Decarbonising Freight Transport: a review of the technical, operatio nal and managerial options

Guest Speaker | Alan McKinnon
Professor of Logistics
Kühne Logistics University, Hamburg, Germany

Webinar Series | Chair in Energy Sector Management
HEC Montréal,
November 7th 2017
About Kühne Logistics University

• Private, state-accredited university in Hamburg, Germany
• Founded in 2010 by the Kuehne Foundation
• Specialises in logistics and supply chain management
• Sustainability of logistics is a major research focus
• www.the-klu.org

KLU wins German government Higher Education prize for freight transport and logistics 2017
Freight Transport Contribution to Greenhouse Gas Emissions

**Transport:**

- 2010: **6.5** bn tonnes of CO$_2$e
- 2050: **12** bn tonnes of CO$_2$e business-as-usual trend
- 2050: Limit CO$_2$e from all activity to 20bn tonnes
- 2050: 14% transport share of 20 bn = **2.8** bn tonnes

**IDDRI / SDSN (2014)**

Freight share of total GHG emissions:

- 2010: 7%
- 2050: 16% (business as usual projection)

One of the ‘most challenging sectors’ in which to achieve ‘deep emission reductions’

To meet EU target of 60% reduction in total CO$_2$ emissions from freight transport between 1990 and 2050 current carbon intensity of freight transport must fall 80-85%

‘factor 6 reduction’ (Smokers et al, 2017)

Only 13% of 154 Intended Nationally Determined Contributions (INDCs) submitted to COP21 mention freight transport (source: Sudhir Gota)
Global Projection of Freight Traffic Growth: \( bn \text{ tonne-kms by all modes} \)

<table>
<thead>
<tr>
<th></th>
<th>2015</th>
<th>2030</th>
<th>2050</th>
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<tbody>
<tr>
<td>Rail</td>
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<td>Road</td>
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<tr>
<td>Total</td>
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</table>

% of \( CO_2 \) emissions
Surface freight (road + rail)
- 2015: 71%
- 2050: 68%

Forecast Growth of Surface Freight (road + rail)
\( bn \text{ tonne-kms} \)

Global road share in 2050: 62%

Source: OECD / ITF Transport Outlook 2017
Global Freight Traffic Growth, GDP and CO₂ Emissions

Close correlation between GDP and road freight growth

1% increase in GDP → 1.07% increase in road tonne-km

Data points for large sample of countries between 1971 and 2014

Source: IEA (2017)

Relationship between road tonne-kms per capita and GDP per capita

Source: Eom, Schipper and Thompson, 2012
Scoping the Decarbonisation of Freight Transport

Logistics System Design / Supply Chain Restructuring

Freight Modal Shift

Vehicle Routing and Scheduling

Vehicle Loading

Driving

Vehicle Maintenance

Vehicle Technology / Alternative Fuels

emissions per vehicle-km

total emissions

total vehicle-kms

emissions per vehicle-km
Adapting the Kaya Identity to Freight Transport

Kaya Identity (IPCC 1990)

**Total CO₂ Emissions** = Population x GDP / Population x Energy/GDP x CO₂ / Energy

Freight application of the Kaya Identity

**Freight CO₂ Emissions** = GDP x tonne-km / GDP x vehicle–km / tonne-km x energy / vehicle-km x CO2 / energy

<table>
<thead>
<tr>
<th>Mode</th>
<th>transport intensity</th>
<th>asset utilisation</th>
<th>energy efficiency</th>
<th>carbon content</th>
</tr>
</thead>
<tbody>
<tr>
<td>road</td>
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<td>rail</td>
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<tr>
<td>waterborne</td>
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<tr>
<td>aviation</td>
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</tbody>
</table>
Kaya Identity (IPCC)

Total CO₂ Emissions = Population x GDP/Population x Energy/GDP x CO₂ / Energy

Freight application of the Kaya Identity

- **Freight CO₂ Emissions** = GDP x tonne-km / GDP x vehicle-km / tonne-km x energy / vehicle-km x CO₂ / energy
  - transport intensity
  - asset utilisation
  - energy efficiency
  - carbon content

**modal split**

- **road**
- **rail**
- **waterborne**
- **aviation**

**total freight-related CO₂ emissions**

Most countries lack necessary freight data to calibrate the key parameters.
Potential for Decarbonising Freight Transport in 15 Countries: 2010 - 2050

- Decoupling freight tonne-km from GDP
- Decoupling energy use from freight t-km
- Decoupling freight energy use from related emissions

Estimation of CO₂ Emissions from Freight Transport: *an inexact science*

Estimates of CO₂ emissions from UK road haulage 1990-2006


Industry / commodity level of disaggregation

Multi-dimensional harmonisation

Geography / supply chain transport mode

Level of disaggregation
Targets to Reduce the Carbon Intensity of Freight Transport

<table>
<thead>
<tr>
<th>company</th>
<th>normaliser</th>
<th>time period</th>
<th>% carbon reduction target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deutsche Post / DHL</td>
<td>‘every letter and parcel delivered, every tonne of cargo transported and every sq.m. of warehouse space’</td>
<td>2007-2020</td>
<td>30%</td>
</tr>
<tr>
<td>DB-Schenker</td>
<td>Tonne-km</td>
<td>2006-2020</td>
<td>At least 20%</td>
</tr>
<tr>
<td>UPS</td>
<td>UPS Transportation Index</td>
<td>2010-2017</td>
<td>5%</td>
</tr>
<tr>
<td>UPS Airlines – Global</td>
<td>Pounds of CO₂ emitted for every ton of capacity transported on nautical mile</td>
<td>2005-2020</td>
<td>20%</td>
</tr>
<tr>
<td>Fedex (aircraft)</td>
<td>available ton mile (ATM)</td>
<td>2005-2020</td>
<td>20%</td>
</tr>
<tr>
<td>TNT (Mail and Express)</td>
<td>not specified</td>
<td>2007-2020</td>
<td>45%</td>
</tr>
<tr>
<td>Maersk Line</td>
<td>not specified</td>
<td>2007-2020</td>
<td>25%</td>
</tr>
<tr>
<td>NYK</td>
<td>‘unit of transportation from vessels’</td>
<td>2006-2013</td>
<td>10%</td>
</tr>
</tbody>
</table>

Source: McKinnon and Piecyk, 2012

Inconsistency: government targets for absolute CO₂ reductions vs corporate CO₂ intensity targets

Deutsche Post DHL Group commits to zero emissions logistics by 2050

- Ambitious interim goals for carbon efficiency, local emissions, green customer solutions and employee engagement by 2025
- Previous climate protection target achieved ahead of schedule
- Frank Appel: “The decisions we make today will determine how our children live 30 years down the line.”

Source: DHL website

40% improvement in carbon intensity of global logistics between 2010 and 2020

Strong growth in the total amount of logistics activity offsets carbon intensity reductions

Freight is in the residual ‘Other transport’ category

Source: DHL website
Five Sets of Decarbonisation Initiatives for Freight Transport

- Reduce Demand for Freight Transport
- Shift Freight to Lower Carbon Transport Modes
- Optimise Vehicle Loading
- Increase Energy Efficiency of Freight Movement
- Reduce the Carbon Content of Freight Transport Energy
‘De-growth’ – reaching ‘peak stuff’? (Steve Howard, IKEA)

- substituting experiences for physical goods?
- move to ‘sustainable consumption’?

Dematerialisation: improve ‘material efficiency’:

- Increased recycling and remanufacturing: circular economy
- Digitisation of physical products: freight movement → electronic transmission
- Designing products with less material: miniaturisation, lightweighting
- 3D Printing: less material, less wastage, eliminates supply chain links

To have large impact on freight emissions:

- Need major uptake of 3D printing at domestic level and local ‘fab’ shops
- Huge increase in functionality of 3D printers
- Collapse in unit price of 3D printing

Developed world perspective

Huge future demand for material consumption in lower income countries

Future Material Content of the Economy

Source: ING (2017)
Relationship between trade and global GDP

Declining ratio of trade to GDP

- Trade-income elasticity (left-hand scale)
- Exports / GDP % ratio at 2005 prices (right-hand scale)

Are the lower trend lines temporary aberrations or structural changes in the global economy?

Potential New era of protectionism?
- Doha Round failed
- TPP and TTIP stalled
- Brexit / Trump

WTO Trade Facilitation Agreement (Bali 2013)
- Will reduce total trade costs by 13-15%
- Generate additional $1 trillion in trade

Reshoring debate

- Boston Consulting Group (2015)
- A T Kearney (2015)

- Future Trends in International Trade and Globalisation

- Boston Consulting Group (2015)
- A T Kearney (2015)

- Reshoring debate
Restructuring of supply chains

- relocalize production / sourcing
- decentralize inventory
- reversal of key business trends
- high carbon-mitigation costs

Overall CO\textsubscript{2} impact of relocation

Transport = typically a small % of life cycle emissions

Source products where production-related emissions are minimised

Roughly 40% of international trade yields net CO\textsubscript{2} emission reductions (Cristea et al 2013)

Fossil fuel phase-out

- 4.1 billion tonnes of coal, oil and gas were moved internationally by sea in 2015 - 41% of all maritime trade by weight
- Constructing renewable energy infrastructure is material- and transport-intensive

New freight growth sectors

- carbon capture and storage
- air conditioning
- resettlement of populations
- adaptation of infrastructure to climate change

Source: Malo, 2017

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Freight decarbonisation measures in INDCs submitted to COP21
Source: Sudhir Gota (2015)

**Carbon intensity of intermodal services?**

Need to express modal carbon intensities on a door-to-door basis

Need to base policy and mode choice decisions on projection of **future** modal carbon intensities

**Average Carbon Intensity of Freight Modes**

<table>
<thead>
<tr>
<th>Mode</th>
<th>gCO₂e/tonne-km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk Carrier vessel</td>
<td></td>
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<tr>
<td>Pipeline</td>
<td></td>
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<tr>
<td>Container ship</td>
<td></td>
</tr>
<tr>
<td>Rail</td>
<td></td>
</tr>
<tr>
<td>RoRo ferry</td>
<td></td>
</tr>
<tr>
<td>Articulated truck</td>
<td></td>
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<tr>
<td>Rigid truck</td>
<td></td>
</tr>
<tr>
<td>Van</td>
<td></td>
</tr>
<tr>
<td>Airfreight long-haul</td>
<td></td>
</tr>
<tr>
<td>Airfreight short-haul</td>
<td></td>
</tr>
</tbody>
</table>

**Defra (2016)**

**Need holistic measurement of freight-related emissions**
Shifting Freight to Lower Carbon Modes

Long term shift to trucking:
- EU28: road increased share of tonne-kms from 67% (1995) to 72% (2014)
- US: road increased share of tonne-kms from 41% (1995) to 48% (2013)
- India: rail share of tonne-kms halved between 1990 (63%) and 2015 (31%)

*based on analysis by Tavasszy and van Meijeren (2011)

2030 modal shares if EU 2011 White Paper target is achieved*

- difficult to reverse of past modal trends
- past government efforts merely eased the decline of lower carbon modes
- ‘logistical lock-in’ – alignment of industrial property to road network
- managerial reluctance to risk shifting mode
Promoting the Use of Low Carbon Freight Transport Modes

- Concentrate modal shift efforts on strategic intermodal corridors
- Support development of intermodal hubs
- Apply synchromodality principle
- Internalise the external costs of freight transport
- Subsidise use of alternative modes which cut CO₂
- Use land use planning policies to favour modes
- Prioritise investment in rail and water infrastructure
- Alter regulatory / competitive frameworks
- Provide advisory services on modal shift

Investigating synchromodality from a supply chain perspective

Chuanwen Dong, Robert Boute, Alan McKinnon, Marc Verelst

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Empty Running of Freight Vehicles

Data only for trucking

EU28: % of truck-kms run empty (2014)
- Within countries: 25%
- International: 13%
- All trucking: 21%

US SmartWay fleets: 16.7% (2014)
Australia: 29% (2012)
India: estimates of 40-50%

Main reasons for empty running:
- geographical imbalances in traffic flow: triangulation
- lack of knowledge of available loads: online freight exchanges
- incompatibility of vehicles and loads
- tight scheduling of deliveries
- journeys too short to justify backloading
- lack of co-ordination between transport and purchasing depts

Retrospective assessment of the potential for backloading

Cumulative reduction in opportunities

31.6%
23.2%
10.6%
2.4%

screening criterion

Source: McKinnon and Ge (2005)

29 fleets: 8995 journey legs
Optimise Vehicle Loading

- weight-based measures
  - 2-dimensional view
    - deck-area coverage
    - ‘load length”
  - 3-dimensional view
    - stacking height
    - cube utilisation
- freight density
- space-related measures
- loaded trips
Density of Freight and Vehicle Carrying Capacity

- optimum density to fill 40 tonne truck

vehicles ‘cubing out’ space is the constraint
vehicles ‘weighing out’ weight limit is the constraint

- very difficult to assess the potential for increasing vehicle utilization and cutting CO₂ by this means
- under-utilization of vehicle capacity is usually not due to inefficiency / poor management
- logistics optimization often involves trading off vehicle utilization for less inventory, higher sales etc

Time to relax the Just-in-Time principle?
Just-in-Time Replenishment

Relaxing JIT:
- more time to consolidate loads and find backhauls
- easier for rail and water to compete for freight

But:
- JIT is business paradigm that minimizes waste
- contributes to energy and CO₂ savings elsewhere

Potential for rescheduling supply chain processes to cut CO₂ emissions?

1. processing of inbound order
2. internal administration / checks
3. order picking
4. order awaiting loading
5. vehicle loading
6. vehicle waiting time
7. delivery
8. waiting time at reception point
9. vehicle off-loading and put-away
10. product storage prior to use / sale

- accelerate internal processes
- Internal time savings offset longer transit times
- net CO₂ saving within fixed order lead time

Freight Transport Deceleration: Its Possible Contribution to the Decarbonisation of Logistics

McKinnon (2016) Transport Reviews
Supply Chain Collaboration

Deep decarbonisation of freight transport will require much greater sharing of logistics assets

- change in the corporate mindset
- exhaustion of internal efficiency improvements
- confirmation of legality
- new IT tools support collaborative working

Nestle – Pepsico Horizontal Collaboration in Benelux

<table>
<thead>
<tr>
<th>Deliveries</th>
<th>Kg CO2 / tonne</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Separate delivery</td>
<td>43.8</td>
</tr>
<tr>
<td>2. Groupage</td>
<td>27.3</td>
</tr>
<tr>
<td>3. Collaborative synchronisation</td>
<td>20.3</td>
</tr>
</tbody>
</table>

Source: Jacobs et al 2014

Examples

P&G and Tupperware (EU)

Nestle–United Biscuits (UK)

• change in the corporate mindset
• exhaustion of internal efficiency improvements
• confirmation of legality
• new IT tools support collaborative working
The Physical Internet

applying the networking of principles of the internet to the physical movement of freight

Open, collaborative network with full visibility and incentivized asset sharing

‘Physical encapsulation’ of goods in a new generation of modularised containers’

Vision for the future of logistics

Potentially large efficiency gains and CO₂ savings

Is it likely to be realized in time to meet carbon reduction targets?
Raise Truck Size and Weight Limits – within infrastructural constraints

2 truck for 3 substitution: load consolidation → reduced energy use and emissions per tonne-km

% reduction in carbon intensity against baseline vehicle

<table>
<thead>
<tr>
<th>Model</th>
<th>Weight Limit</th>
<th>% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>25.5 m truck – variable maximum weight limit</td>
<td>40t</td>
<td>25%</td>
</tr>
<tr>
<td>25.5 m truck – variable maximum weight limit</td>
<td>50t</td>
<td>20%</td>
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<td>25.5 m truck – variable maximum weight limit</td>
<td>50t</td>
<td>15%</td>
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<td>25.5 m truck – variable maximum weight limit</td>
<td>44t</td>
<td>10%</td>
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<td>25.5 m truck – variable maximum weight limit</td>
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<tr>
<td>25.5 m truck – variable maximum weight limit</td>
<td>44t</td>
<td>0%</td>
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</table>

Assumed modal and cross-modal price elasticities?

Conflict between freight decarbonisation strategies

freight modal shift

versus

road freight efficiency improvement
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Improving the Energy Efficiency of Freight Transport: *Truck Technology*

**UK**
- Improve Efficiency of Powertrain
- Reduce Power required by vehicle
  - Reduced rolling resistance: 5% (high speed)
  - Reduced aerodynamic drag: <1.1% (high speed)
  - Energy recovery (hybrid): 20% (city)
  - Waste heat recovery: 5%
  - Higher combustion efficiency: 2-3%
  - Anollaries: 5%
  - Automated manual trans: 10% (city)

**France**
- 19% penetration in the air
- 16% résistance au roulement
- 8% refroidissement d’air de suralimentation
- 29% Gaz d’échappement
- 10% refroidissement
- 4% Frictions internes moteur
- 3% Accessoires
- 3% Friction chaine cinématique

**US**
- Truck Technology Adoption Level (US)
- MY 2010 baseline: 94 g/ton-mile
- MY 2017 target: 72 g/ton-mile
- 23% Reduction

**Source:** Ricardo

Retrofitting fuel saving devices
Government vehicle scrappage schemes
Global trade in second-hand trucks

Source: NACFE
### Use of Fuel Economy Standards to Drive Efficiency Improvement

#### Fuel Economy Standards for Heavy Duty Vehicles

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<tr>
<td>Japan</td>
<td>Phase 1</td>
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<td>Phase 2</td>
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<td>U.S.</td>
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<td>Canada</td>
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<td>Phase 3</td>
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<td>EU</td>
<td>Phase 1</td>
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<td>Certification, Monitoring, Reporting</td>
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<td>S. Korea</td>
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<td>Phase 1</td>
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</tbody>
</table>

*Hashed areas represent unconfirmed projections of the ICCT*

Source: ICCT (2015)

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**EEDI ship efficiency ratings**

<table>
<thead>
<tr>
<th>EEDI Ship Type/Size</th>
<th>EEDI (grams CO2 per tonne nautical mile)</th>
<th>EEDI Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Container, TEU 8,000+</td>
<td>13.719</td>
<td>2.603</td>
</tr>
</tbody>
</table>

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**EU lagging**
Improving the Aerodynamic Profiling of Individual Trucks and Platoons

Fuel efficiency gains for improved aerodynamics:

‘individual components: 0.5 – 3%’
(IEA, 2017)

Less benefit in developing countries where speeds are lower

Fuel efficiency gains for US Class 8 trucks:
Lead vehicle – 5.3%
Trailing vehicle – 9.7%
(Lammert et al, 2014)

EU long haul road freight

<table>
<thead>
<tr>
<th>Year</th>
<th>% in platoons</th>
<th>% CO2 savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>2030</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>2050</td>
<td>40</td>
<td>4</td>
</tr>
</tbody>
</table>

IRU (2017)
More Fuel Efficient Truck Driving

With driver training and fuel performance monitoring: typical 5-10% fuel efficiency gain

- Driver training and incentives
- Telematic monitoring
- Vehicle checking and defect reporting

- Anti-idling devices
- Adaptive cruise control
- Predictive cruise control

International Transport Forum ‘conservative scenario’
25% of trucks driverless by 2040

US Postal Service: 28,000 rural delivery routes served by automated vans by 2025

IEA (2017): truck automation
15-25% improvement in fuel efficiency

Roland Berger (2016): with truck automation
10% lower fuel consumption by US trucks than BAU by 2040
‘Down-speeding’ Freight Transport: *Energy Saving + CO₂ Reduction*

**Slow Driving**

![Image of truck](image1)

Source: AEA / Ricardo (2011)

- Heavy Duty Truck 40t
- 90 → 70 km/hr 12% fuel saving

**Slow Steaming**

![Image of ship](image2)

Source: Miloni, Paul and Gligor, 2013

Source: IMO (2014)

- 2007-2012
- Average at-sea speed relative to design speed 12% lower
- Average daily fuel consumption 27% lower

IMO (2014)
Five Sets of Decarbonisation Initiatives for Freight Transport

- Reduce Demand for Freight Transport
- Shift Freight to Lower Carbon Transport Modes
- Optimise Vehicle Loading
- Increase Energy Efficiency of Freight Movement
- Reduce the Carbon Content of Freight Transport Energy
Switch to Cleaner, Low Carbon Energy

WTW CO$_2$e emissions

- Current CO$_2$ benefits of freight electrification?
  - biofuel fuels: slow uptake
    - uncertainty about net GHG impact
    - limited supply of biofuels
    - inter-sectoral competition for supplies
    - lack of refuelling infrastructure
    - methane leakage problem

- Short-term: electrified rail
  - local road delivery
    - recharging infrastructure
    - future battery performance
    - E-vehicle price differential

- Long term: cold ironing of ships in port

Carbon intensity of electricity generation (gCO2 / kWh)

http://shrinkthatfootprint.com/electricity-emissions-around-the-world
### Energy Efficiency and Cost of Different Methods of Electrifying Long Haul Road Freight

<table>
<thead>
<tr>
<th>Pathway</th>
<th>Range Cost per km</th>
<th>Efficiency WTW</th>
<th>Example vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electric Road Systems</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>100 kWh 6c / kWh</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grid (calorific)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>eTruck (Calorific-Hybrid)</td>
<td>60 km</td>
<td>77%</td>
</tr>
<tr>
<td></td>
<td>96 kWh 12 ct/kWh</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>eTruck (Battery)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>98 kWh 2 ct/kWh</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Battery</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>48 km 20 ct/km</td>
<td>62%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grid</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>eTruck (Battery)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>58 kWh 2 ct/kWh</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hydrogen</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>24 km 55 ct/km</td>
<td>29%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grid</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>H₂-network 1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>H₂-fuel station</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CH₄-fuel truck</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fuel cell truck</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>65 kWh 10 ct/kWh</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>65 kWh 22 ct/kWh</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Power-to-Gas</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>17 km 70 ct/km</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grid</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Methanation 2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CH₄-network 1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>NG-network 1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CNG-fuel station</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CNG Gas-truck</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>55 kWh 15 ct/kWh</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>55 kWh 20 ct/kWh</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>55 kWh 22 ct/kWh</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: German Ministry of Environment (quoted by Akerman, 2016)

**electrified roads: Trials in Sweden, Germany and the US**
Electric Road System (ERS)

Catenary

Inductive

Slide-in rail
Assessing Carbon Savings from Efficiency Improvements and Switch to Alternative Energy

CO₂ emissions from road freight transport: reference (i.e. baseline) scenario vs modern truck (i.e. low carbon) scenario

source: IEA (2017)


<table>
<thead>
<tr>
<th>Long haul</th>
<th>2030</th>
<th>2050</th>
<th>Comment</th>
<th>cumulative reduction 2030</th>
<th>cumulative reduction 2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powertrain efficiency (diesel)</td>
<td>10%</td>
<td>15%</td>
<td>Includes engine, transmission, auxiliaries,…</td>
<td>10.0%</td>
<td>15.0%</td>
</tr>
<tr>
<td>Gas vehicles</td>
<td>2%</td>
<td>4%</td>
<td>Minimise methane emissions</td>
<td>11.8%</td>
<td>18.4%</td>
</tr>
<tr>
<td>Renewable fuels (gas &amp; liquid)</td>
<td>2%</td>
<td>24%</td>
<td>IEA general target, large increase in 2nd generation biofuels needed. Includes biogas</td>
<td>13.6%</td>
<td>38.2%</td>
</tr>
<tr>
<td>Driver training and driver assistance systems</td>
<td>6%</td>
<td>8%</td>
<td>Includes ACC, PCC,…</td>
<td>18.8%</td>
<td>43.2%</td>
</tr>
<tr>
<td>Reduce max speed</td>
<td>2%</td>
<td>2%</td>
<td>To 60 km/h</td>
<td>20.4%</td>
<td>62.8%</td>
</tr>
<tr>
<td>ITS &amp; communications</td>
<td>1%</td>
<td>4%</td>
<td>Platooning</td>
<td>21.2%</td>
<td>46.5%</td>
</tr>
<tr>
<td>Aerodynamics</td>
<td>6%</td>
<td>10%</td>
<td>Important contribution expected from trailers and semi-trailers, including solutions developed in the TRANSFORMERS Project</td>
<td>25.9%</td>
<td>51.3%</td>
</tr>
<tr>
<td>Tyres</td>
<td>7.5%</td>
<td>12.6%</td>
<td>Includes super singles</td>
<td>31.5%</td>
<td>57.4%</td>
</tr>
<tr>
<td>Lightweighting</td>
<td>0%</td>
<td>0%</td>
<td>Compensated by increased weight from other measures</td>
<td>31.5%</td>
<td>57.4%</td>
</tr>
<tr>
<td>Pavement</td>
<td>3%</td>
<td>3%</td>
<td>Improved rolling resistance (maintenance or new pavement)</td>
<td>33.5%</td>
<td>58.7%</td>
</tr>
<tr>
<td>Reduce empty running, improve load factors, digitalisation</td>
<td>2%</td>
<td>10%</td>
<td>Rollout of coordinated system needed</td>
<td>34.8%</td>
<td>62.8%</td>
</tr>
<tr>
<td>More flexibility in weights and dimensions (including EMS)</td>
<td>3.5%</td>
<td>7.5%</td>
<td>Allowance of EMS in cross border transport in the EU</td>
<td>37.1%</td>
<td>66.6%</td>
</tr>
<tr>
<td>More renewables – hybridisation (2030)/electrification (2050)</td>
<td>3%</td>
<td>37%</td>
<td>For 2050, most from full electrification</td>
<td>39.0%</td>
<td>78.2%</td>
</tr>
</tbody>
</table>

new TESLA truck a gamechanger?

- battery powered
- 300 mile range
- autonomous
- Platooning-ready
Overview of Decarbonisation Options for the Freight Transport Sector

Source: Smart Freight Centre ‘Solutions Map’ based on IEA and Prof David Cebon
Economics of Decarbonising Freight Transport

Close correlation between cutting carbon emissions and saving money

Marginal Abatement Cost Analysis of Shipping Decarbonisation Measures

- Self-financing
- Risk of rebound effects
- Lower cost stimulating freight traffic growth
- Offsetting CO₂ savings

Adapted from Tavasszy (2014)
Green Freight Programs

THE Global Green Freight Action Plan

Reducing the Climate and Health Impacts of Goods Transport

May 2015
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References to reports, papers and other data sources used in this presentation can be found at:
http://www.alanmckinnon.co.uk/newslayout.html?IDX=773&b=74&q=2017