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Liquefied Biomethane in HDV Transportation in Switzerland

The project "HelloLBG"

Prof. Dr. Elimar Frank, Zoe Stadler (IET), Fabian Ruoss (IET)
IEA AMF Webinar, 20 October 2021

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Ostschweizer Fachhochschule

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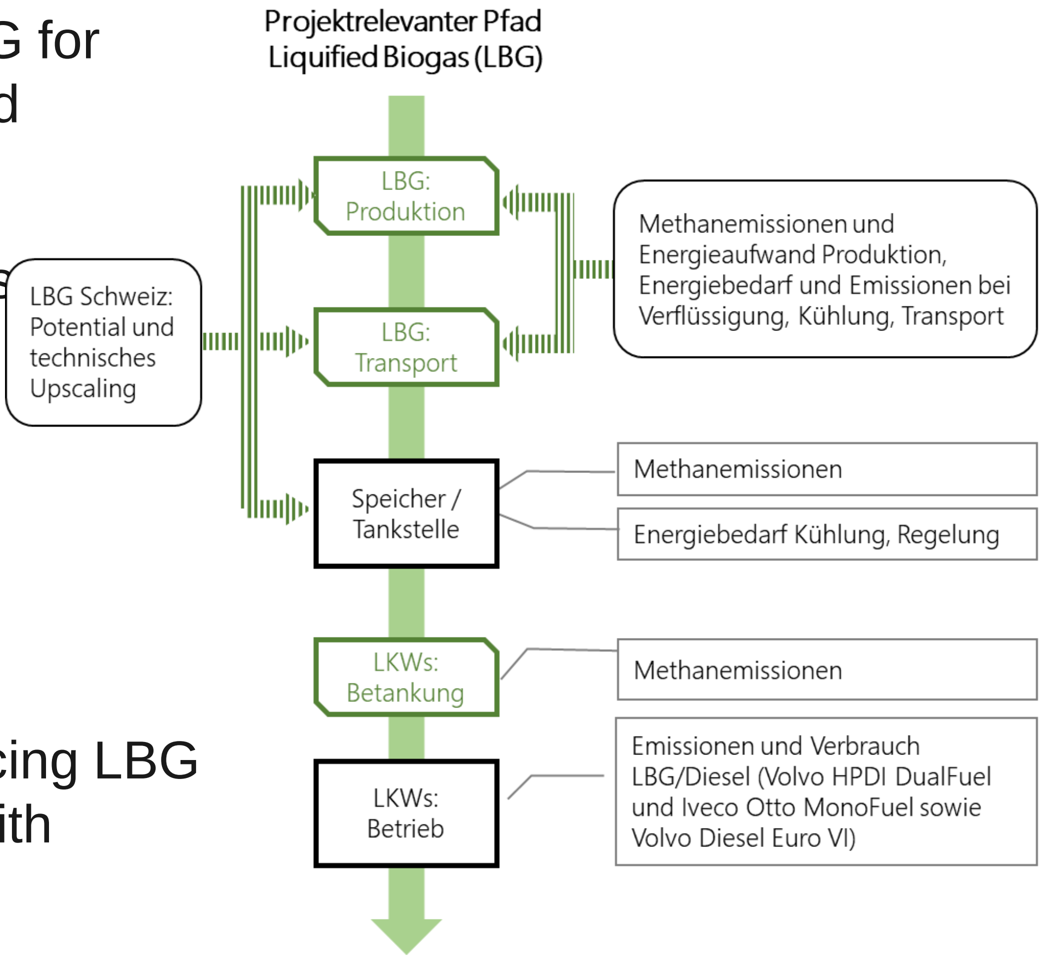
FRANK ENERGY

The project HelloLBG

Core question: Under which conditions is the use of LBG for Swiss heavy-duty transport energetically, technically and economically reasonable?

- Technic.: Pilot operation of fuelling station / trucks
  (a) Energy / emissions measurements
  (b) Operation / procurement
- Energetic.: WTW-Analysis LBG (g $CO_{2,eq}$ per MJ)
  (a) WTT
  (b) TTW
- Economic.: LBG-procurement, szenarios for producing LBG in Switzerland, cost comparison LBG with LNG and diesel, regulatory and political boundary conditions



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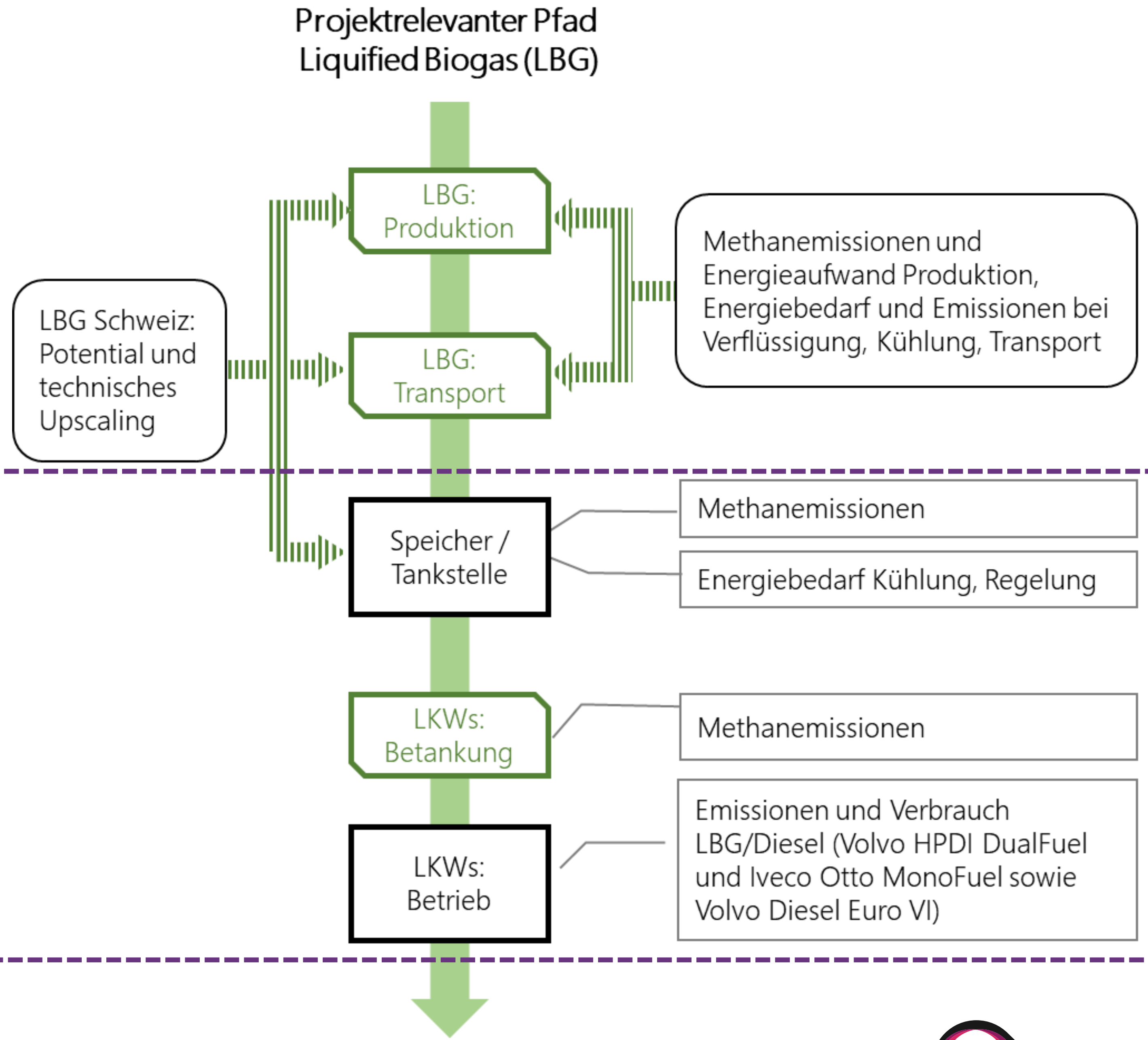
Operation

Measurements fuelling station and trucks



The measurements of fuelling station and trucks follow two aims:

- Provide a data basis for parts of the WTW analysis
- Gain operational experience LNG/LBG in general and for the purpose of operational optimization

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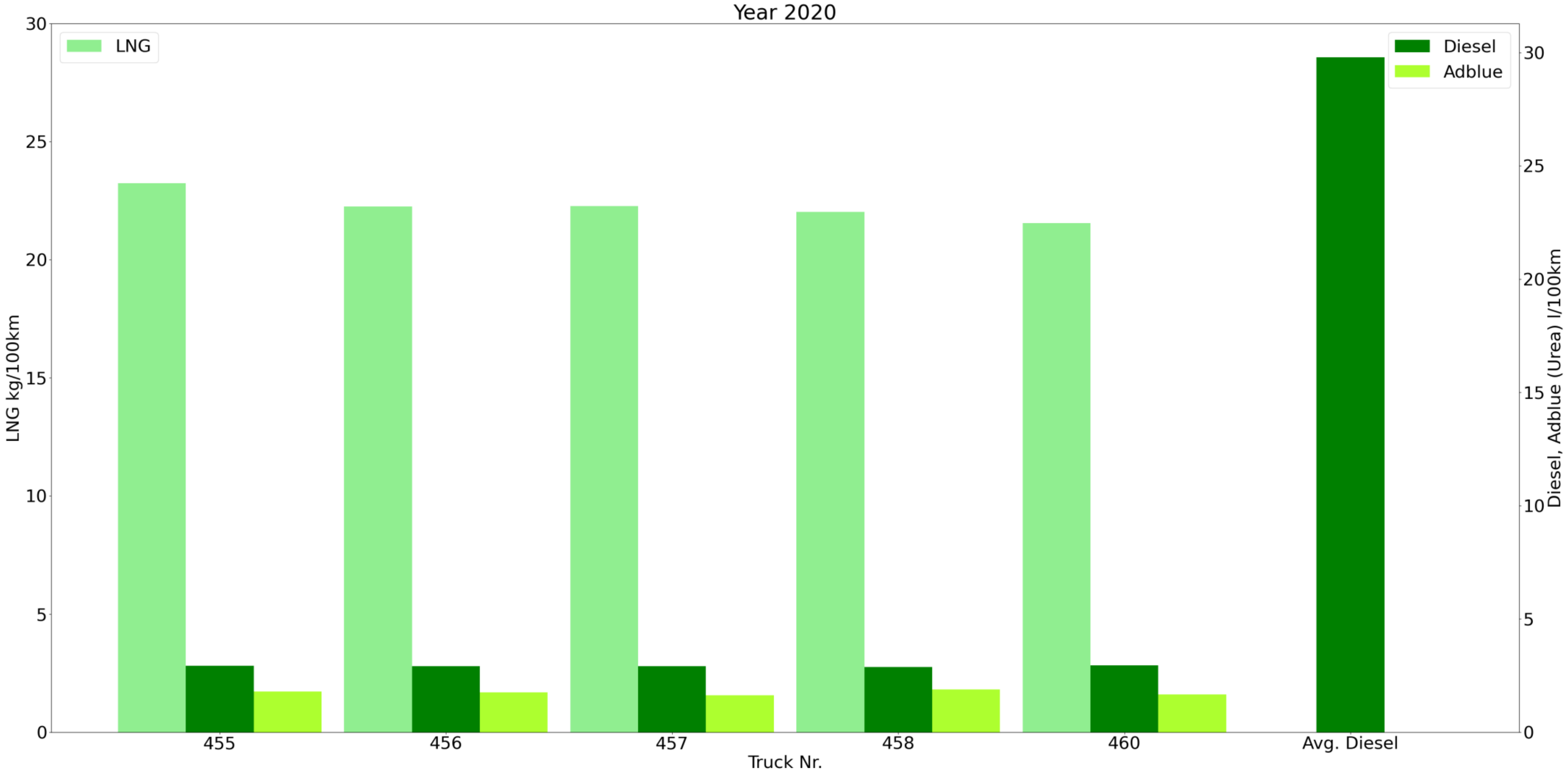
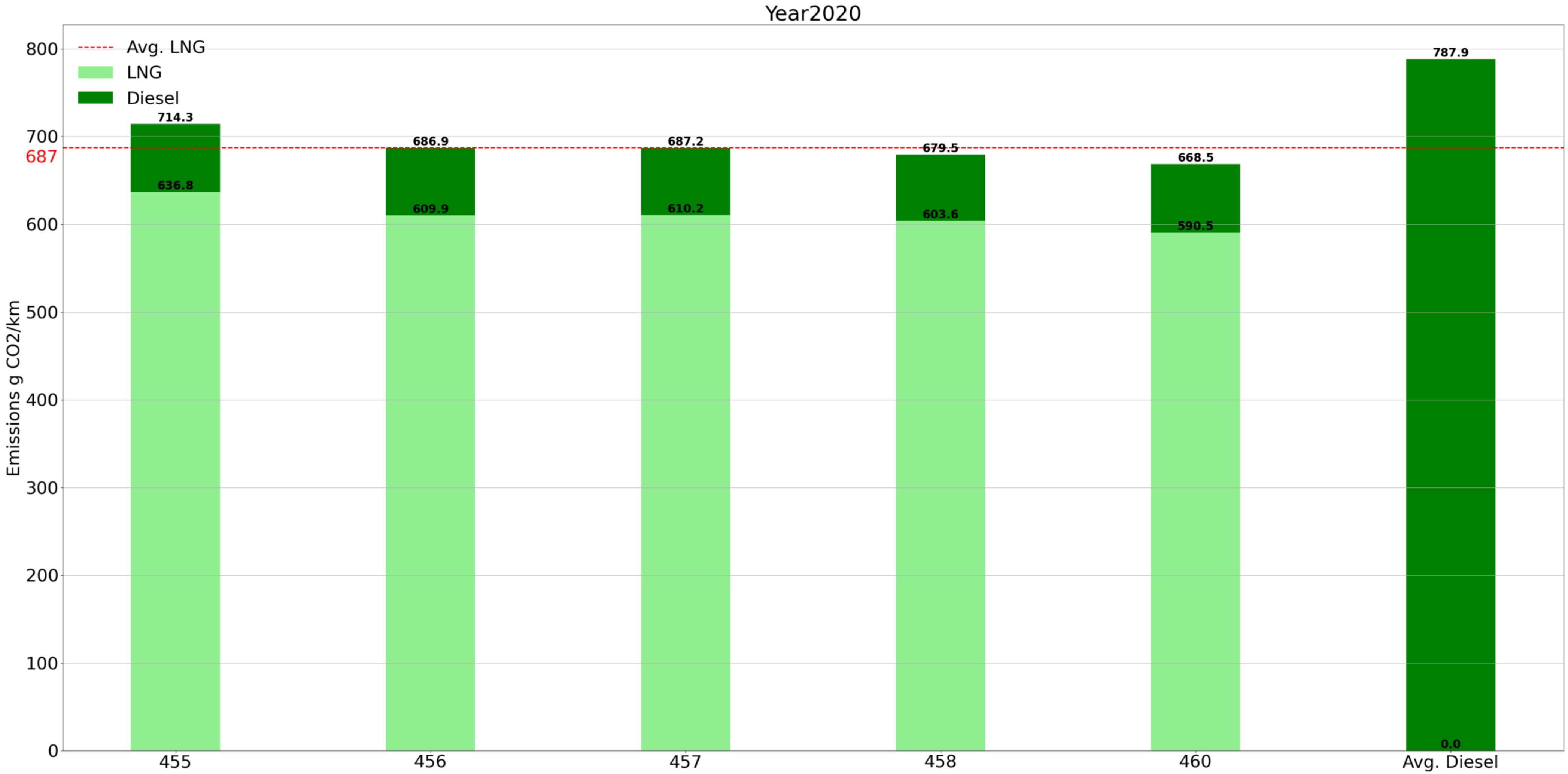
Measurements truck fleet: Fuel consumption (VMS)



Operation

Measurements truck fleet: CO_2 emissions



-12%

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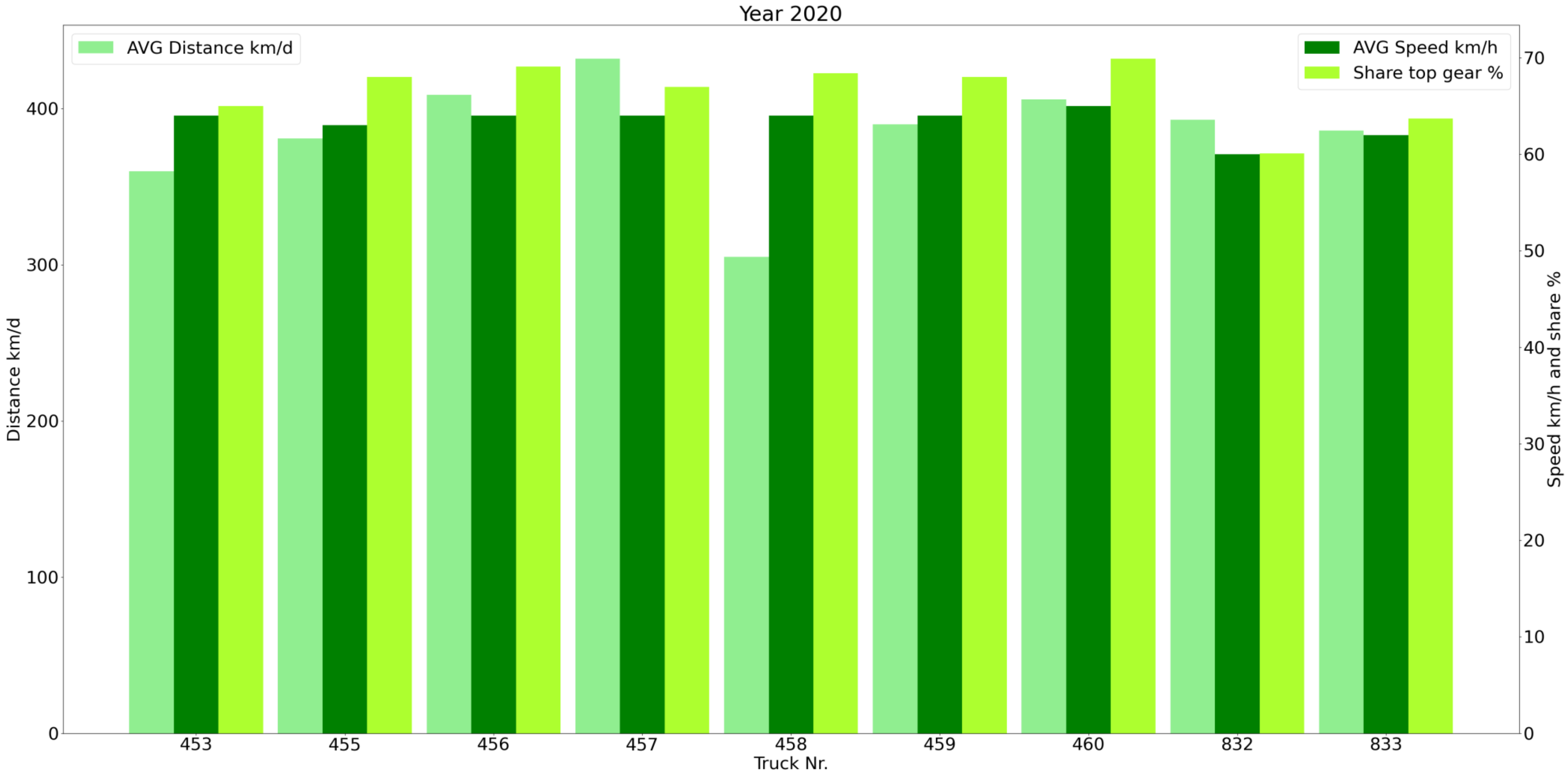
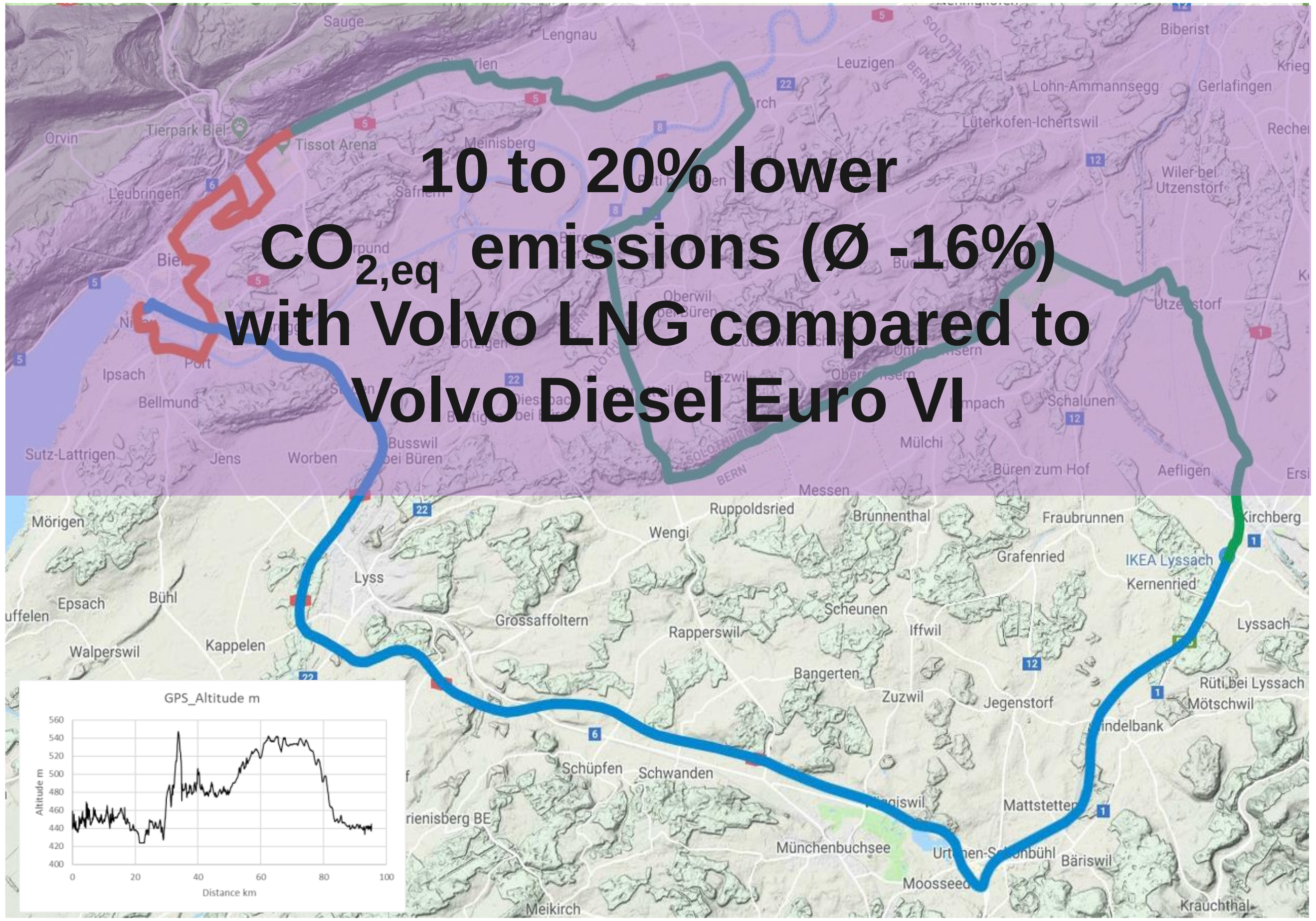
Measurements truck fleet: Characteristics



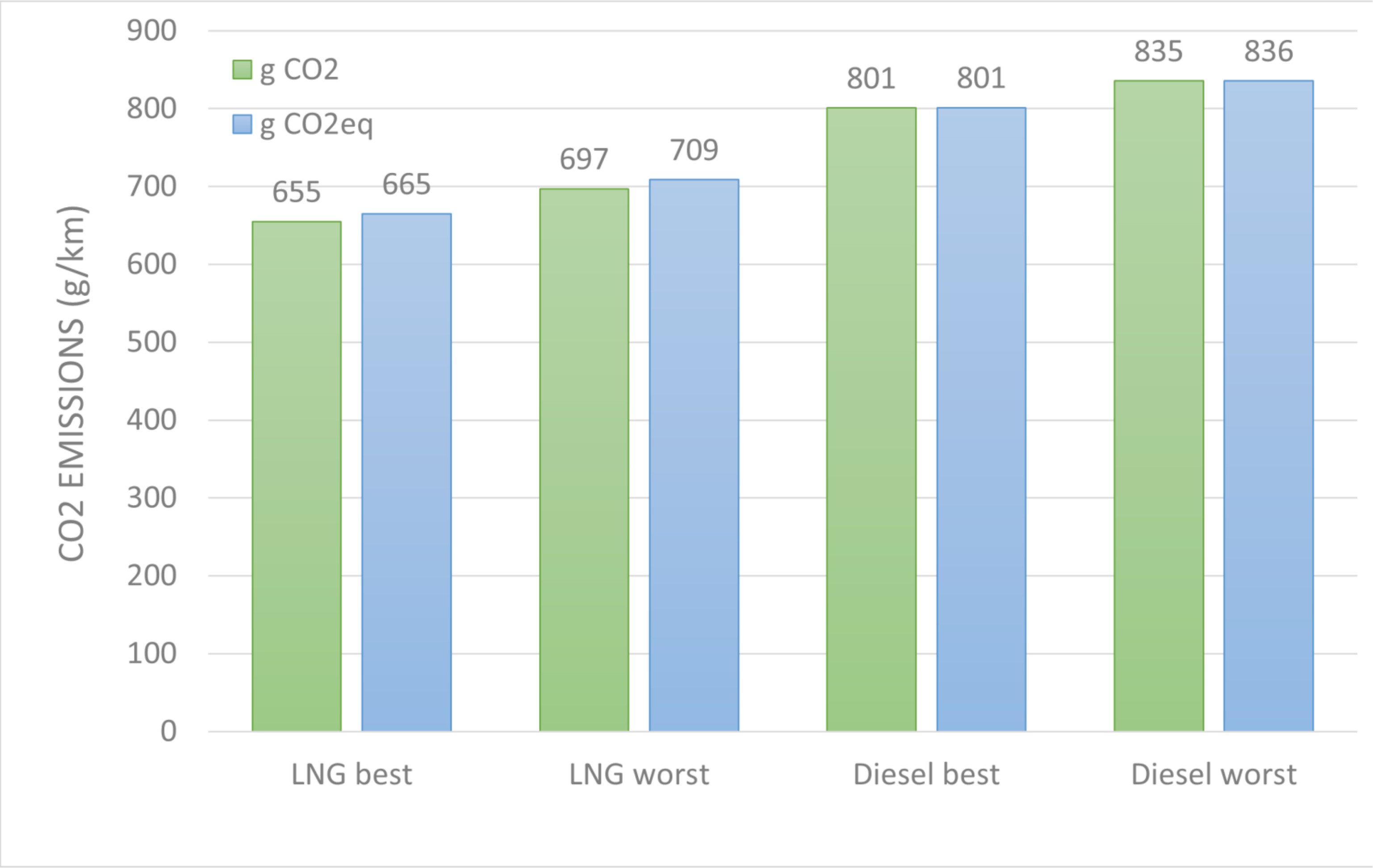
Measurements truck fleet: Specific cycle



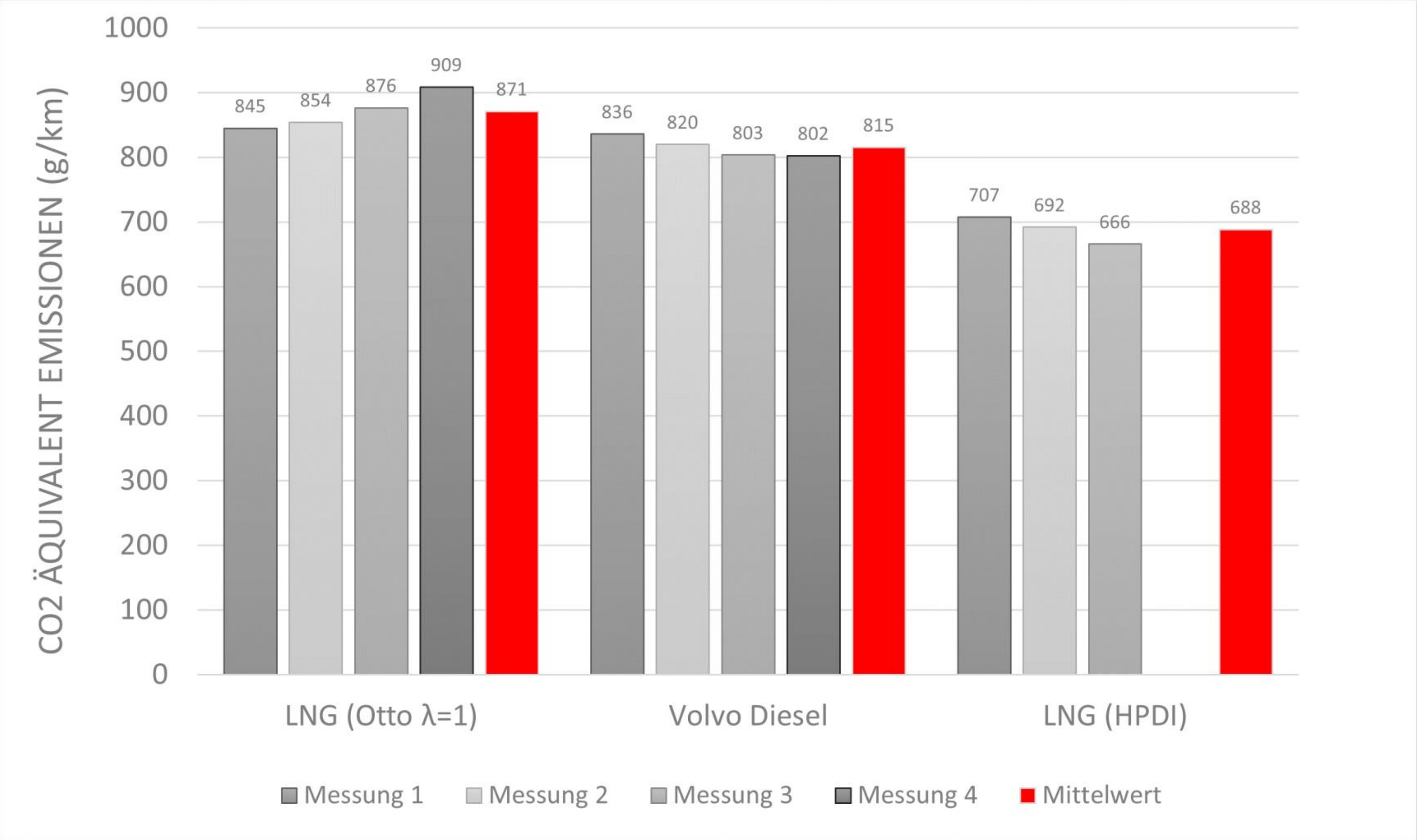
- PEMS measurements: CO_2, CO, THC, CH_4, NO_x, NO_2 and PN
- Logging of GPS data, OBD data and exhaust gas flow rate
- Truck incl. trailer 22.5 t (payload 15 t)
- RDE route (EU regulation 1151/2017):
  95 km, appr. 2h15. Share highway < statutory truck emission measurements, but equivalent urban-, interurban and highway proportions.
- Total 12 measurements between 17.06.20 and 02.07.20 with same driver
- In addition, two warm start exhaust gas measurements with both LNG trucks (engine started warm, then idling for approx. 15 minutes).

Measurements truck fleet: Specific Cycle

- Volvo LNG has the lowest CO2,eq emissions for all route segments
- Volvo LNG shows 10 to 20% lower CO2,eq emissions (average: minus 16%)
- Comparison NOx: Volvo LNG higher than diesel, but mainly at cold start and also still Euro VI compliant

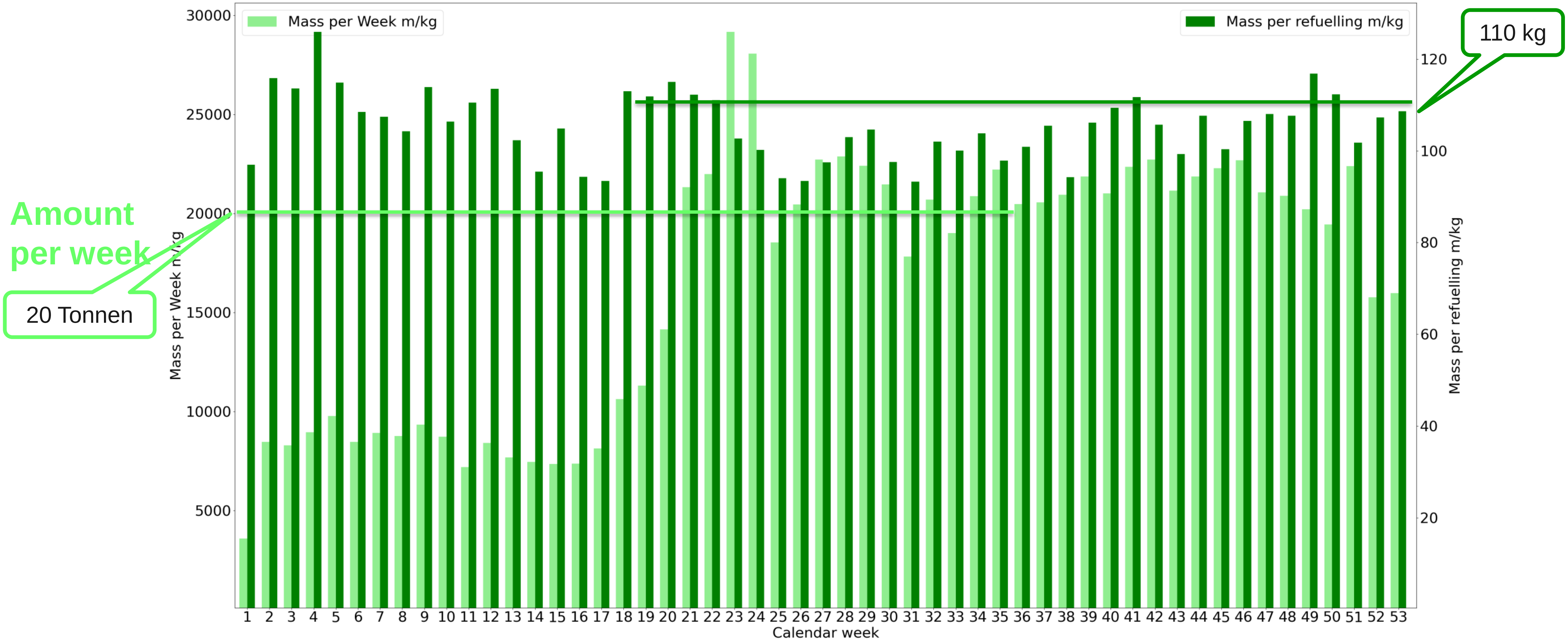


Comparison Otto engine and HPDI (Tank-to-Wheel)



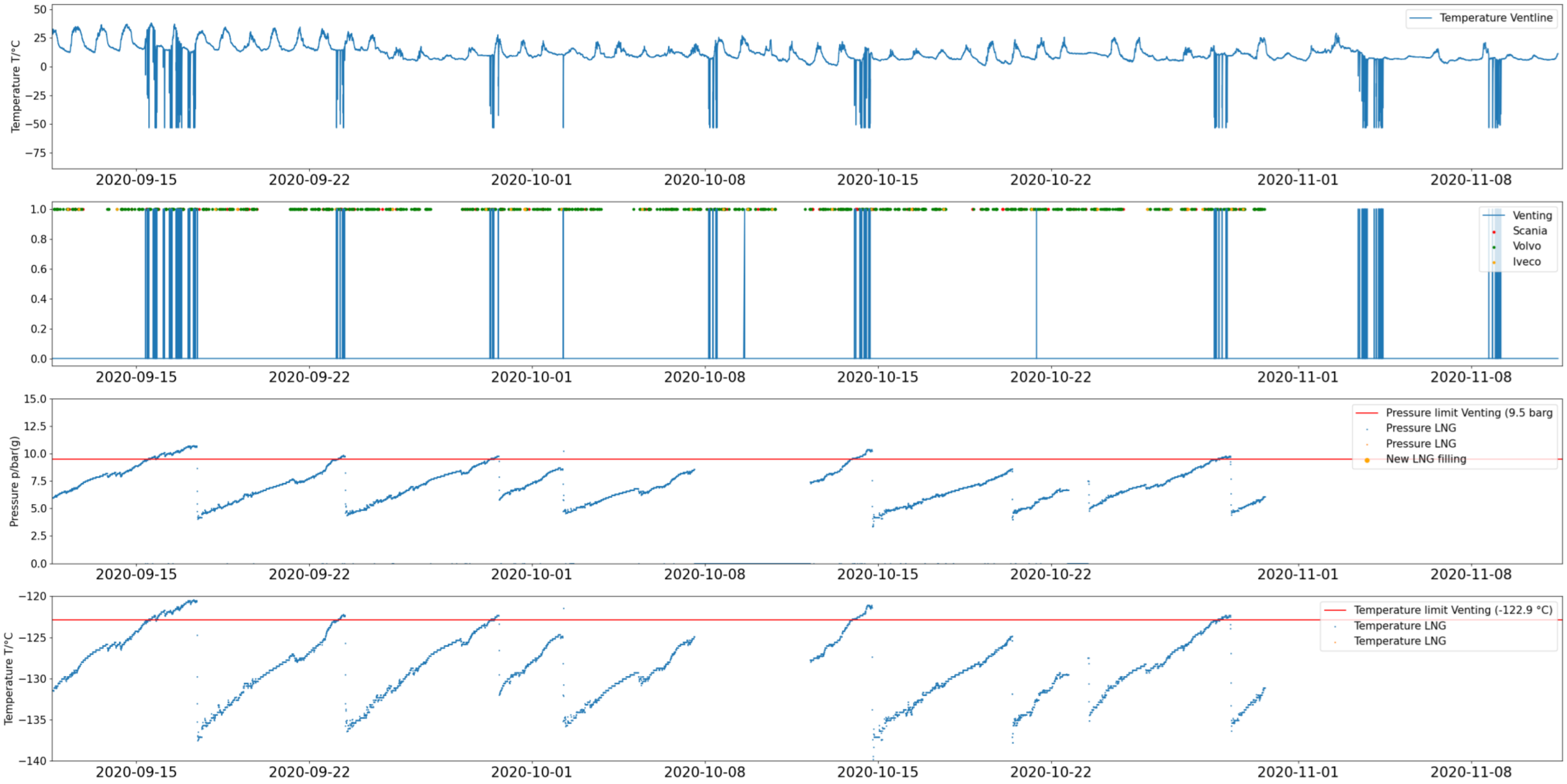
Measurements fuelling station

Amount per fuelling



Operation

Measurements fuelling station



Pilot operation: Selected Lessons Learnt

Fuelling station:

- Empty as far as possible and fill regularly
- Avoid venting: high and uniform capacity utilization is crucial

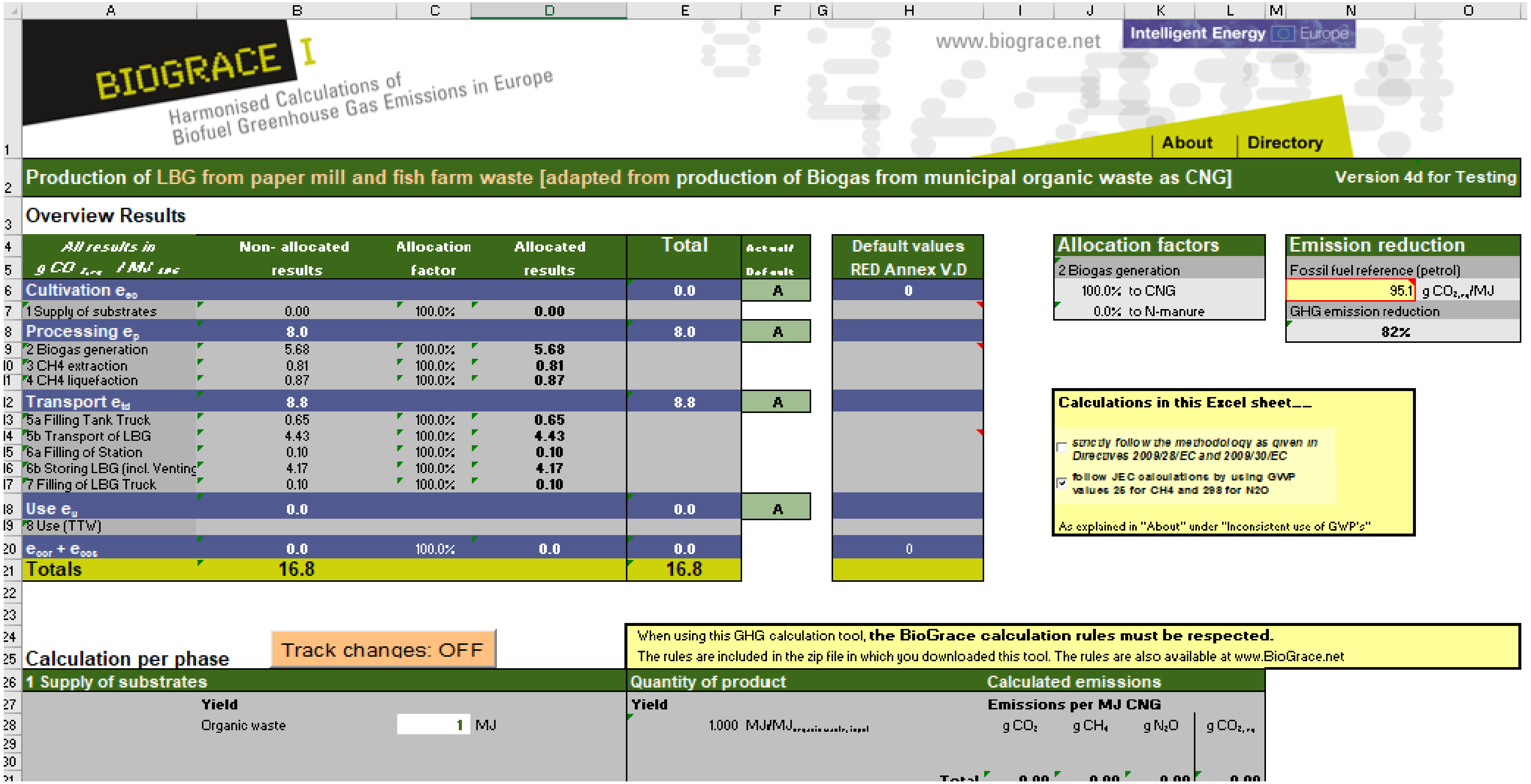
Trucks

- No problems specific to LNG/LBG.
- Consumption/emissions: Efficient technology, minus 10 to 20% CO2,eq vs. diesel Euro VI

Methane emissionens (excluding ventings):

- No gas leaks at truck and filling station (incl. filling station filling)
- No significant gas leaks at the couplings during refueling operations

Extension of the tool "Biograce"


BIOGRACE I
Harmonised Calculations of Biofuel Greenhouse Gas Emissions in Europe
www.biograce.net
Intelligent Energy Europe
About | Directory

Production of LBG from paper mill and fish farm waste [adapted from production of Biogas from municipal organic waste as CNG] — Version 4d for Testing

Overview Results

All results in g $CO_{2,eq}$ / MJ_{LBG}	Non- allocated results	Allocation factor	Allocated results	Total	Actual/Default	Default values RED Annex V.D
Cultivation e_{ec}				0.0	A	0
1 Supply of substrates	0.00	100.0%	0.00			
Processing e_p	8.0			8.0	A	
2 Biogas generation	5.68	100.0%	5.68			
3 CH4 extraction	0.81	100.0%	0.81			
4 CH4 liquefaction	0.87	100.0%	0.87			
Transport e_{td}	8.8			8.8	A	
5a Filling Tank Truck	0.65	100.0%	0.65			
5b Transport of LBG	4.43	100.0%	4.43			
6a Filling of Station	0.10	100.0%	0.10			
6b Storing LBG (incl. Venting	4.17	100.0%	4.17			
7 Filling of LBG Truck	0.10	100.0%	0.10			
Use e_u	0.0			0.0	A	
8 Use (TTW)						
$e_{ccr} + e_{ccs}$	0.0	100.0%	0.0	0.0		0
Totals	16.8			16.8		

Allocation factors	
2 Biogas generation	
100.0%	to CNG
0.0%	to N-manure

Emission reduction	
Fossil fuel reference (petrol)	
95.1	g $CO_{2,eq}$/MJ
GHG emission reduction	
82%	

Calculations in this Excel sheet...

- [ ] strictly follow the methodology as given in Directives 2009/28/EC and 2009/30/EC
- [x] follow JEC calculations by using GWP values 25 for CH4 and 298 for N2O

As explained in "About" under "Inconsistent use of GWP's"

When using this GHG calculation tool, **the BioGrace calculation rules must be respected.**
The rules are included in the zip file in which you downloaded this tool. The rules are also available at www.BioGrace.net

Calculation per phase — Track changes: OFF

1 Supply of substrates			Quantity of product		Calculated emissions			
Yield			Yield		Emissions per MJ CNG			
Organic waste	1	MJ	1.000	MJ/MJ organic waste, input	g CO_2	g CH_4	g N_2O	g $CO_{2,eq}$
				Total	0.00	0.00	0.00	0.00

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LBG from Norwegen

All results in g $CO_{2,eq}$ / MJ_{LBG}	**Non- allocated results**
Cultivation e_{ec}	
1 Supply of substrates	0.00
Processing e_p	**8.0**
2 Biogas generation	5.68
3 CH4 extraction	0.81
4 CH4 liquefaction	0.87
Transport e_{td}	**8.8**
5a Filling Tank Truck	0.65
5b Transport of LBG	4.43
6a Filling of Station	0.10
6b Storing LBG (incl. Venting)	4.17
7 Filling of LBG Truck	0.10
Use e_u	**0.0**
8 Use (TTW)	
e_{ccr} + e_{ccs}	**0.0**
Totals	**16.8**

- Plant for approx. 20 tpd
- -82% compared to fossile diesel (RED II: 95.1)
- Energy source Processing is crucial in this case (non-renewable: -46%)
- Processing and Transport in this assessment with roughly the same level of contributions
- Contribution "Transport & Storing" can be considerably lower:
  - Shorter distances and/or LBG
  - Venting can be reduced or avoided

Example: Liquefaction (with 1.4 kWh_{el}/kg_{LBG})

4 CH_4 liquefaction	via Mixed-Refrigerant Liquefaction			Quantity of product	Calculated emissions			
	Yield				**Emissions per MJ LBG**			
	CH4	**0.999**	MJ_LBG / MJ_CH4	0.620 MJ_LBG/MJorganic waste, input 1.027 MJ_LBG/MJCNG	g CO_2	g CH_4	g N_2O	g $CO_{2,\ eq}$
	Factor from typical to default	**1.0**						
	Energy consumption							
=B61 if same for all	**ElecMixNorwayProduction**	**0.101**	MJ / $MJ_{CH4(f)}$		0.52	0.00	0.00	**0.52**
	Direct emissions							
	Methane	**0.001**	MJ / MJ_{CH4}			0.02		**0.51**
					Result	**g $CO_{2,eq}$ / MJ_LBG**		**1.03**

- Big difference from large scale to small (and nano) scale
  - Literature data often in CO2,eq/kg
  - Data in kWh/kg would be better, because: electricity origin can make a difference
- Nano-scale (< 20 tpd): Manufacturer specifications vary from 0.7 to 1.8 kWh_{el}/kg
  - Attention: Partly including, partly excluding pre-treatment

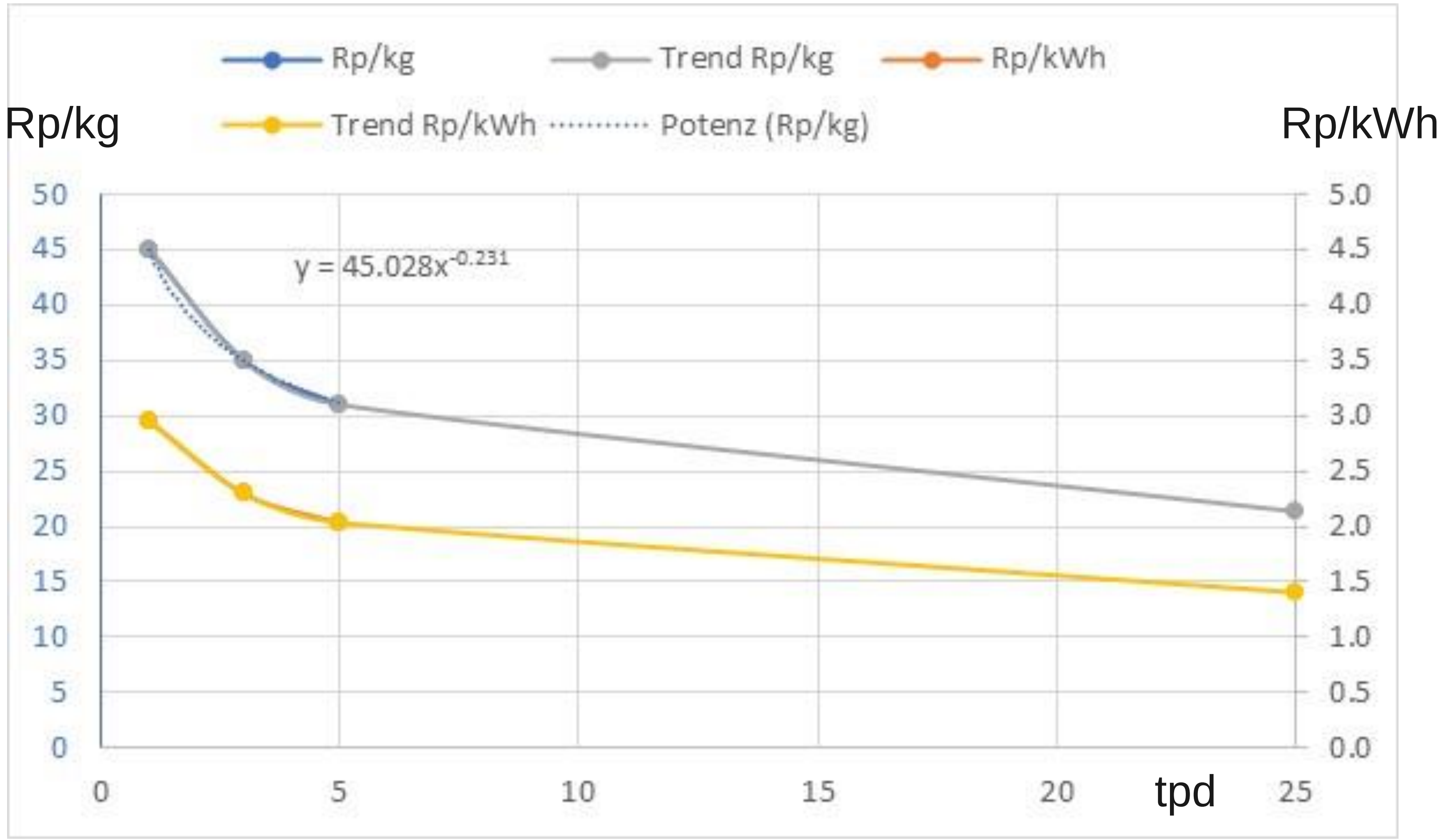
Example: Transport

5b Transport of LBG	(Road to Switzerland, empty return)			Quantity of product	Calculated emissions			
	Yield							
	LBG	0.999	MJ_LBG-out / MJ_LBG-i	0.354 MJ_LBG/MJorganic waste, input	**Emissions per MJ CNG**			
				1.009	g CO_2	g CH_4	g N_2O	g $CO_{2,eq}$
	Transport per							
	Truck for liquids (Diesel)	2500	km		2.11	0.00	0.00	**2.11**
	Fuel	Diesel						
	Fuel consumption	29	l/100km					
	Direct emissions							
	Methane	0.001	MJ_LBG / MJ_LBG			0.02		**0.50**
	Empty return							
	Truck for liquids (Diesel)	2500	km		1.82	0.00	0.00	**1.82**
	Fuel	Diesel						
	Fuel consumption	25	l/100km					
					Result	**g $CO_{2,eq}$ / MJ_{LBG}**		**4.43**

Biograce recommends 0.1% (Manuf. 0.0%) (indep. of distance)

- **Further options** (LBG from Northern Italy, distance 400km, no "direct emissions"): Reduction transport to **0.63 g$CO_{2,eq}$/MJ**

Costs upgrading / liquefaction



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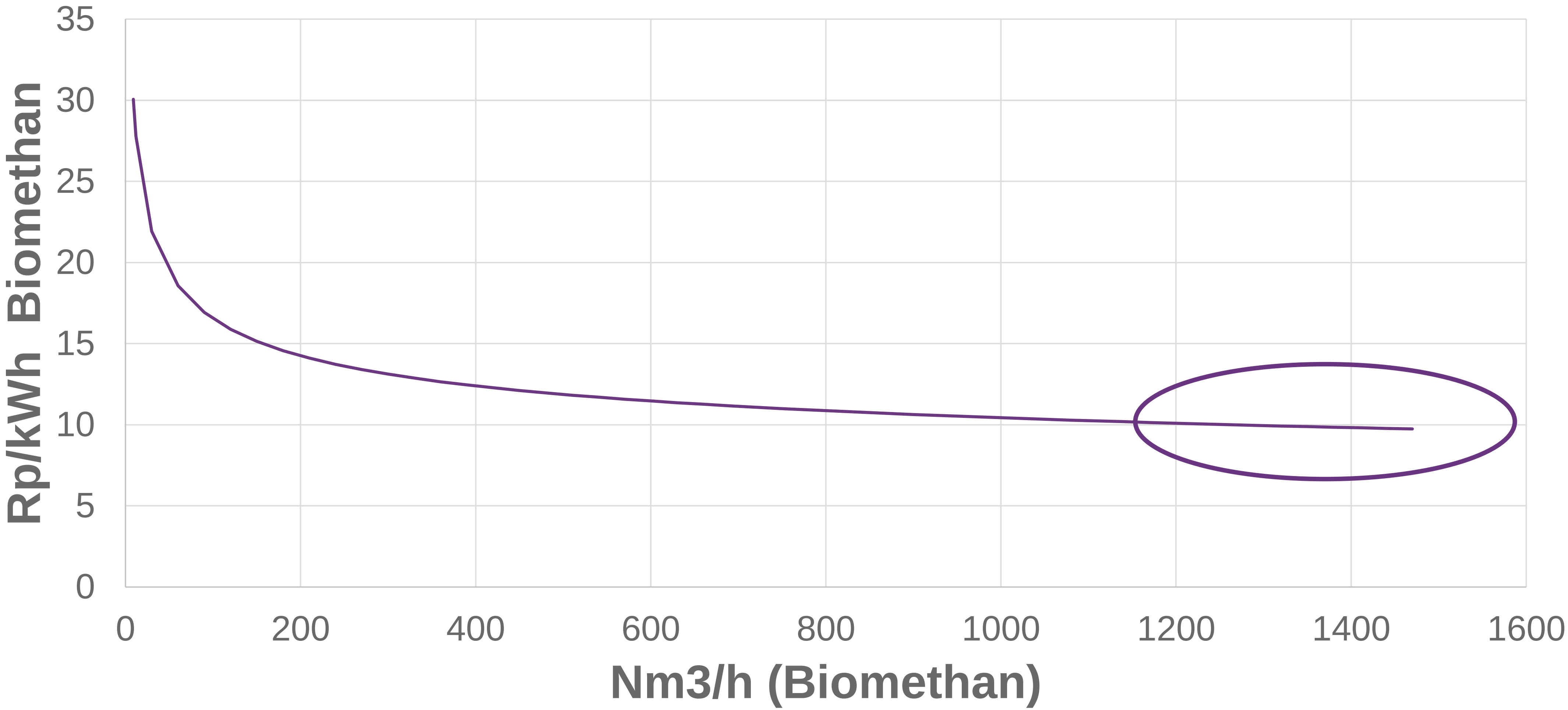
Costs biogas production



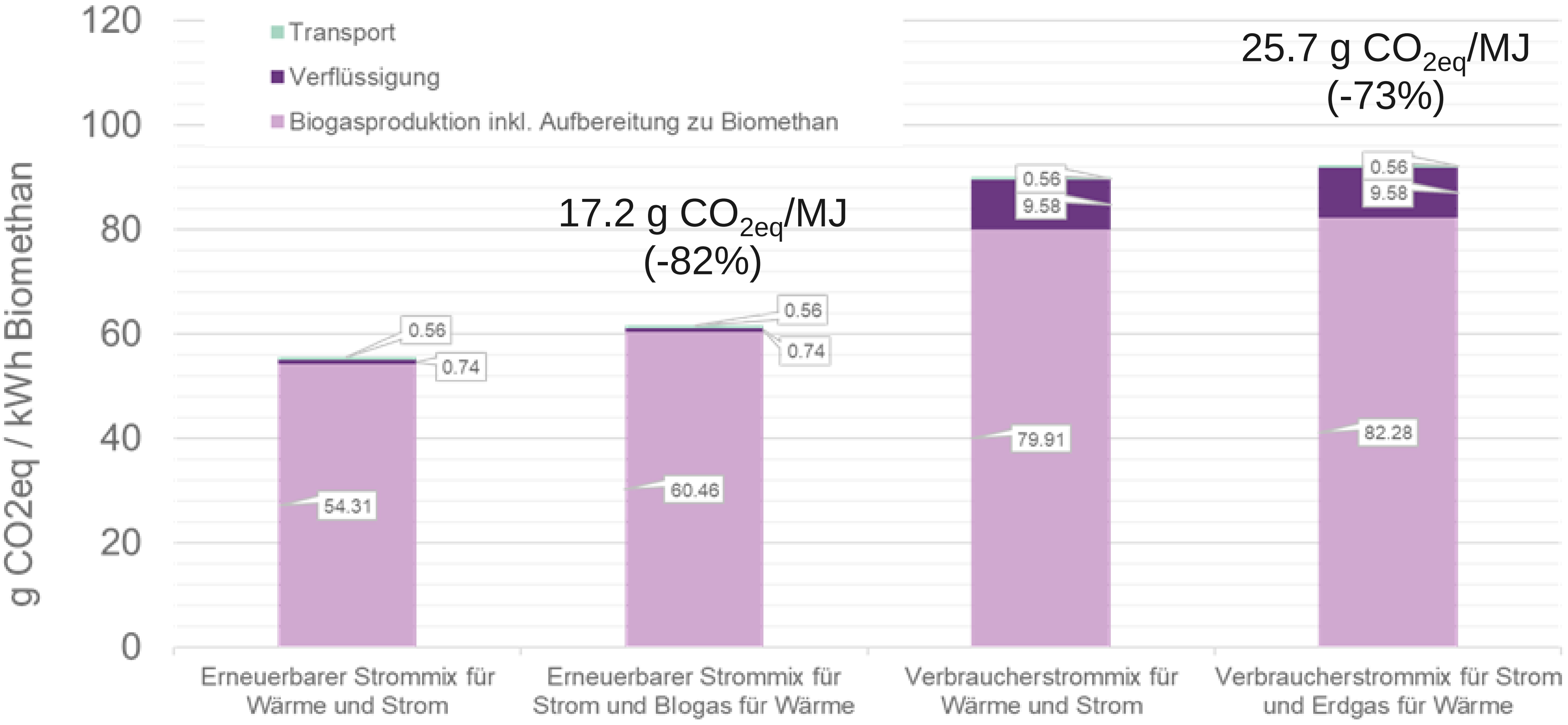
First estimates for plants > 5 tpd

	Rappen pro kWh	CHF pro kg
Biogas production costs	10.0	1.39
Upgrading and liquefaction	2.0	0.28
Transport to fuelling station	0.4	0.06
TOTAL	**12.4**	**1.73**
Comparison LNG	8.0	1.15

- **The decisive factor is the biogas costs, not upgrading/liquefaction**
- Learning curves Upgrading and Liquefaction not yet considered

Scenarios LBG production Switzerland

Total emissions (720 Nm^3/h biomethane)



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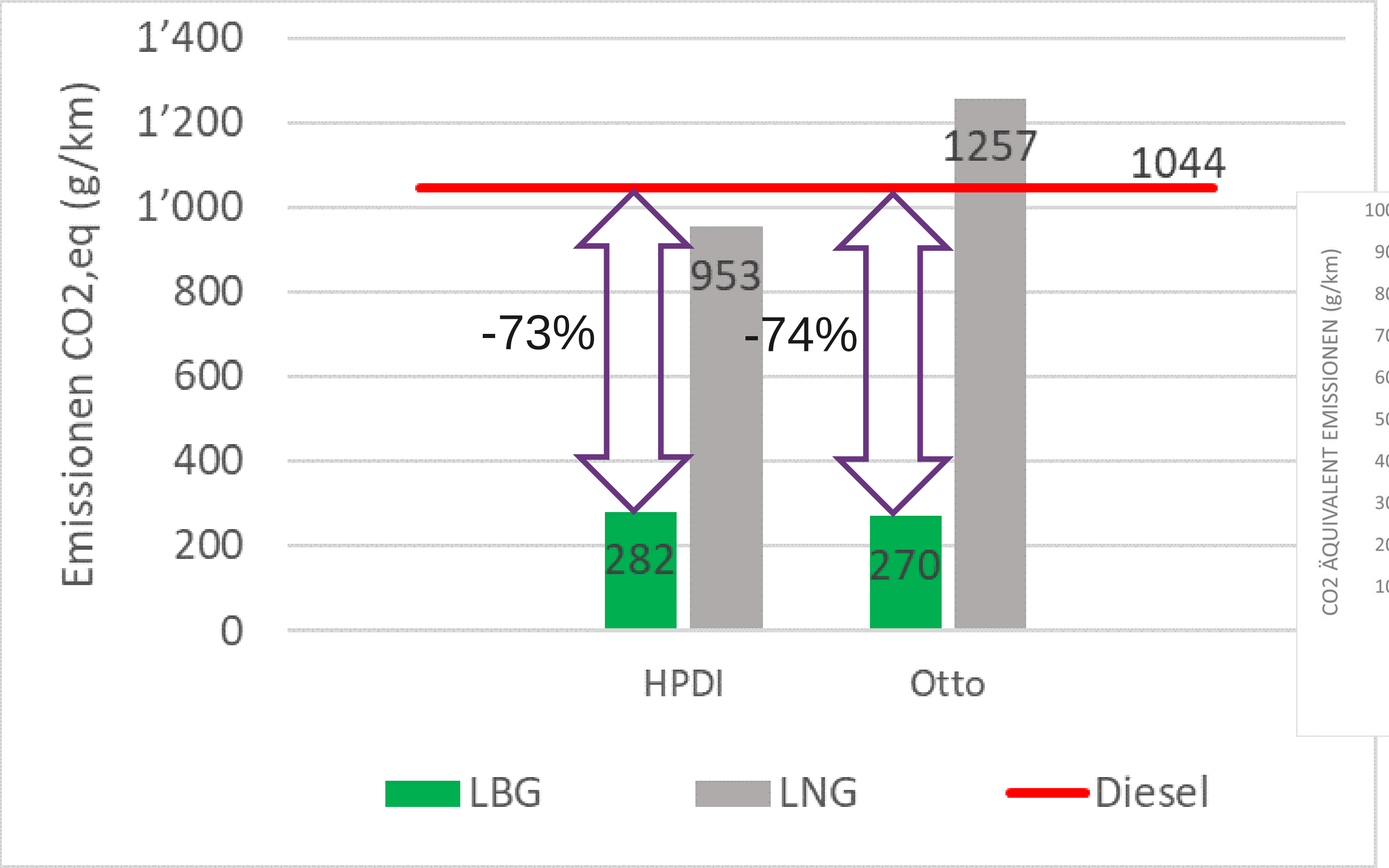
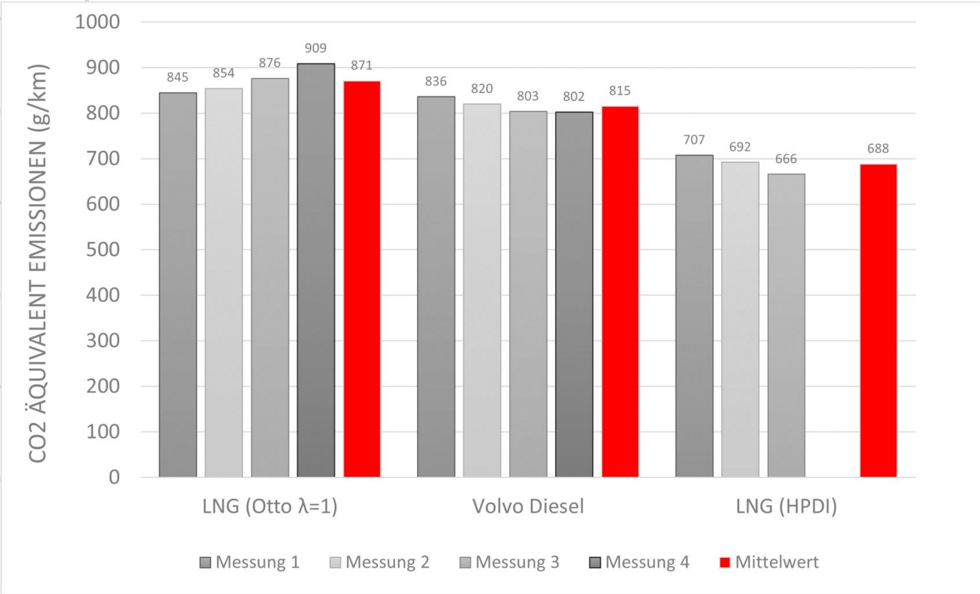
Comparison Otto engine and HPDI (Well-to-Wheel)





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Thank you for your attention.

elimar.frank@ost.ch

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