventional distance driving
	B0 R33 B10 R51 B30			
Car A		R33 B10	B10 B7 g.s.	
Car B		B0 R33 B10 R51 B30		
Car B'		R33 B10		
Car C				R33 B10

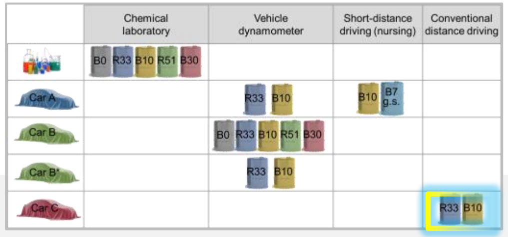
Fuel research at Coburg University

Fuel synthesis

Chemical laboratories	Sensor development	Multi-cylinder engine testing	Vehicle dynamometer	Real-life test driving	Fuel fleet testing

Customer use

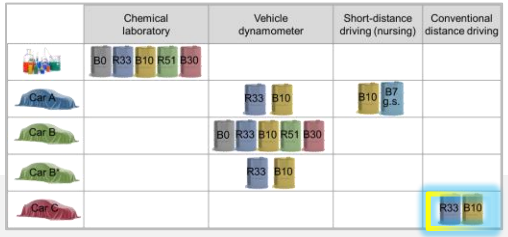


Methods and Materials – Test car: Vehicle C

Vehicle dynamometer	Illustration	Description

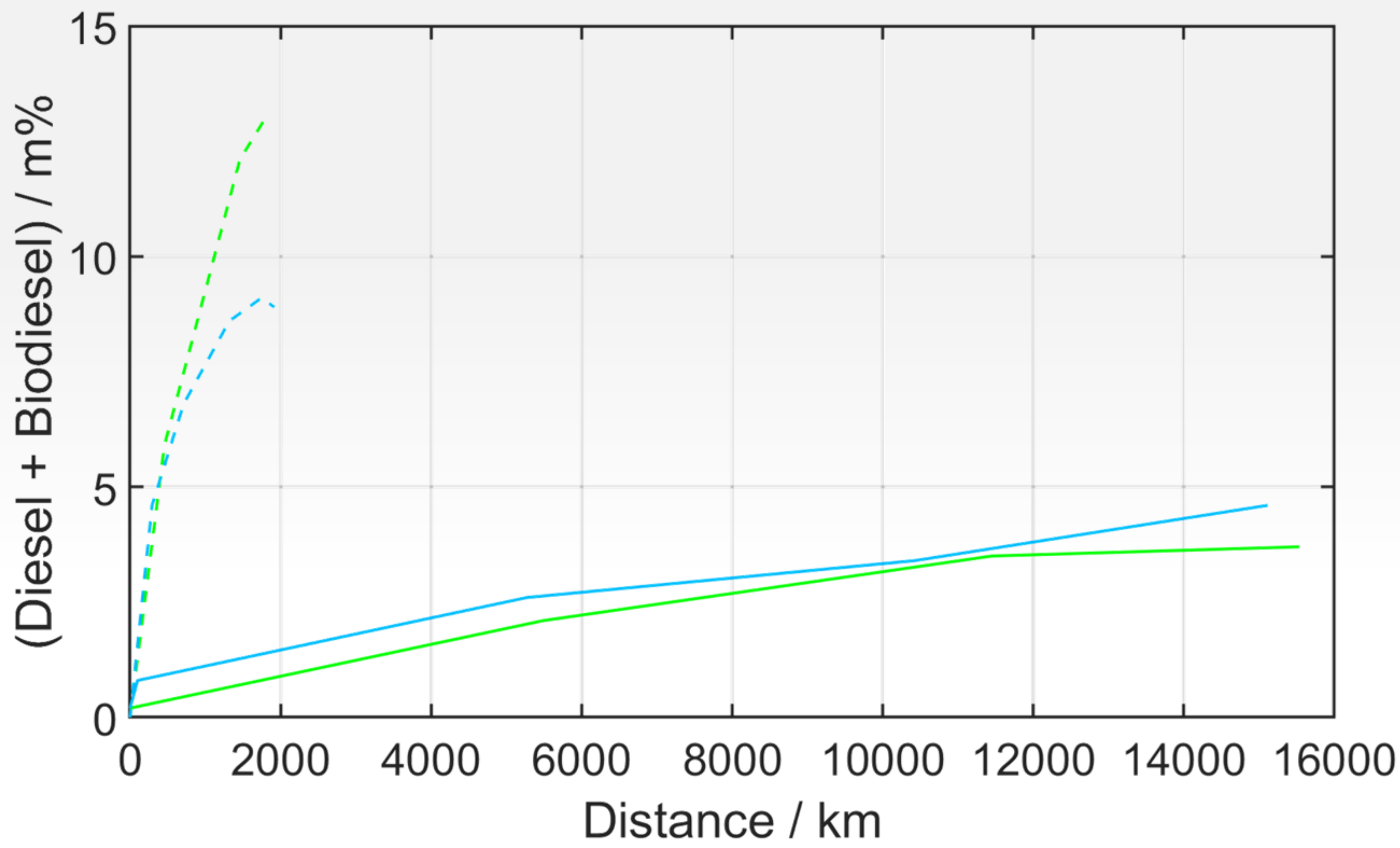
		○ Transmission: DQ381 (DSG/4WD)
		○ Emissioning: Euro 6d (EA288 EVO)
		○ Engine: 2.0l TDI SCR
		  ○ 400 Nm @ 1750 - 3500 rpm
		  ○ 147 kW @ 3500 - 4000 rpm
		○ Certified consumption:
		  ○ 4,7 l/100 km
		  ○ 124 g/km
		○ Used in task E

In total, the oil-dilution with B7 in long distance driving is slightly less present than the oil dilution with B10



Task E1: Long distance (ld) driving of vehicle C by VW

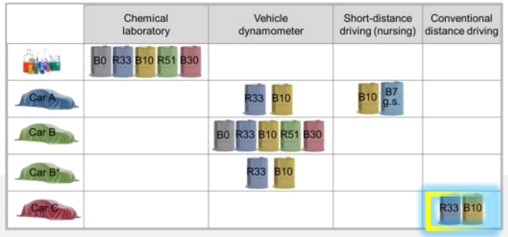
Illustration



Description

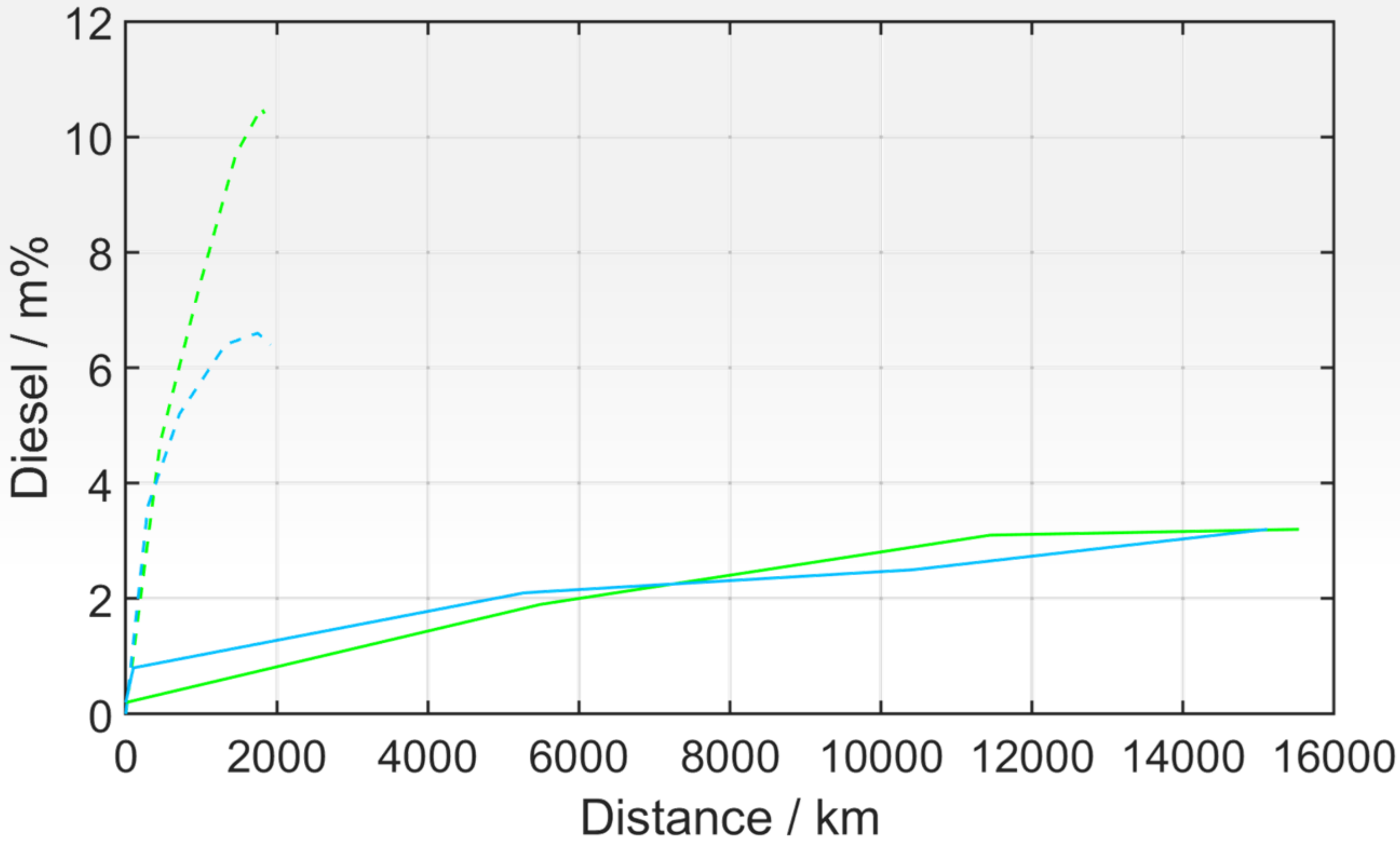
- The long-distance driving tests are done by VW with vehicle C using R33 from a public fuel station and B10 for 15.000 km each.
- The total amount of diesel and biodiesel oil dilution can be affected by an accumulation of biodiesel if the oil temperatures are still too low for biodiesel re-evaporation

A_sd_B7 C_ld_B7
A_sd_ B10 C_ld_ B10



Task E1: Long distance (ld) driving of vehicle C by VW

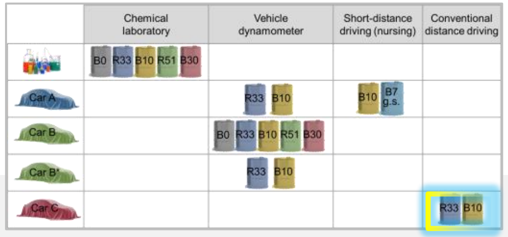
Illustration



Description

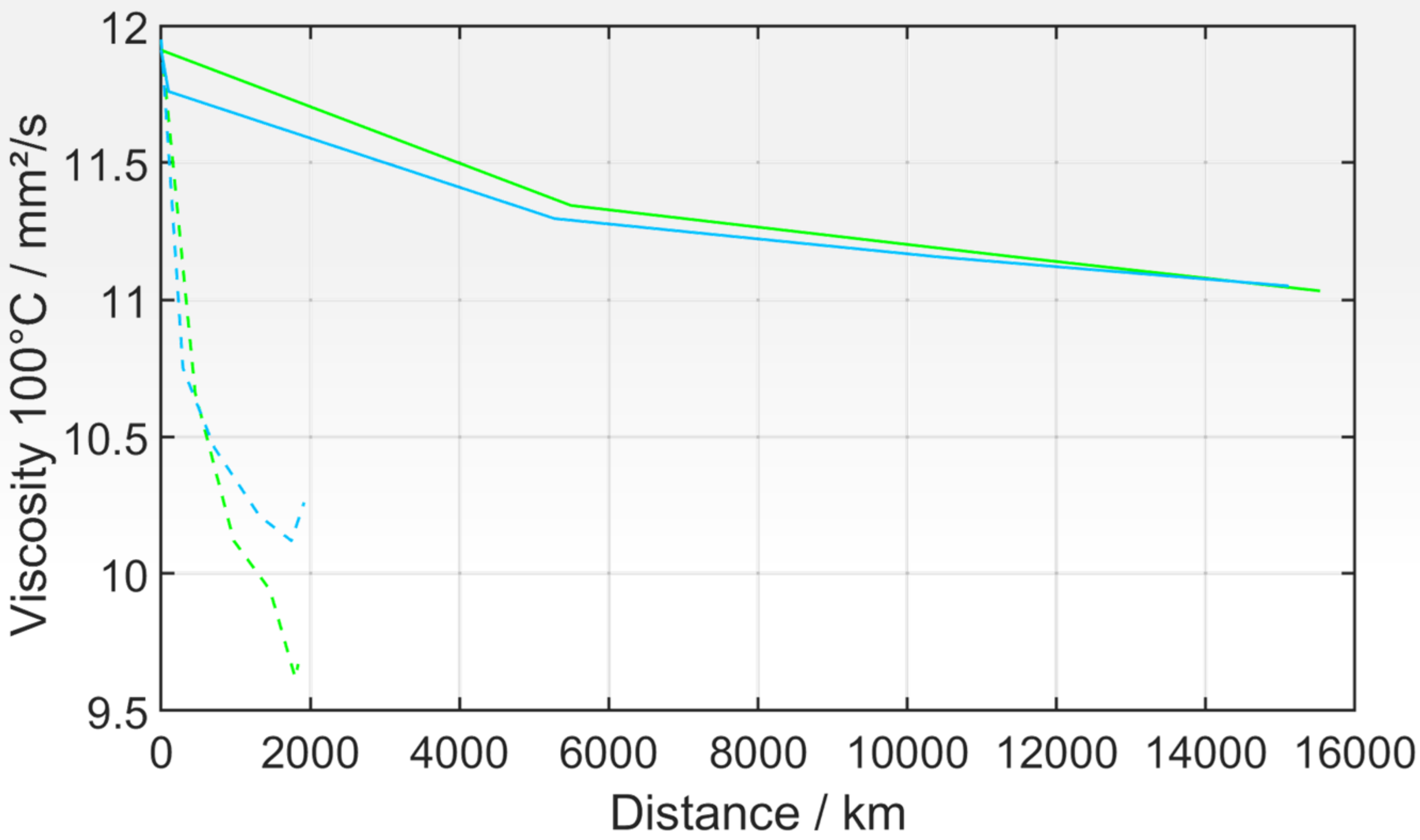
- The long-distance driving tests are done by VW with vehicle C using R33 from a public fuel station and B10 for 15.000 km each.
- This result is similar to the oil dilution tests of task D2. In both tasks, the difference in oil-diesel content might be affected by differences in the the fossil fraction of the tested B10 and B7 fuels

A_sd_B7 C_ld_B7
A_sd_ B10 C_ld_ B10



Task E1: Long distance (ld) driving of vehicle C by VW

Illustration



Description

- The long-distance driving tests are done by VW with vehicle C using R33 from a public fuel station and B10 for 15.000 km each.
- The overall oil dilution results in decreased viscosities during the long-distances tests, too. However, the overall decrease in viscosity is lower than the viscosity decrease in short-distance driving.

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- Task X: Thermodynamic raw-emissions

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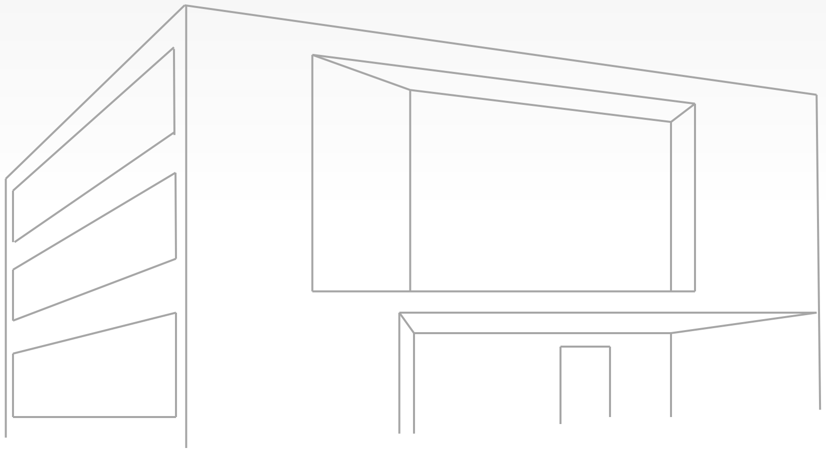
Acknowledgment

Contact information



Executive summary

Executive summary (1/8) - Overview

This project is focused on the investigation of properties and engine-oil dilution of drop-in capable partially regenerative diesel blends including varying shares of fatty acid methyl esters (FAME or biodiesel) and paraffinic diesel (here: hydrotreated vegetable oil - HVO).

Therefore, the project tested a variety of different fuel blends listed below.

B10
- 10 % FAME
- 90 % fossil fuel

Diesel R51
- 10 % FAME
- 41 % HVO
- 49 % fossil fuel

Diesel R33
- 7 % FAME
- 26 % HVO
- 67 % fossil fuel

B30
- 30 % FAME
- 70 % fossil fuel

B7 gas station
- 7 % FAME
- 93 % fossil fuel

B0 fossil fuel as reference fuel

FAME: fatty acid methyl ester
HVO: hydrotreated vegetable oil

Executive summary

Executive summary (2/8) – Fuel analysis and aging

The results of the chemical fuel investigations show:

- A blend of 10 vol% FAME and 41 vol% HVO (called R51) still provides a density ρ = 815 kg/m³ and therefore fulfills the DIN EN 16734. The R51 is therefore the fuel blend with the highest regenerative share in the context of this project.
- All tested fuel blends achieve induction times of more than 40 hours in thermo-oxidative aging, which is significantly longer than required by the standard.
- Furthermore, the aged B10 and R51 are fairly identical regarding the formation of CO absorption bands within the FTIR spectrum, which shows that the HVO share does not have a visible effect influence regarding the storage stability.
- However, the aging experiments also show that a diesel R33 shows a lower deposit formation tendency after 80 hours thermo-oxidative aging compared to a B10 and R51. Therefore, the results can find a different fuel aging behaviour after extended thermo-oxidative aging.

Executive summary

Executive summary (3/8) – Fuel and engine-oil analysis
The investigations of the fuel and engine-oil aging interactions are also done at thermo-oxidative conditions. Here, the fuel-oil samples are applied with a fixed mixing ratio of 20 vol% fuel to 80 vol% engine oil. Moreover, the tests include a variation of the 0W20 engine oil coming from Shell and Castrol. The results of the fuel and engine-oil aging experiments show: ○ All fuel-oil blends show an increase in density and kinematic viscosity over the duration of thermo-oxidative aging. In contrast, the oils, which are aged without being blended with a fuel are fairly stable regarding density and kinematic viscosity, which indicates an aging interaction within the fuel-oil blends. ○ The comparison between the different fuels shows no major differences between the aging behavior. This means that the amount of oil aging can be assumed to be similar as long as the amount of oil dilution is at a comparable level. ○ Moreover, the GPC results show a decrease of smaller molecules and an increase of larger molecules over the duration of aging. However, it needs to be noted that aging apparatus is constantly scavenged with air. As a result, it is possible that volatile components are leaving the sample over time. ○ The results of the GCMS allow for a differentiation between the the Shell and Castrol base oil.

Executive summary

Executive summary (4/8) – Chassis dynamometer tests

The investigations of the emission behavior and the oil dilution behavior of the test fuels are done with three series production vehicles, which are operated in different testing conditions.

- Vehicle A is a non-instrumented 2.0l TDI Passat (FWD) provided by the AGQM
- Vehicle B is an instrumented 2.0l TDI Passat (FWD) provided by Volkswagen
- Vehicle C is a non-instrumented 2.0l TDI Passat (AWD) operated by Volkswagen.

- Vehicle A is tested in WLTC emission test cycles with 2 fuels and in short-distance driving with 2 fuels
- Vehicle B is tested in WLTC emission test cycles with 5 fuels and in an artifical oil-dilution test using an adapted ECU while operating the vehicle in WLTC with 2 fuels.
- Vehicle C is tested in a long-distance driving profile with 2 fuels.

Executive summary

Executive summary (5/8) – Emissions

The investigations of the emission behavior of the test fuels are done with three series production vehicles, which are operated in different testing conditions.

The results of the WLTC emission tests show:

- The emission results of vehicle A and vehicle B are very comparable using B10 and R33 with no issues regarding Euro 6 emissions and no issues regarding CH_2O, NH_3 or N_2O. The only noticable difference between vehicle A and B is that vehicle A achieves good PN emission results and vehicle B achieves very good PN emission results.
- The emission results of vehicle B with B10, R33, B0, R51 and B30 show that none of the tested fuels shows issues regarding emissions or operational stability. Vehicle C is tested in a long-distance driving profile with 2 fuels. Therefore, none of the tested fuels is assumed to be critical regarding Euro 6 emissions. Moreover, none of the tested fuels shows significant emission concentrations regarding CH_2O, NH_3 or N_2O. It is therefore assumed that the tested fuels are also capable for upcoming Euro 7 legislations.

CH_2O: Formaldehydde, NH_3: Ammonia, N_2O: Nitrous oxide

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Executive summary

Executive summary (6/8) – Engine oil dilution
The investigations of the oil dilution behavior of the test fuels are done with three series production vehicles, which are operated in different testing conditions. The results of oil dilution tests show similar levels of oil dilution with slightly indifferent tendencies: ○ The oil dilution tests with vehicle A are done in a short-distance driving profile by a nursery service. These results show that B7 provides a higher total oil dilution than B10 with vehicle A in a short-distance profile. ○ The oil dilution tests with vehicle B are done at the chassis dynamometer with adapted ECU. These results show R33 provides a slightly higher total oil dilution than B10 in these testing conditions. ○ The oil dilution tests with vehicle C are done on a long-distance driving profile for 15.000 km each. These results show that B10 provides a slightly higher total oil dilution than B7 in these conditions. ○ The differences between these results can be attributed to two points. Firstly, all three tests are very different regarding the achievable maximum oil temperature, which can affect the re-evaporation. Secondly, it is possible that the applied test fuels are different regarding the base fuel properties. ○ However, none of the tests shows major differences between the test fuels. And this result is important, since similar amounts of oil dilution show similar oil aging effects in the chemical experiments.

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Executive summary

Executive summary (7/8) – Thermodynamic engine tests

Finally, the report also includes the results of thermodynamic parameter variations at the heavy-duty engine applied at Coburg University. Here, the tests include EGR variations with fixed MFB50 and single injection operation with R33, R51, HVO and B100.

The results of thermodynamic engine tests show:

- The raw-emission results of R51 are in-between the raw emission results of R33 and HVO. This verification is important to confirm that the R51 fuel blend provides no unusual emission tendencies.
- In detail, all fuels show increasing PN and CO emissions while decreasing the NOx emission via EGR.
- However, increasing EGR also shows beneficial results regarding decreased NH_3 and N_2O emissions as a result of decreased nitrogen reactions following decreased peak flame temperatures.
- Moreover, increased EGR also shows benefits regarding decreased combustion sound levels.

PN: particle number, CO: Carbon monoxide NH_3: Ammonia, N_2O: Nitrous oxide
EGR: Exhaust gas recirculation, MFB50: center of combustion (50 % conversion)

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Executive summary

Executive summary (8/8)

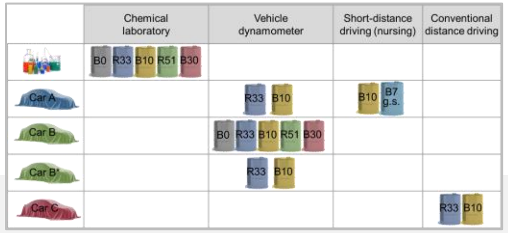
The results of this research project show that partially regenerative fuel blends such as the R51 provide major potentials for the defossilization of the existing fleet.

- All tested fuels provide induction times of more than 40 hours.
- All tested fuels show no issues in emission regarding Euro 6, CH_2O, NH_3 or N_2O.
- All tests show that the oil dilution tendencies of B7 and B10 fuel blends are on a similar level.
- And the chemical results show that the oil-fuel aging interactions are on a similar level as long as the oil dilution tendency is on a similar level as well.

- As a result, B10 and R51 are very promising fuel blends that contain an increased proportion of regenerative fuels.

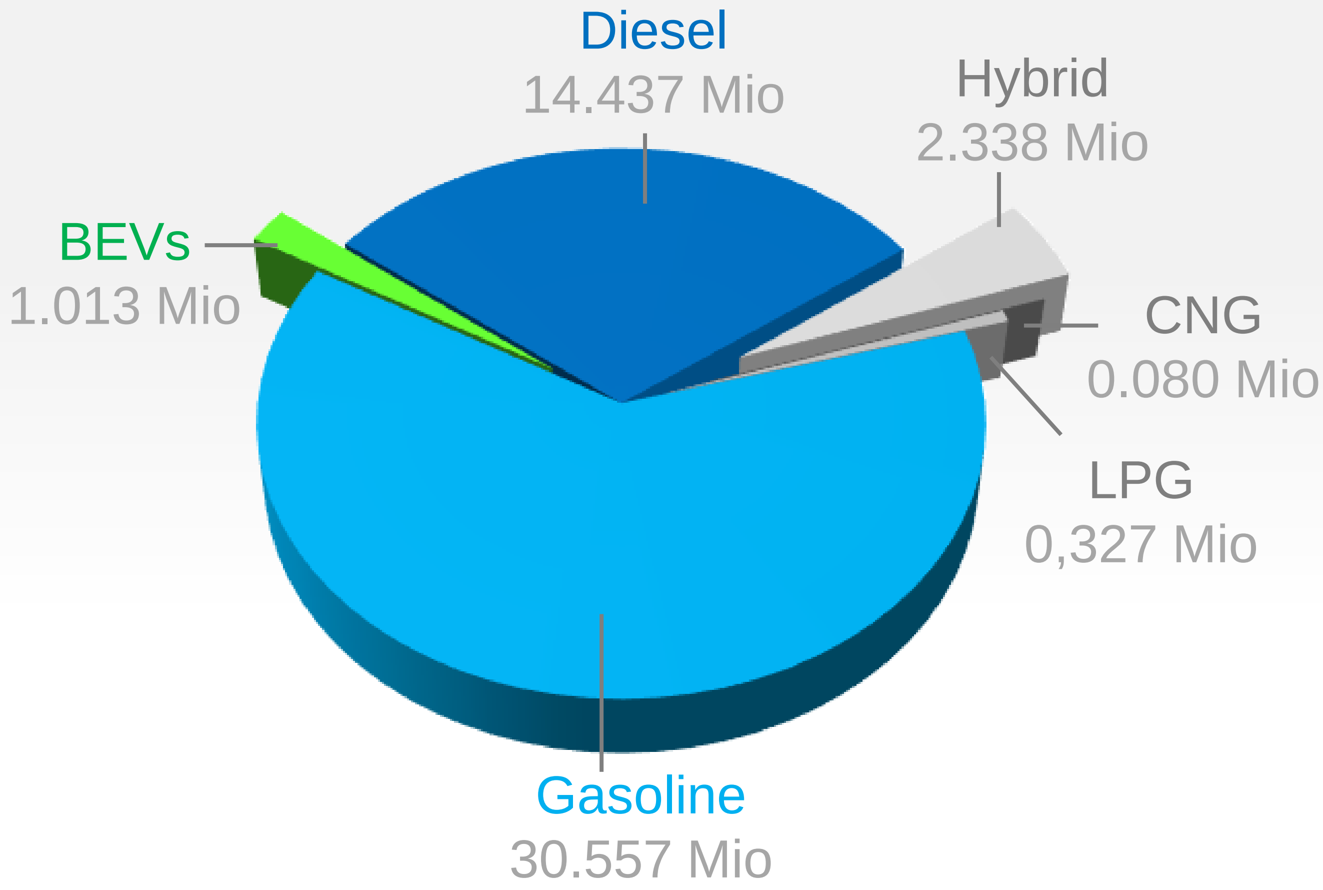
Outlook

Outlook
The following pie-charts show that the utilization of R51 could generate an equivalent 4.812 Mio vehicles, which are operated fully sustainably in Germany.



Potentials of R51 blends

German passenger car fleet 2023



Total car fleet

- 48.752 Mio cars in total
- 1.013 Mio BEVs

→ 2.08 % BEVs

Sustainable car fleet

1.013 Mio sustainable BEVs

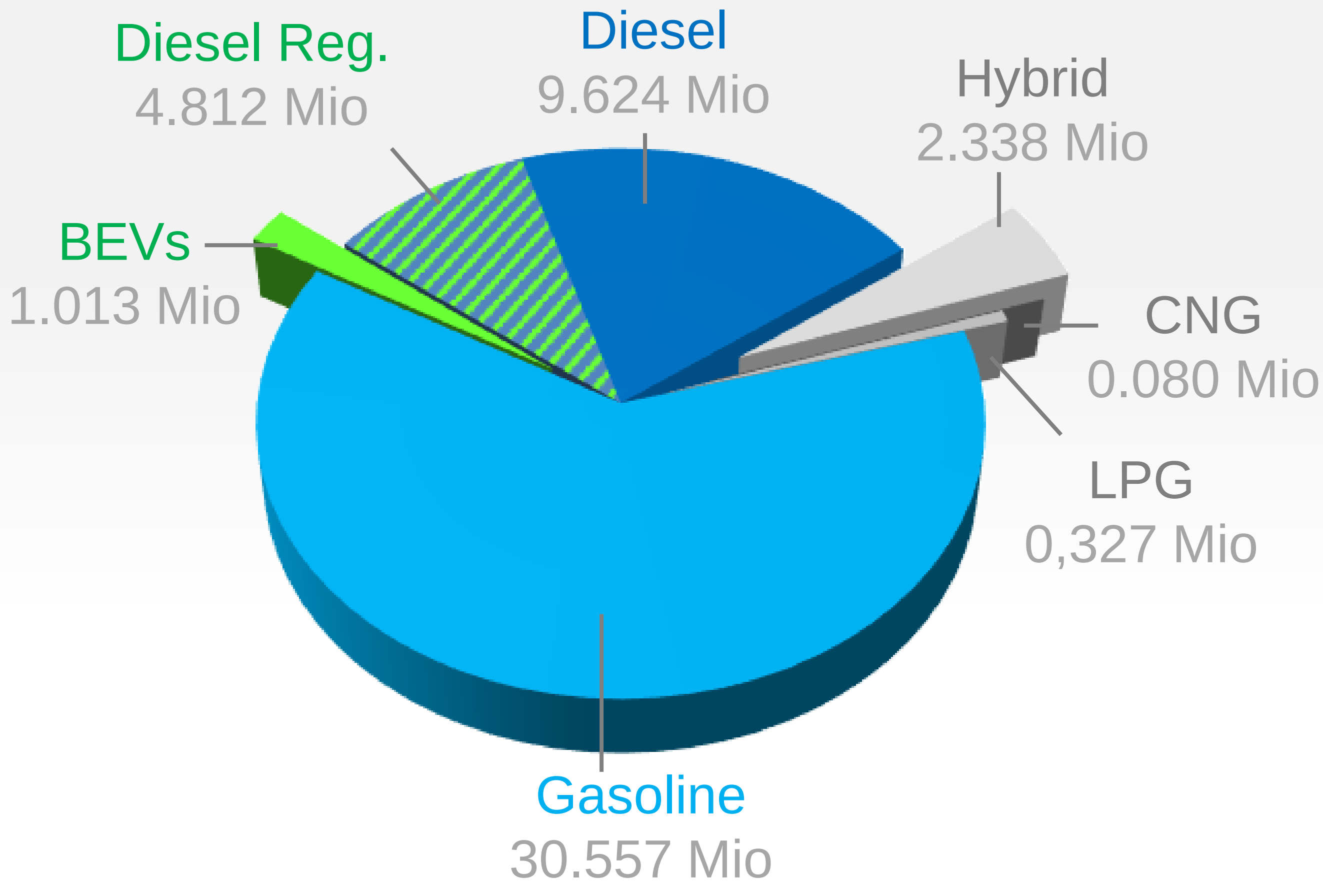
1.013 Mio sustainable cars

→ 2.08 % sustainable cars

	Chemical laboratory	Vehicle dynamometer	Short-distance driving (nursing)	Conventional distance driving
	B0 R33 B10 R51 B30			
Car A		R33 B10	B10 B7 g.s.	
Car B		B0 R33 B10 R51 B30		
Car B*		R33 B10		
Car C				R33 B10

Potentials of R51 blends in Diesel cars

German passenger car fleet 2023



Total car fleet

- 48.752 Mio cars in total
- 1.013 Mio BEVs

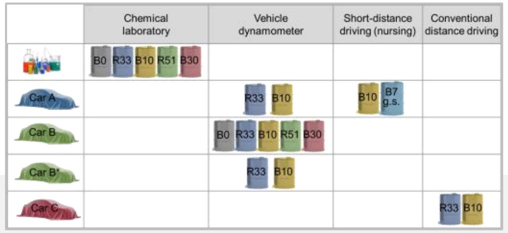
→ 2.08 % BEVs

Sustainable car fleet

1.013 Mio sustainable BEVs

1.013 Mio sustainable cars

→ 2.08 % sustainable cars



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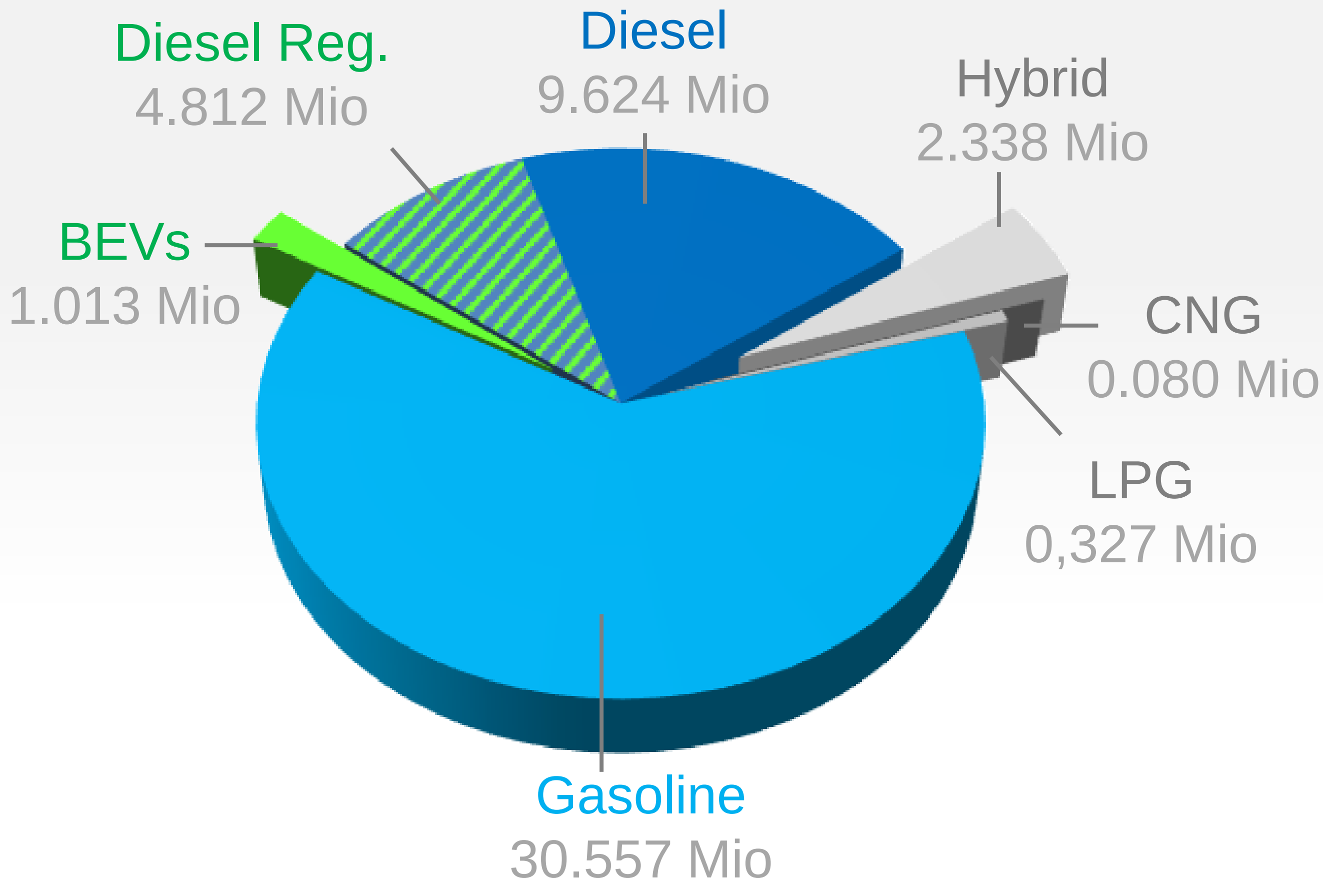

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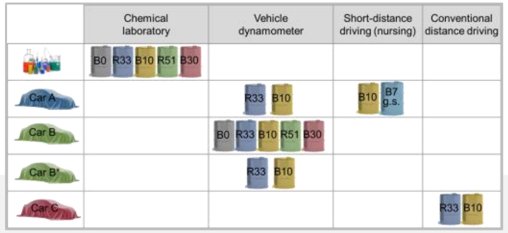
\+ 4.812 Mio sustainable Diesel cars

5.825 Mio sustainable cars

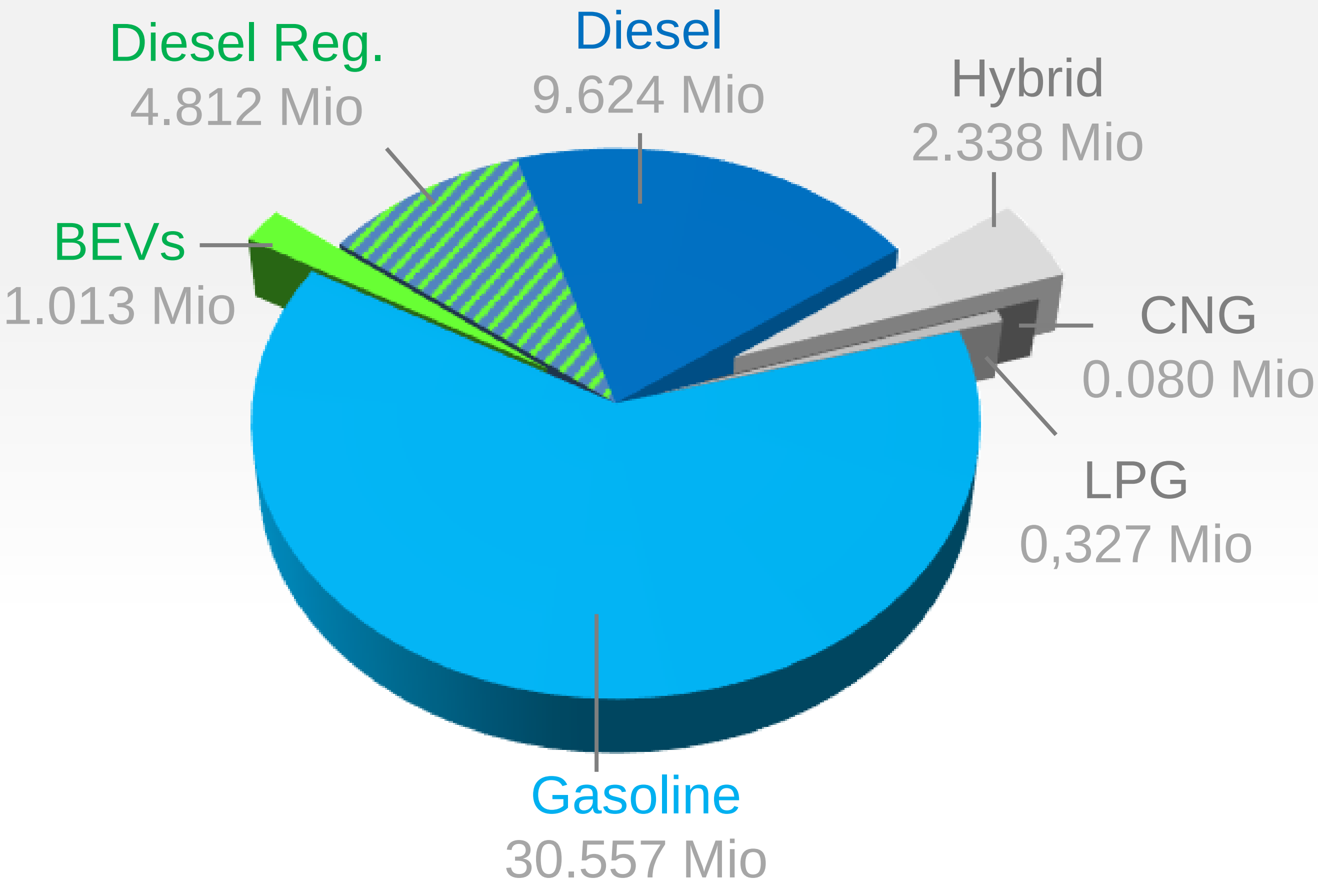
→ 11.95 % sustainable cars



R51 could provide an equivalent of 4.812 Mio sustainable vehicles in Germany

Potentials of R51 blends in Diesel cars

German passenger car fleet 2023



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Agenda:

Executive summary

Theoretical introduction

Methods and Materials

Experimental results

- Task A: Chemical analysis of fuels and oils
- Task B: Reception of test vehicles
- Task C: WLTC emission testing
- Task D: WLTC oil dilution tests
- Task E: Real-driving oil dilution testing
- Task X: Thermodynamic raw-emissions

Executive summary and outlook

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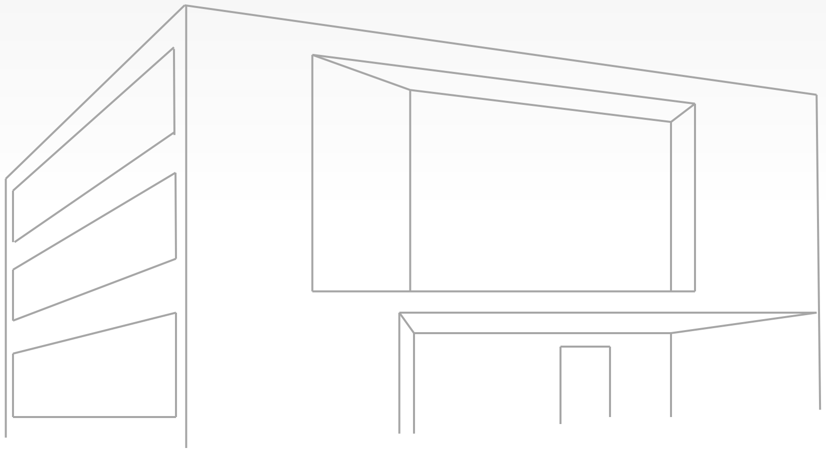

HOCHSCHULE COBURG

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a) Our cooperation partners for supporting us during the testing phase

b) The DFG for funding the research facilities at Coburg University

Deutsche Forschungsgemeinschaft

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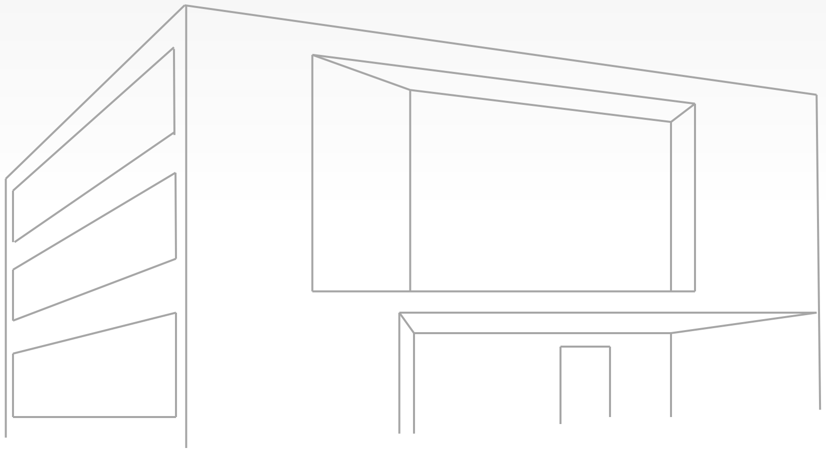

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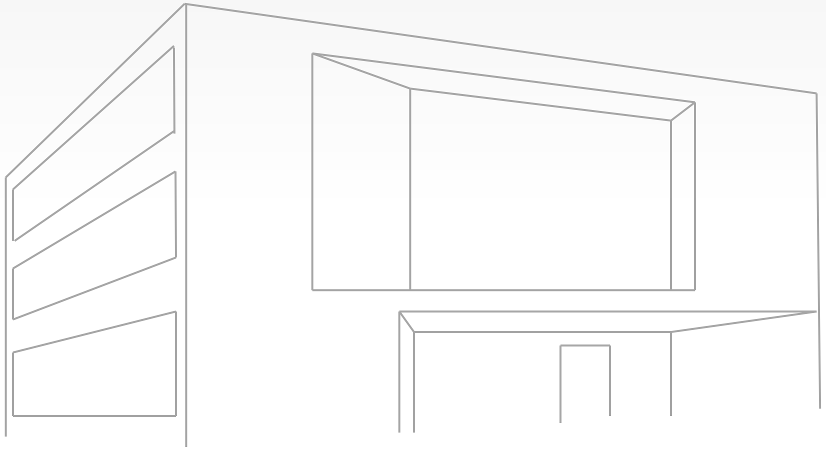

http://fuels.hs-coburg.de