eHighway
Catenary electrification of heavy road freight: a rationale and a path forward
Highway electrification for trucks has already started
Agenda:
Catenary electrification of heavy trucking corridors
Climate action is urgent, because waiting makes the necessary transition to zero carbon emissions much shorter and disruptive.

We need to put emissions, including those from road freight,

- on a path towards zero
- with minimum total emissions getting there

Source: Figueres et al, *Nature* June 2017

*Data from The Global Carbon Project.*
Decarbonization is a challenge for all sectors, but transport and in particular heavy long-haul transport is seen as especially difficult.

As power and other sectors decarbonize, transport is forecast to cause 40% of EU CO₂ emissions.

Road freight decarbonization is particularly a challenge for the few vehicles that emit the majority of CO₂.

Source: European Commission reference scenario for 2050 (2013) page 53

Source: Oeko Institute, Fraunhofer ISI & IFEU – Alternative drive trains and fuels in road freight transport – recommendations for action in Germany
Surface freight density: 2010
Shows high density of freight on European corridors

Source: ITF - Transport Infrastructure Needs for Future Trade Growth (2016) page 31
Surface freight density: 2050
Shows global need for road freight solutions suitable for corridors

Remember: 2050 needs to be a world with no net greenhouse gas emissions

Source: ITF - Transport Infrastructure Needs for Future Trade Growth (2016) page 31
Long haul road transport is highly concentrated to the highway network, as illustrated by German data.

The analysis of the German road network leads to the following key messages:

1. **60% of the HDV emissions occur on 2% of the road network** (BAB = 12,394 km)

2. **89% of German truck trips after leaving the highway are 50 km or less**

Source: BMVI website. Study available [here](#).

Image: HDV density on BAB-network; Source: Verkehr in Zahlen 2012; TREMOD 2012

Length of road network:
- BAB = Federal freeways (12,394 km)
- BS = Federal roads (40,400 km)
- LS = State roads (86,600 km)
- KS = District roads (91,600 km)
- GS = Municipal roads (>420,000 km)

CO₂ emissions from HDV:
- Urban roads
- Non-urban roads
- Federal freeways

Source:
- BMVI website
- Study available [here](#)
Agenda:
Catenary electrification of heavy trucking corridors

Why

What

How
eHighway truck technology – from proof-of-concept to field trials

Development of the eHighway vehicle technology

2010
1. Generation
Proof of concept

2019
2. Generation
Swedish and US Demonstration projects

3. Generation
Field trials

Operations up to 100 km/h possible
Connection and disconnection to catenary in motion
Recharging of onboard energy storage while driving
No limitations for first and last mile
Catenary solution for trucks is seen as the most efficient and economical among known alternative propulsion solutions

- Price between 1.5m - 2.3m EUR/km* largely depending on no. of trucks, topography, distance of net-infeeding points and condition of the motorway according to studies**

- Upgrade of initial infrastructure design possible when more hybrid trucks with additional power demand are deployed later

- Price for Catenary Hybrid Truck expected to be in the range of 20% on top of standard tractor with ICE***

- BEV Truck expected to be even cheaper compared to standard tractor with ICE by 2050 in ERS scenario****

*) per km in both driving directions
**) ICCT P.21ff, Fraunhofer P.33/44
***) Oeko Institute, P45
****) European Climate Foundation P.43

Source: Oeko Institute, Fraunhofer ISI & IFEU – Alternative drive trains and fuels in road freight transport – recommendations for action in Germany, page 10
Agenda:
Catenary electrification of heavy trucking corridors

Why
What
How
German field trials in 2019 are a necessary near term step for the development of the system

**Information and routing**

**Federal State of Hesse**
- Infrastructure project awarded to Siemens
- Track length / Amount of trucks: 5km / 5
- Construction: April-Nov 2018
- Demonstration: Official start May 7 2019

**Federal State of Schleswig Holstein**
- Infrastructure project awarded to Siemens
- Track length / Amount of trucks: 5-6km / 5
- Construction: Started Oct 2018
- Demonstration: Start in 2019

**Federal State of Baden-Wuerttemberg**
- Tender published Nov 2018
- Track length / Amount of trucks: 5-6km / 5
- Customer’s targeted start of Demonstration: 2019

Project homepage: **ELISA**
Project homepage: **FESH**
Project homepage: **eWayBW**
Infrastructure construction with minimum disruption, delivered on time and on budget

- Search shafts checking on underground wires and pipes
- Bringing in the steel tubes as foundation
- Setting up the poles
- Installation of the cantilevers
- Pulling the wires
- Connecting the substations

Unrestricted © Siemens Mobility GmbH 2019
Eco-Mobility 2019, 14./15.11.2019 Vienna
Commercialization of zero emission trucking starts with shuttles, which are then linked up to form a larger network

Shuttle applications (ca 20-100 km)

• The next steps should be pilot projects proving that zero-emission heavy road freight is both economical and practical\(^1\)

• Experts on highway trucking recommend local or regional catenary trucking projects, the most feasible approach for the zero-emission technologies\(^2\)

CEO of Scania & CTO Volvo Group

Network roll-out

• The systemic transition to zero emission road freight requires breaking out from early shuttles to large scale network

• Possible important role of hybrids (driving a very high share on electricity) as users of partial infrastructure network

• Nearly completed network will facilitate transition to fully zero-emission mobility

→ Providing the right infrastructure is a necessary precondition for zero emission long-haul trucking


Climate protection measures of German Ministry for Transport include catenary solution for HDV

UBA-Ö: Reduction of 7.2 Mio. t CO₂ until 2030 in transport sector

- 2.7 Mio. t CO₂ potential reduction through electrification (e.g. catenary)

M6 Einführung eines elektrifizierten Systems auf dem hochrangigen Straßenetz (z.B. Oberleitungen)

Intensität 1:
Schaffung eines flächendeckendes Stromversorgungsnetz am hochrangigen Straßenetz für SNF in Anhängigkeit von Fahrzeugen (z.B. Oberleitungen) bis 2040

Potential in Intensität 1: sehr groß (2.7 Mio. t THG)


German Climate Protection Program 2030: Major steps towards zero emission by 2050

«The goal is that by 2030 about one third of the mileage in heavy road freight transport will be electric or based on electricity-based fuels» (p. 80)

Kapitel im Klimaschutzprogramm 2030

3.4.3.11 Kurzbeschreibung: Maßnahmen für emissionsfreie Logistik

Quelle: BMU (2019) Klimaschutzprogramm 2030
A European and harmonized solution could take shape already today - enabling zero emission trucking on TEN-T corridors by 2050

**UK**
- £ 400m invest in charging infrastructure (PEV) announced
- DfT: dynamic electrification of HDV supports zero emission pathway

**Germany**
- 2018-2022: Three fields trials on motorways A1 and A5 and B462 publicly funded by BMU € 45,3m
- Extension of catenary network part of climate protection program 2030

**Hungary**
- Minister of Technology & Innovation announced to cooperate in third German Field trial in Baden-Württemberg

**Austria**
- Federal Environment Agency considers catenary solution high potential intensity in order to abate 2,7m t CO₂ emissions

**USA**
- UC Davis study outlines advantages of catenary solution compared to alternative propulsion solutions for trucks

---

- **Sweden**
  - 2km Demonstration project on E16 in operation since 2016
  - Start / roll-out of national ERS by 2022

---

Legend:
- Interest in catenary solution exists
- Study with regard to catenary solution for HDV exists
- Catenary solution: demo / field trial realized or in preparation
Questions?
Your point of contact for eHighway at Siemens Mobility Germany

Gerrit Stumpe
Business Developer eHighway
Siemens Mobility GmbH
Mobility
Technology & Innovation
eHighway
Erlangen
Mobil: +49 (173) 702 7740
E-mail: gerrit.stumpe@siemens.com

www.siemens.com/ehighway
#eHighway
Zero emission trucks are possible with renewable energy, but efficiency varies greatly.

<table>
<thead>
<tr>
<th>Pathway</th>
<th>Range</th>
<th>Cost per km</th>
<th>Efficiency</th>
<th>Example vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electric Road Systems</strong></td>
<td>60 km</td>
<td>19 ct/km</td>
<td>77%</td>
<td></td>
</tr>
<tr>
<td><strong>Battery</strong></td>
<td>48 km</td>
<td>20 ct/km</td>
<td>62%</td>
<td></td>
</tr>
<tr>
<td><strong>Hydrogen</strong></td>
<td>24 km</td>
<td>55 ct/km</td>
<td>29%</td>
<td></td>
</tr>
<tr>
<td><strong>Power-to-Gas</strong></td>
<td>17 km</td>
<td>70 ct/km</td>
<td>20%</td>
<td></td>
</tr>
</tbody>
</table>

1) Including storage

Source: German Ministry of Environment
eHighway offers efficient and low cost electricity supply, thanks to smooth load profiles and high connection voltage

- Flexible distributed loads are essential for an energy supply based mainly on fluctuating renewable based generation.

- The charging of BEV and PHEV vehicles leads to daily peak loads. eHighway exhibits a smoother load profile.

- eHighway-enabled trucks using hybrid drives (e.g. combustion engine using sustainable biofuels) can contribute to system peak load reduction (active load management/deferrable load).

- Grid connected eHighway truck systems enable a more efficient use of energy.

Source: [http://www.energieversorgung-elektromobilitaet.de/Kernaussagen.html](http://www.energieversorgung-elektromobilitaet.de/Kernaussagen.html)
## Translated Table 7 from German Transport Ministry (BMVI) report

<table>
<thead>
<tr>
<th>Components</th>
<th>Basis for calculations</th>
<th>Costs (EUR/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid connection point</td>
<td>Ca. 15.000 EUR per connection. At a pattern of a connection point every 3 km leads to 5.000 EUR/km</td>
<td>5.000,--</td>
</tr>
<tr>
<td>Feed line from grid connection point to</td>
<td>Ca. 200 EUR per m of cable trench (underground, built up area), ca. 100 EUR per m cable; At an average of 2.5km connection length leads to 750.000 EUR per connection. At a pattern of a connection point every 3 km leads to 250.000 EUR/km</td>
<td>250.000,--</td>
</tr>
<tr>
<td>substation along the route</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Substation</td>
<td>Ca. 300.000 EUR per MVA (incl. communication and safety technology); A 6 MVA power rating results in costs of 1,8m EUR per substation; At a pattern of a connection point every 3 km leads to 0,6m EUR/km</td>
<td>600.000,--</td>
</tr>
<tr>
<td>Poles</td>
<td>Ca. 10.000 EUR per pole (incl. cantilever and foundations); A pole distance of 50m results in costs of 400.000 EUR per km (covering both road directions)</td>
<td>400.000,--</td>
</tr>
<tr>
<td>Catenary (contact line)</td>
<td>Ca. 300 EUR per m, e.g. 600.000 EUR per km (covering both road directions)</td>
<td>600.000,--</td>
</tr>
<tr>
<td>Guard rails</td>
<td>Ca. 100 EUR per m; under the assumption that the entire route needs to be equipped, costs are 200.000 EUR/km (covering both road directions)</td>
<td>200.000,--</td>
</tr>
<tr>
<td>Planning, Procurement and Project</td>
<td>Ca. 10% of the investment costs</td>
<td>205.000,--</td>
</tr>
<tr>
<td>management</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>2.260.000,--</strong></td>
</tr>
</tbody>
</table>

### Overview of alternative power trains and fuels for trucks

<table>
<thead>
<tr>
<th>Fuel cell (FC)</th>
<th>Battery electric (BE)</th>
<th>Overhead catenary (OC)</th>
<th>Synthetic fuels (PTG / PTL)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Motors and technology</strong></td>
<td>Electric motor and fuel cell with hydrogen as energy storage</td>
<td>Electric motor and battery as energy storage</td>
<td>Internal combustion engine and pressurized gas or liquid tank as energy storage device</td>
</tr>
<tr>
<td><strong>Conversion steps</strong></td>
<td>Conversion to hydrogen (electrolysis)</td>
<td>Direct Use</td>
<td>Conversion to hydrogen (electrolysis) and further to carbonaceous fuel</td>
</tr>
<tr>
<td><strong>Fuel production from electricity</strong></td>
<td></td>
<td>Direct Use</td>
<td></td>
</tr>
<tr>
<td><strong>Efficiency today with the use of renewable electricity</strong></td>
<td>Circa 40 – 50 % 60 – 70 % 25 – 35 %</td>
<td>Circa 90 % 90 % 80 %</td>
<td>Circa 35 – 40 % 50 – 60 % 20 – 25 %</td>
</tr>
<tr>
<td><strong>tank-to-wheel</strong></td>
<td>First commercially available vehicles (TRL 6-7)¹¹</td>
<td>Several test projects (TRL 6-7)¹¹</td>
<td>Conventional vehicles</td>
</tr>
<tr>
<td><strong>well-to-tank</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>well-to-wheel</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Technological readiness level of vehicles</strong></td>
<td>Several test projects (TRL 6-7)¹¹</td>
<td>First commercially available vehicles (TRL 6-7)¹¹</td>
<td>Conventional vehicles</td>
</tr>
<tr>
<td><strong>Key challenges</strong></td>
<td>Infrastructure development and increased power requirements due to high conversion losses, cost reduction in fuel production</td>
<td>Limited range, long charging time and payload losses</td>
<td>Infrastructure development, acceptance, integration in logistics processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Strongly increased power demand due to highest conversion losses, cost reduction in vehicle and fuel production</td>
</tr>
</tbody>
</table>

Source: Oeko Institute, Fraunhofer ISI & IFEU – *Alternative drive trains and fuels in road freight transport – recommendations for action in Germany* page 10