HOW TO DECARBONISE HEAVY ROAD TRANSPORT?

Till Gnann, Patrick Plötz, André Kühn, Martin Wietschel
presented by Antoine Durand

Source: Siemens AG

Presentation at eceee summer study, Hyères, France
May, 29th – June, 2nd, 2017. Paper no: 4-346-17

Fraunhofer ISI

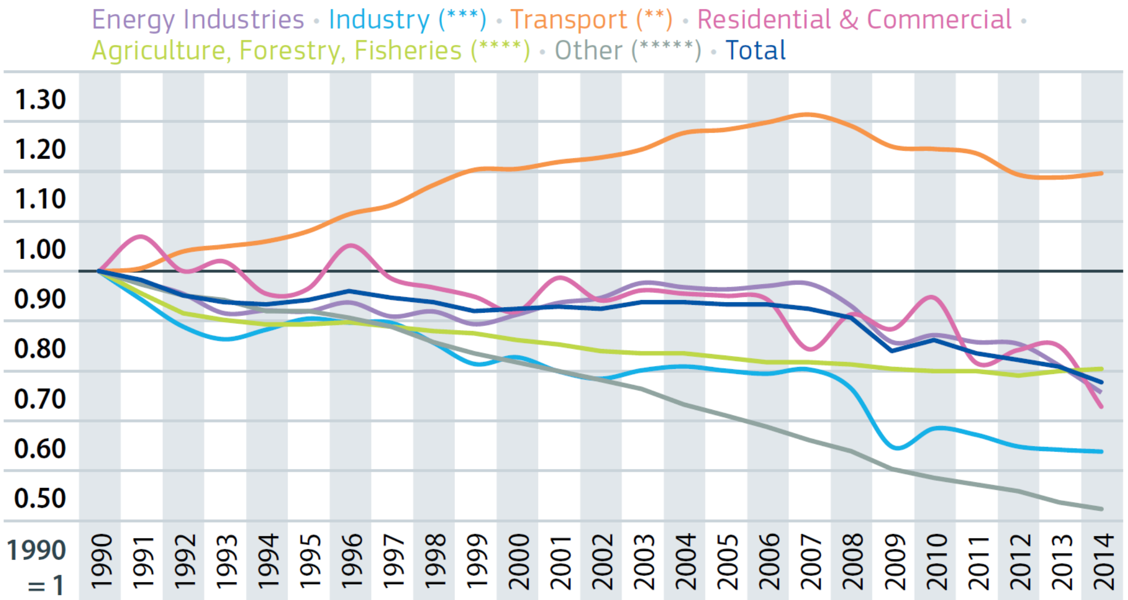
STUDY

- This paper/presentation is partly based on this report
- Technical, economical and environmental assessment of overhead catenary trucks (Funded by the Federal German Ministry of Transport and Digital Infrastructure)
- Authors
  - Fraunhofer ISI. Main authors: Martin Wietschel, Patrick Plötz, Till Gnann, André Kühn
  - Fraunhofer IML
  - PTV Transport Consult GmbH
  - TU Hamburg-Harburg
  - M-Five
- Final report finalized in 2017 (200 pages in German only)

OUTLINE

1. Motivation for research on heavy duty vehicles
2. Methodology
3. Results
    1. Technical perspective
    2. Economical perspective
    3. Environmental perspective
4. Summary and further research

Why is there a need for research on heavy duty vehicles?



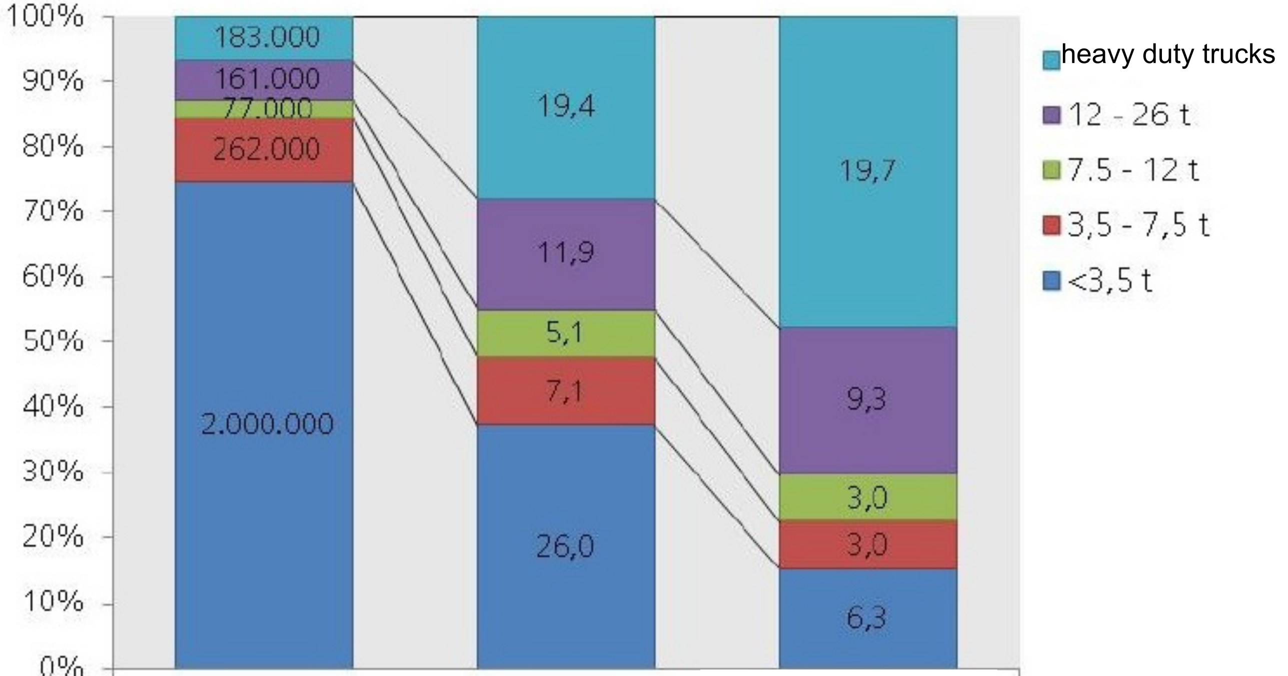
GHG Emissions by Sector – EU-28

- Massive decarbonisation in the transport sector is required

Why is there a need for research on heavy duty vehicles?

- Passenger cars account for 2/3 of CO_2 emissions from on-road transport in Germany
- Heavy duty trucks with much higher mileage, specific consumption and CO_2 emissions → CO_2 emissions of average heavy duty truck about 55 times higher than for average passenger car in Germany
- Not much research on alternative fuels in heavy duty vehicles and not many technically ready solutions for vehicles and infrastructure

Why is there a need for research on heavy duty vehicles?



	vehicle stock	vehicle mileage [bn. vkm/a]	CO_2 emissions [Mt CO_2/a, WtW]
heavy duty trucks	183.000	19,4	19,7
12 - 26 t	161.000	11,9	9,3
7.5 - 12 t	77.000	5,1	3,0
3,5 - 7,5 t	262.000	7,1	3,0
<3,5 t	2.000.000	26,0	6,3

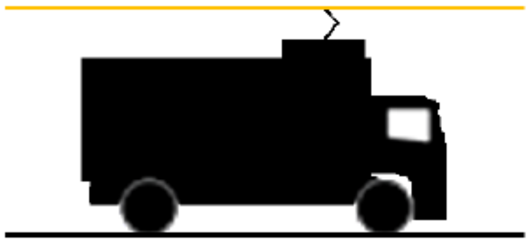
Fraunhofer ISI

We compare four alternative drive trains from three different perspectives.

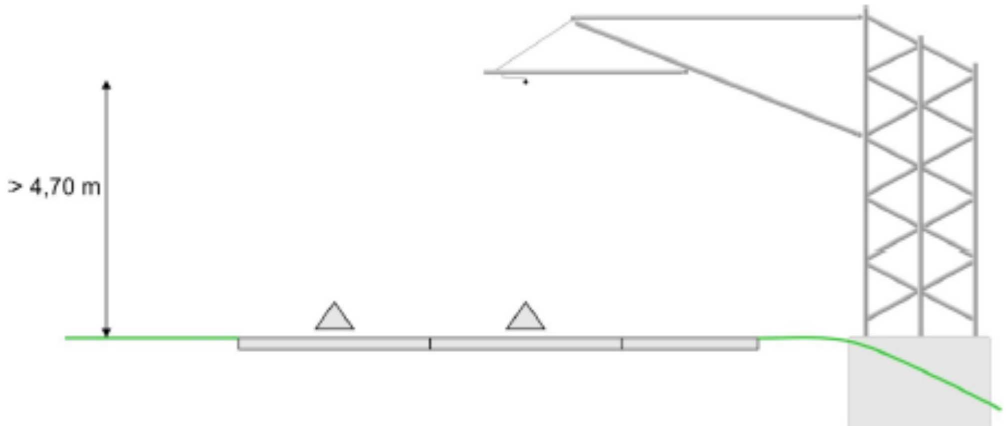
- *Diesel*
- Liquefied Natural Gas (LNG – methane)
- Fuel Cell Electric Vehicle (FCEV – hydrogen)
- Battery Electric Vehicle (BEV)
- Catenary Hybrid Vehicle (CVH) or overhead-line hybrid vehicle

Diesel hybrid truck

(with only 1 kWh battery)



Infrastructure

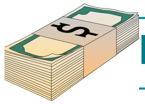


We compare four alternative drive trains from three different perspectives.

Technical perspective

- Readiness level: Technological Readiness level of European Commission
- WtW efficiency: Energy efficiency of drive train from well-to-wheel

Economical perspective



- Decision relevant operating cost: costs that differ between drive trains
- Infrastructure cost: cost for refueling or recharging infrastructure

Environmental perspective

© Can Stock Photo

- CO_2 emission: based on electricity mix and efficiency losses / natural gas
- Renewable energy needed: renewable energy needed for complete replacement of heavy duty trucks with drive train

Focus of the analysis is 2030 for Germany.

Technical perspective

Attribute	Diesel	LNG	Hydrogen (FCEV)	BEV	CHV
Technological **R**eadiness **L**evel	TRL9 actual system proven in operational environment		TRL5 technology validated in relevant environment		TRL6 technology demonstrated in relevant environment

- Diesel & LNG: available for sale
- Hydrogen & BEV: no demonstrators for heavy duty trucks up to now
- CHV: test sites in Sweden, US and Germany

Attribute	Unit	Diesel	LNG	Hydrogen (FCEV)	BEV	CHV (elec. mode)
WtT efficiency from Renewables	./.	n/a	40%	66%	95%	97%
Consumption (TtW)	kWh/km	2.46	2.78	2.25	1.23	1.60

- High efficiency losses through conversions to different fuels and aggregate phases
- Higher efficiency for drive trains without combustion

Economical perspective

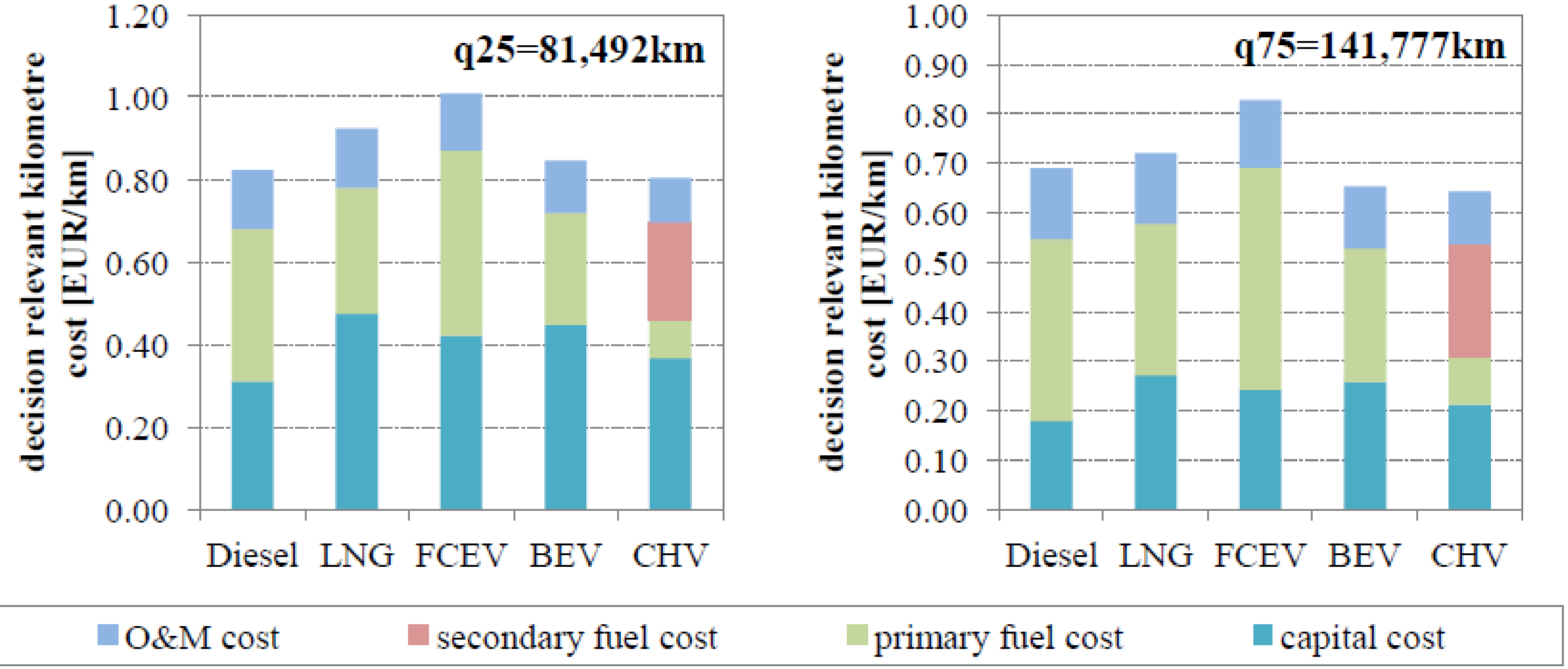
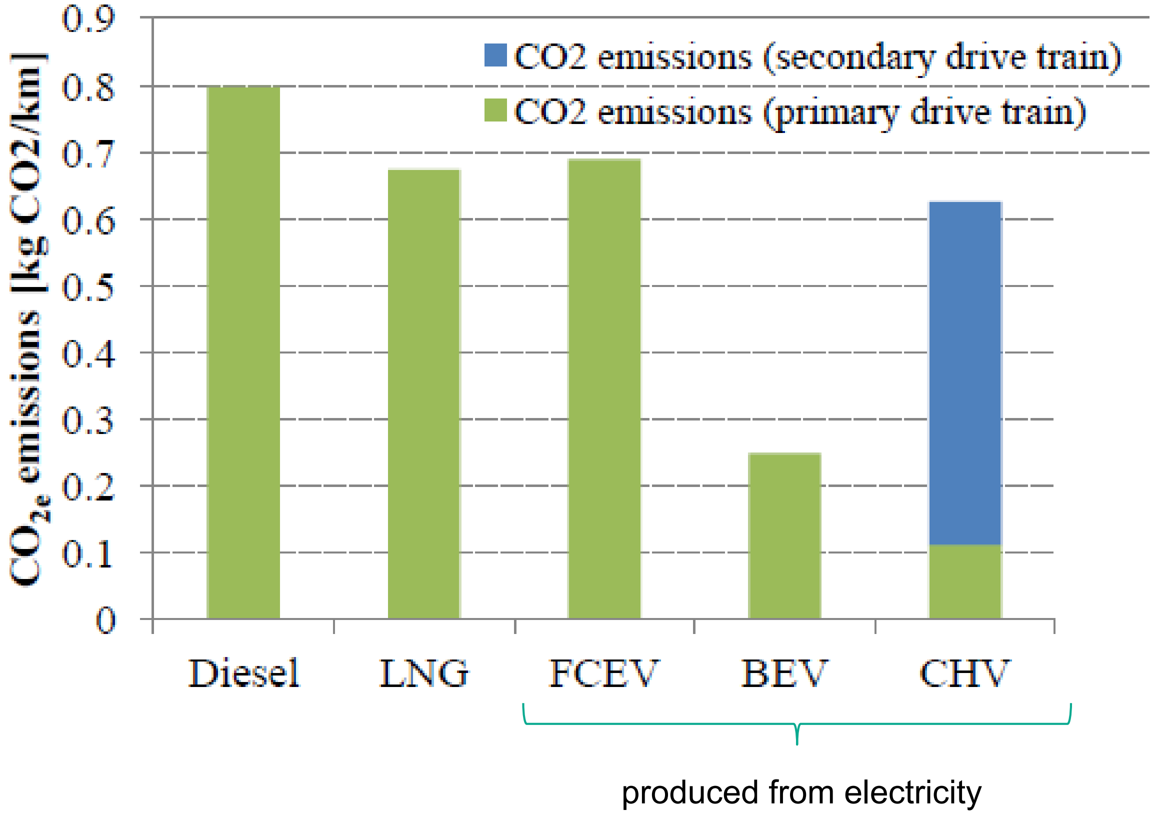


Figure 3. Cost comparison of different drive trains for heavy duty vehicles. Comparison of decision relevant cost for different annual vehicle kilometres travelled.

- Diesel vehicles still very cost efficient in 2030
- electrical drive trains benefit even more from higher VKT
- BUT: infrastructure costs are not included here

Environmental perspective (average CO2 emissions)

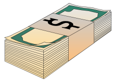


with assumed 192 g CO2/kWh for the electricity mix in Germany in 2030

- CO2 emissions may be reduced with electric drive trains
- FCEV suffers from conversion steps and transport (electrolysation, losses in electricity grid)

Synthesis of results and further research

Table 5. Summary of comparison of alternatives.



Measure	Diesel	LNG	FCEV	(BEV)	CHV
Readiness level	0	0	--	--	-
WtW efficiency	0	-	+	++	++
Decision relevant operating cost	0	-	--	++	+
Infrastructure cost	0	-	--	--	--
CO_2 emission	0	+	+	++	+
Renewable energy needed	0	--	0	++	++

LNG: only solution that is available today, but not a long-term solution because of high amount of energy needed if ran on renewable electricity

FCEV: some better WtW efficiency and CO2 emission than diesel, but lot of obstacles (infrastructure cost, operating cost, TRL)

BEV: best option in WtW efficiency, cost and environment, yet considered batteries do not fulfil requirements (175km possible, but 800km needed)

CHV: good WtW efficiency and cost, may be an interesting mid-term solution, BUT: high infrastructure investment and TRL to be improved

➔ No clear winner yet. More research is required for alternative to diesel

Discussion and further research

Methodological improvements:

- Other relevant assessment dimensions not discussed here, e.g. user acceptance, flexibility in operation, long-term energy system integration, political acceptance, and many more
- Combined measure(s) for perspectives/whole comparison

Extensions:

- Other drive trains: e.g. methanol or other liquid synthetic fuels produced from renewable energies
- Variation of technical and economical parameters

Thank you for your attention.

Source: Siemens AG

Antoine Durand

Project Manager in Competence Center Energy Technology and Energy Systems

+49 721 6809-302

antoine.durand@isi.fraunhofer.de

Patrick Plötz

Project Manager in Competence Center Energy Technology and Energy Systems

+49 721 6809-289

patrick.ploetz@isi.fraunhofer.de

Fraunhofer ISI

- WtW Efficiency

Emission WtW	Diesel	LNG	FCEL	BEV	CHV*
kg CO2/ kWh	0,324	0,242	0,306	0,202	0,196

* in elec. mode

Why is there a need for research on heavy duty vehicles?

focus of this presentation

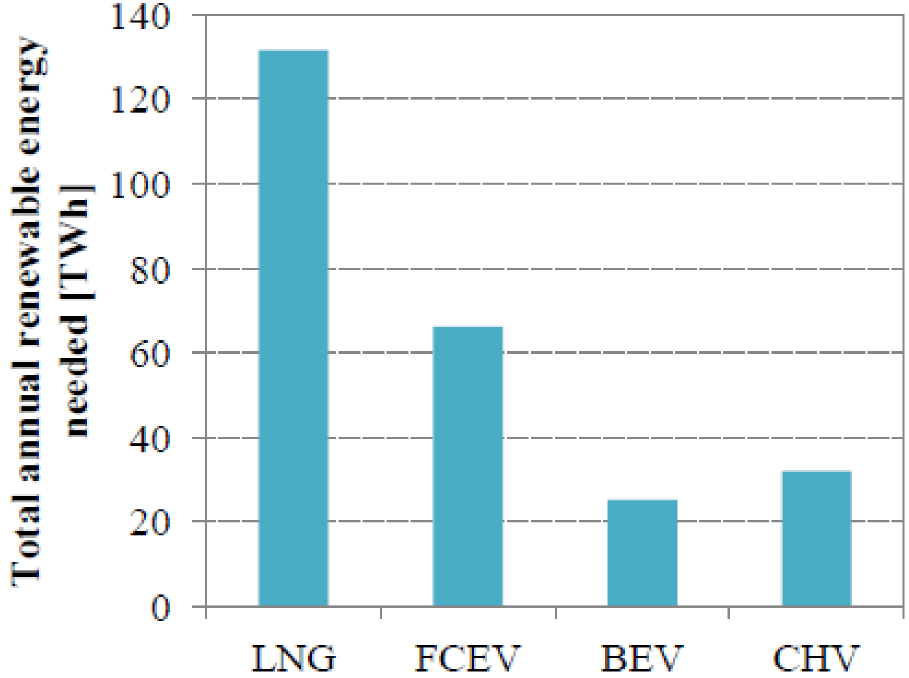
Table 1. Overview of heavy road transport

Vehicle size	Unit	Light commercial vehicle	Light duty vehicle	medium duty vehicle	upper medium duty vehicle	Heavy duty truck
Allowed total weight	Tons	(0 t; 3,5 t]	(3,5 t; 7,5 t]	(7,5 t; 12 t]	(12 t; 26 t]	(40 t)
Average annual vehicle kilometres travelled	km/a	ca. 13,000	ca. 27,000	ca. 66,000	ca. 74,000	ca. 114,000
Vehicle stock	vehicles	ca. 2,000,000	ca. 262,000	ca. 77,000	ca. 161,000	ca. 183.000.
Annual vehicle kilometres travelled	fkm/a	26 billion	7.1 billion	5.1 billion	11.9 billion	19.4 billion
Specific CO_2 emission WtW(1)(2)	g CO_2/km	241	431	594	781 (3)	1,016
CO_2 emission WtW	million t CO_2/a	6.3	3.0	3.0	9.3	19.7
Total energy consumption TtW(4)	TWh/a	19.0	9.2	9.1	28.1	59.5

(1) Well-to-Wheel emissions; (2) average of all street categories, Euro-VI, load factor: 50 % (3) weighed with the average vehicle stock of trucks > 14-20 t and trucks> 20-26 t; (4) Tank-to-Wheel emissions

References: (KBA 2014, KBA 2015, HBEFA 3.1, Truckscout 2013)

Environmental perspective (only renewables)



If we produced all the fuels from electricity....

...BEV and CHV would be most efficient and needed about 30TWh for all heavy duty trucks

...FCEV would need about double of the electric drive trains

...LNG powered vehicles would need about four times the energy.