eHighway
Electrified heavy duty road transport
Greenhouse gas (GHG) emissions of road freight transport are becoming an increasing challenge for the decarbonization.

1) Prognosticated growth in road freight transport
   - Global road freight transport is going to grow by 300% between 2015 and 2050
   - In Germany road freight transport grew between 2015 and 2016 by 2.8%

2) Modal split of freight transport in 2050
   - German freight approx. 60% on road
   - By using the maximum of shift potentials, rail freight is growing up to 30% by 2050

3) Reductions goals of GHG-emissions by 2050
   - Economy wide goal of the German government: reduction by 80% to 95% (basis 1990)
   - Transport-sector: reduction of 98% necessary

4) Transport sector as GHG-emitter
   - 20% of all GHG-emissions generated by transport sector
   - Increase by 5.4m tons emissions in Germany’s transport sector in 2016

Sources:
- ITF Transport Outlook 2017, Januar 2017
- Umweltbundesamt, Pressemitteilung Nr. 09 vom 20.03.2017
- Grünjes / MO TI EH
Requirements for the optimal solution for decarbonization of road freight transport

Compatible with existing infrastructure
System is safe, reliable and easy to maintain
Long lifecycle
High efficiency
Little to no impact on standard operation
Competible with other alternative fuel technologies
Compatible for freight- and passenger transport
Able to achieve 100% decarbonization
Economical
Scalable and interoperable

The solution
eHighway
How it works - Animation

https://www.youtube.com/watch?v=2V2yZkRFBKQ&t=7s
Compatible with and complementary to other alternative fuel technology

The eHighway hybrid truck can be configured to suit specific applications

<table>
<thead>
<tr>
<th>Truck types</th>
<th>Drive system</th>
<th>On-board source of electricity</th>
<th>Combustion engine</th>
<th>Non-electrical source of energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tractor truck (2 axles)</td>
<td>Parallel-hybrid</td>
<td>Battery (small)</td>
<td>Engine (small)</td>
<td>Diesel</td>
</tr>
<tr>
<td>Tractor truck (3 axles)</td>
<td>Serial-hybrid</td>
<td>Battery (medium)</td>
<td>Engine (medium)</td>
<td>Bio-fuel</td>
</tr>
<tr>
<td>Rigid truck (2 axles)</td>
<td>Full electric</td>
<td>Battery (large)</td>
<td>Engine (large)</td>
<td>CNG/LNG</td>
</tr>
<tr>
<td>Rigid truck (3 axles)</td>
<td></td>
<td>Fuel cell</td>
<td></td>
<td>H₂</td>
</tr>
<tr>
<td>Rigid truck (4 axles)</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Zero emission trucks are possible with renewable energy, but efficiency varies greatly.

### Pathway Range

<table>
<thead>
<tr>
<th>Pathway</th>
<th>Cost per km</th>
<th>Efficiency</th>
<th>Example vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric Road Systems</td>
<td>19 ct/km</td>
<td>77%</td>
<td>eTruck (Catenary-Hybrid)</td>
</tr>
<tr>
<td>Battery</td>
<td>20 ct/km</td>
<td>62%</td>
<td>eTruck (Battery)</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>22 ct/km</td>
<td>29%</td>
<td>Fuel cell truck</td>
</tr>
<tr>
<td>Power-to-Gas</td>
<td>15 ct/km</td>
<td>20%</td>
<td>Gas-truck</td>
</tr>
</tbody>
</table>

### Example

- **Electric Road Systems:**
  - Range: 60 km
  - Cost per km: 19 ct/km
  - Efficiency: 77%
  - Example: eTruck (Catenary-Hybrid)

- **Battery:**
  - Range: 48 km
  - Cost per km: 20 ct/km
  - Efficiency: 62%
  - Example: eTruck (Battery)

- **Hydrogen:**
  - Range: 24 km
  - Cost per km: 55 ct/km
  - Efficiency: 29%
  - Example: Fuel cell truck

- **Power-to-Gas:**
  - Range: 17 km
  - Cost per km: 70 ct/km
  - Efficiency: 20%
  - Example: Gas-truck

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1) Including storage

Source: German Ministry of Environment
In comparison to other solutions the eHighway proves its economic advantages

Recently published Umweltbundesamt (UBA) report compares different energy scenarios and options for a greenhouse-gas-neutral transport sector in 2050.

To reach greenhouse gas (GHG) neutrality in the transport sector by 2050 scenarios four different energy supply strategies are developed and compared with each other.

For long haulage the scenario E+ assumes a wide utilization of OC-GIV (Overhead Catenary Grid-Integrated Vehicle).

The report verifies that the E+ scenario (corresponding to the eHighway) has **approx. 50% less difference cost** (CAPEX + OPEX) to the next proposed scenario (FL+) in comparison with the reference scenario*.

* The reference scenario is the F1+ scenario but with conventional fuels. No taxes and environmental benefits are taken into consideration.

**Figure 3-3: Long haul road transport**

<table>
<thead>
<tr>
<th>Energy supply</th>
<th>Energy infrastructure</th>
<th>Vehilces</th>
<th>Total costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>FL+</td>
<td>E+</td>
<td>CH4+</td>
<td>H2+</td>
</tr>
</tbody>
</table>


F1+: PtL-liquid fuels as central GHG-free energy supply option
E+ : Electrical energy as central GHG-free energy supply option (plus Hybrid F1+)
CH4+: PtG-CH4 as central GHG-free energy supply option
H2+: PtG-H2 as central GHG-free energy supply option
German industry association (BDI) recommends 4.000 to 8.000 km of overhead catenary lines as a cost-effective climate action for HDVs

### Background
- BDI commissioned an independent BCG and Prognos report looking at all sectors of the economy
- Investigated the most cost effective ways to reach German climate goals: -80% and -95% GHG
- Involved 68 BDI-member associations and companies, 200 industry experts and 40 workshops

### Major findings
- Reaching the 80% reduction is possible by pushing existing technologies to the max. Has economically positive effects, even if Germany acts alone.
- Reaching the 95% reduction goal touches the limit of what can be expected from technology and citizens. Only in joint action with G20 economies would this be economically manageable.

### Transport highlights
- Shift to rail leads to an increase by 88% of ton-km of freight activity on rail by 2050
- No additional biofuels for transport (other sectors will need biomass more and out-bid transport)
- PtX only in 95% scenario (due to high expected costs of fuel)

### eHighway
- Building overhead catenary is the cheapest solution for HDVs, despite high infrastructure costs.
- Recommends building 4.000 km overhead contact line in the 80% scenario and 8.000 km in 95%
- Based on DE perspective. EU solution brings large synergies and is even more cost-effective
- Investment decision needs to be made by 2025, leading to first 400 km in operation by 2028.
Funded research projects supplement the projects on public roads in Los Angeles and Sweden

<table>
<thead>
<tr>
<th>Research Projects</th>
<th>Projects on Public Roads</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ENUBA (Germany)</strong></td>
<td><strong>Los Angeles – Port Application</strong></td>
</tr>
<tr>
<td>• First research project with BMUB</td>
<td>• One mile demonstration as connection to near-dock rail terminals for cargo vehicles for 6 months</td>
</tr>
<tr>
<td>• Duration: 05/2010 – 09/2011</td>
<td>• Primary goal is to promote the implementation of zero emission goods movement technologies</td>
</tr>
<tr>
<td><strong>ENUBA 2 (Germany)</strong></td>
<td><strong>Sweden – Highway Application</strong></td>
</tr>
<tr>
<td>• Second research project with BMUB</td>
<td>• Cooperation with Volvo trucks and local truck converter</td>
</tr>
<tr>
<td>• Duration: 05/2012 – 12/2015</td>
<td>• Overall aim is to evaluate Electric Road System options prior to introduction on road network</td>
</tr>
<tr>
<td><strong>ELANO (Germany)</strong></td>
<td></td>
</tr>
<tr>
<td>• Third research project with BMUB</td>
<td></td>
</tr>
<tr>
<td>• Duration: 01/2016 – 09/2019</td>
<td></td>
</tr>
</tbody>
</table>
Field Trials in Germany are the next step for the development of the system.
Thank you for your attention

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