eHighway

Sustainable road freight transport

siemens.com/mobility

Highway electrification for trucks has already started

Agenda:
Catenary electrification of heavy trucking corridors

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Catenary trucking basics

The sustainable road freight challenge

The case for eHighway

Alternative fuels and drives

Outlook for implementation

How an eHighway for HDVs works

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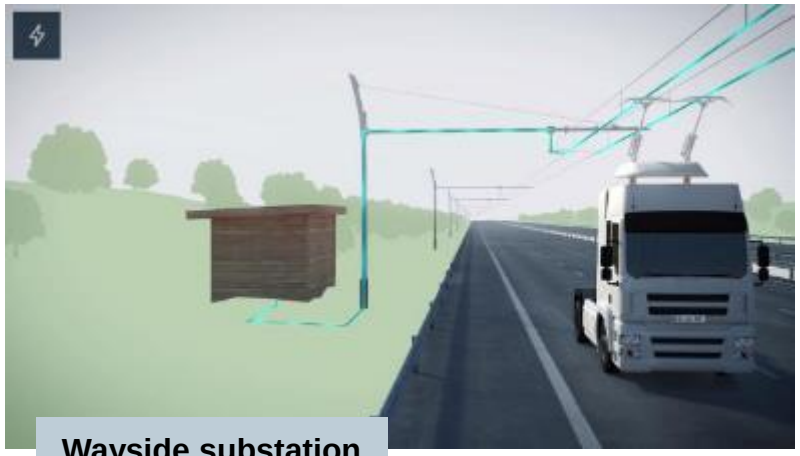
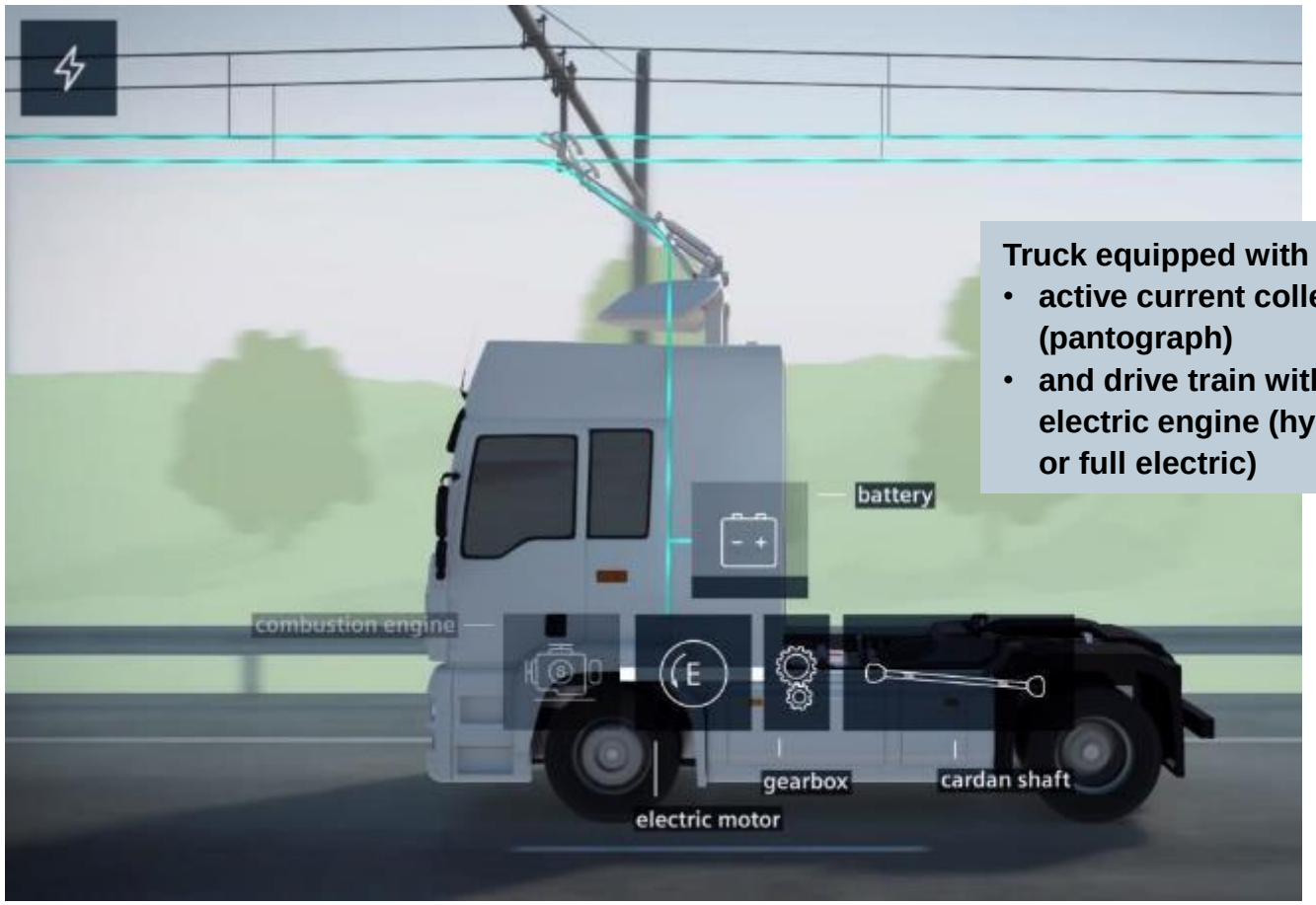
Overhead catenary wires



Wayside substation



Truck equipped with
- active current collector (pantograph)
- and drive train with an electric engine (hybrid or full electric)

https://www.youtube.com/watch?v=zV2yZkRFBK0

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

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Development of the eHighway vehicle technology

2010 — **2019**

1. Generation
Proof of concept

2. Generation
Swedish and US
Demonstration projects

3. Generation
Field trials

Operations up to 100 km/h possible

Connection and dis-connection to catenary in motion

Recharging of onboard energy storage while driving

No limitations for first and last mile

Catenary electrification is compatible with and complementary to other alternative fuel technologies

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The eHighway hybrid truck can be configured to suit specific applications

Truck types


Tractor truck (2 axles)


Tractor truck (3 axles)


Rigid truck (2 axles)


Rigid truck (3 axles)


Rigid truck (4 axles)

Drive system


Parallel-hybrid


Serial-hybrid


Full electric

On-board source of electricity


Battery (small)


Battery (medium)


Battery (large)


Fuel cell

Combustion engine


Engine (small)


Engine (medium)


Engine (large)

Non-electrical source of energy


Diesel


Bio-fuel

CNG/LNG

H_2

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Trucks are responsible for 2/5 of all transport CO_2
Road freight activity and CO_2 are expected grow >2x by 2050

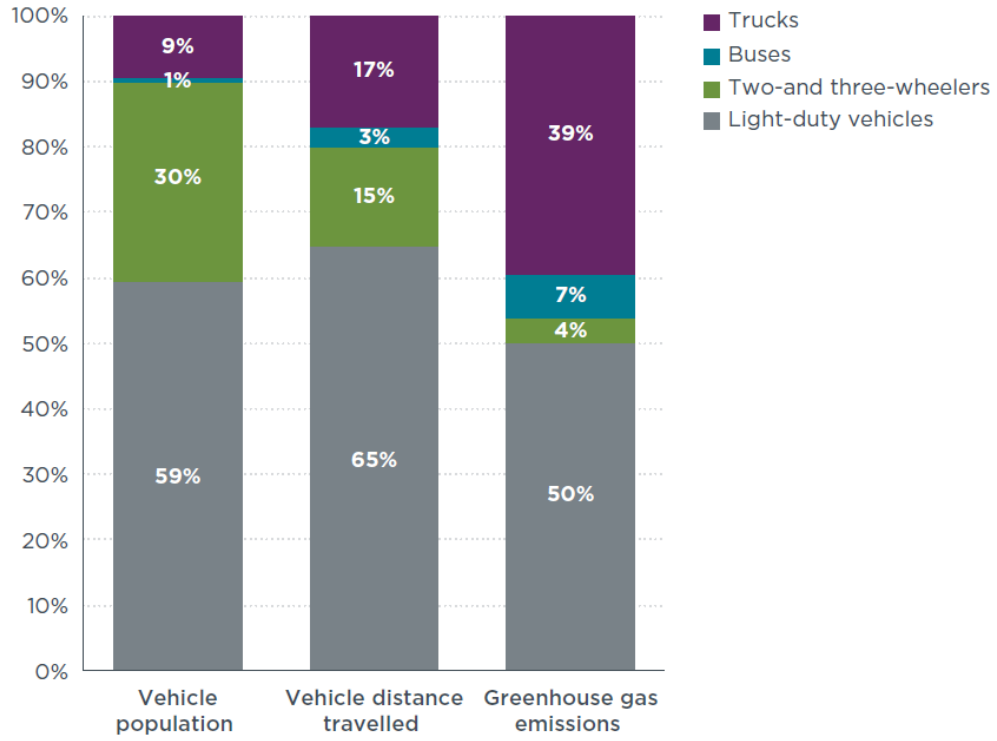

Figure 1. Global vehicle stock, distance traveled, and life-cycle road transport greenhouse gas emissions by vehicle type in 2015.

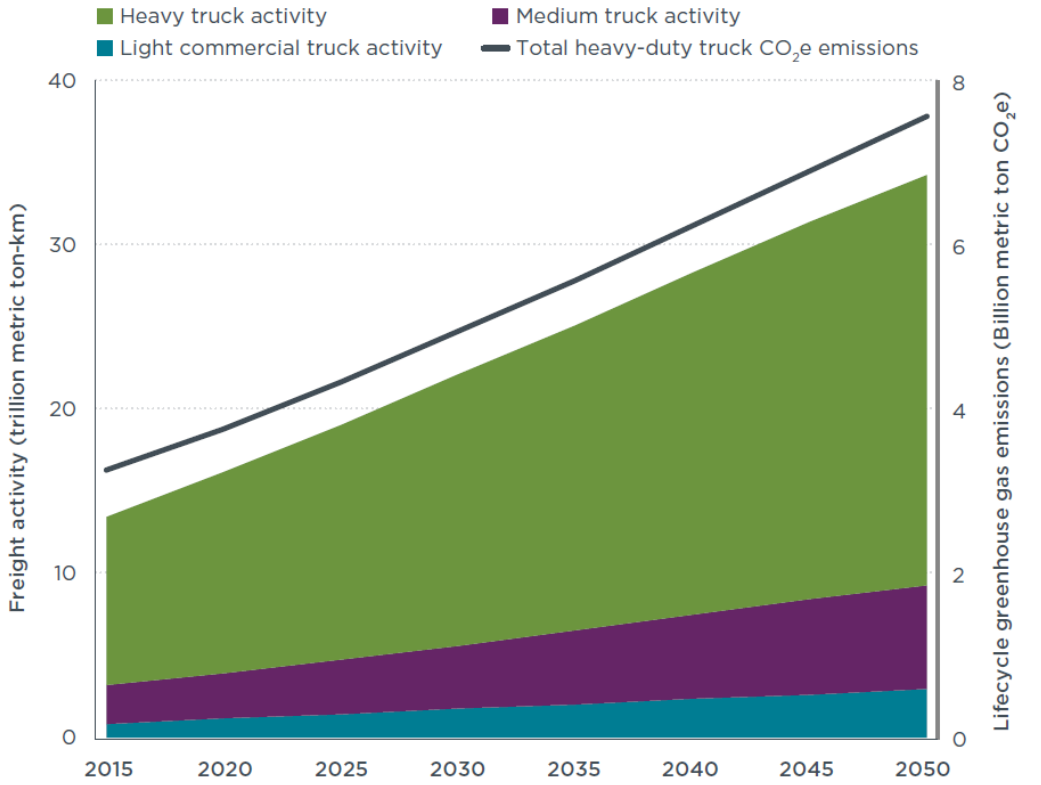

Figure 2. Projected global freight activity and life-cycle greenhouse gas emissions from 2015 to 2050.

Source: ICCT - Transitioning to zero-emission heavy-duty freight vehicles (2017) page 1 & 2

Governments striving for rapid cuts in CO_2, putting truck manufacturers under great pressure to find solutions

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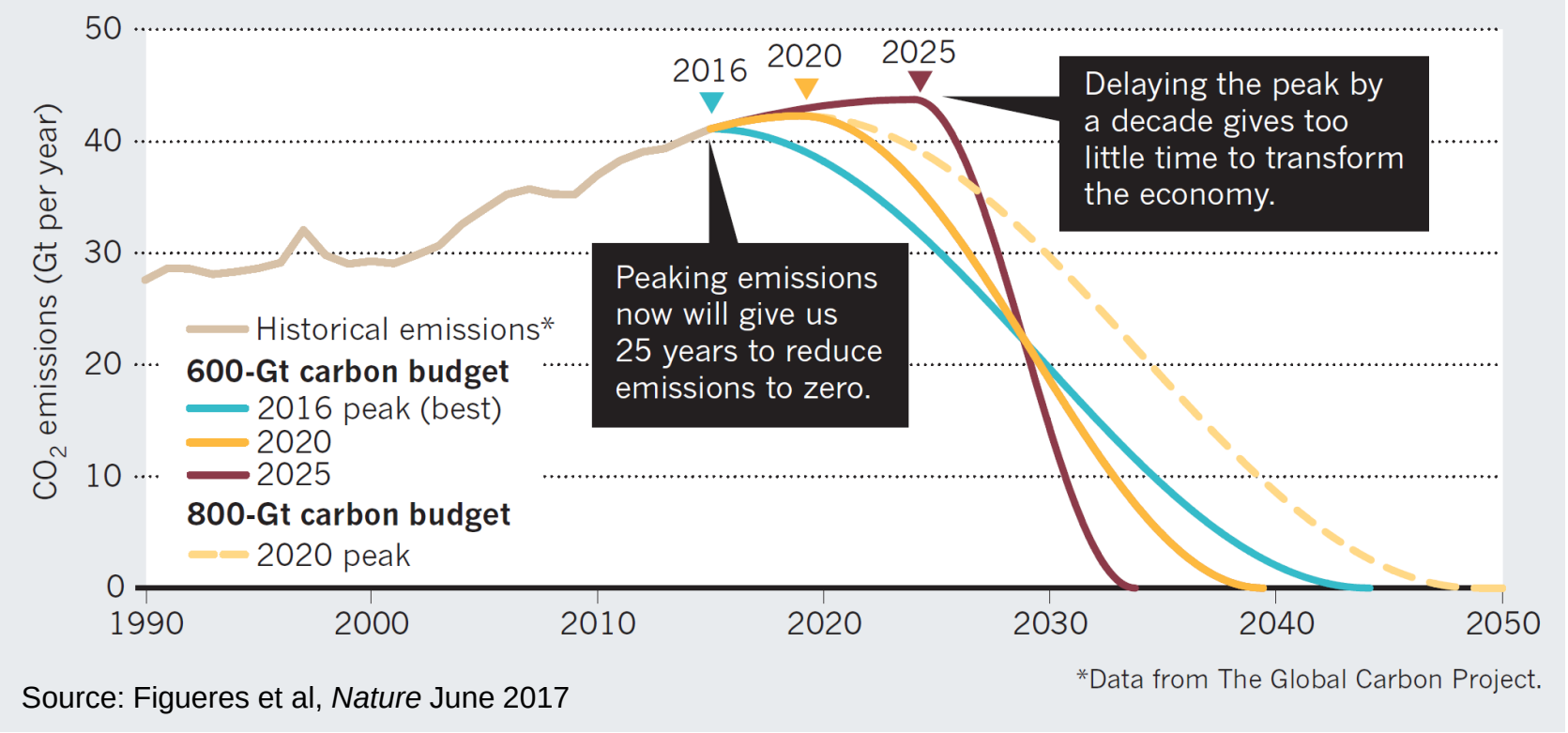
Action is urgent - waiting makes the necessary transition shorter and disruptive



Source: Figueres et al, *Nature* June 2017

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

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

EU regulation raise risk of fines

- New legislation set 30% reduction target of truck CO_2 by 2030. Failure to meet this will results in big financial penalties
- Daimler Truck wrote "*If a manufacturer of 50,000 vehicles missed the target by 10 percent, it would be fined 2 billion euros*". Daimler in 2018 sold 85.000 trucks in the EU and has a global EBIT of 2.75 bn EUR
- Volvo Trucks calculated selling a single ZEV truck can help avoid fines of 820,000 EUR

Source: Daimler 2018 & Volvo 2018

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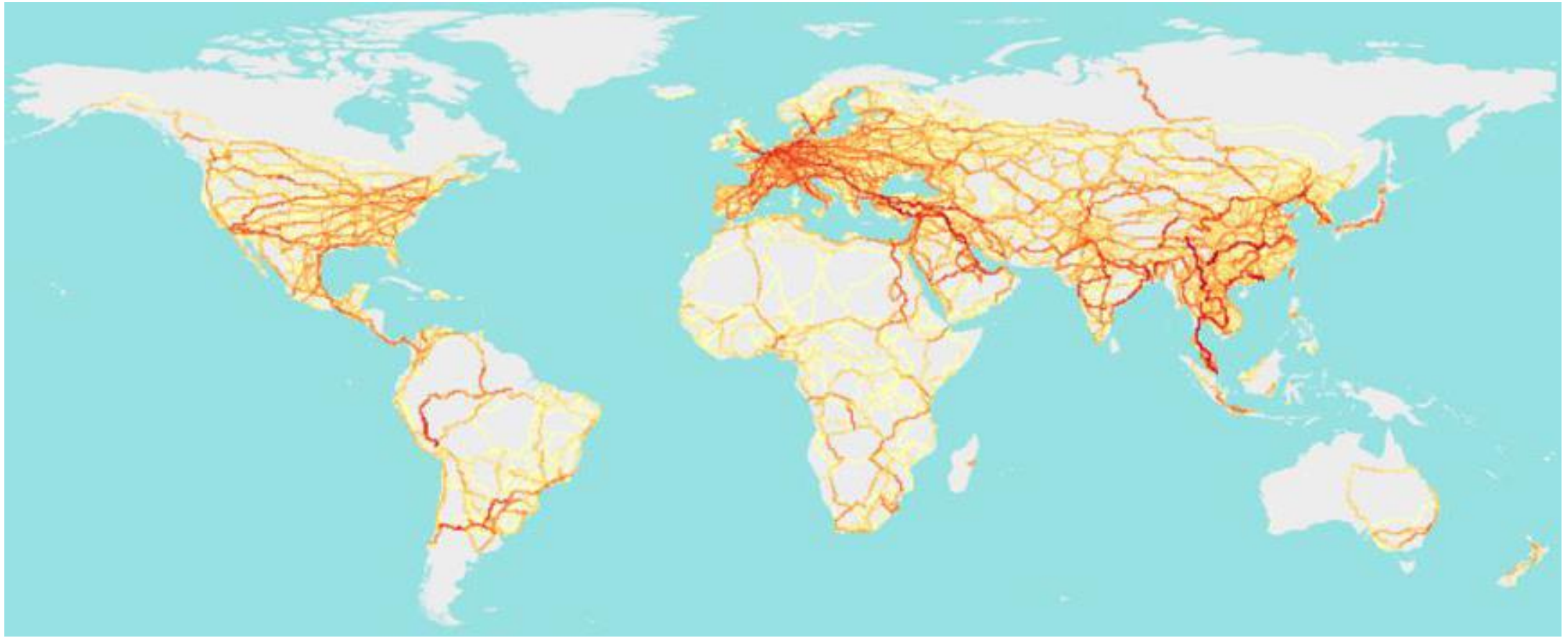
Surface freight density: 2010
Shows high density of freight on European corridors



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

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Source: ITF - Transport Infrastructure Needs for Future Trade Growth (2016) page 31

Surface freight density: 2010
Analysis of Germany at the center of Europe‘s transport network

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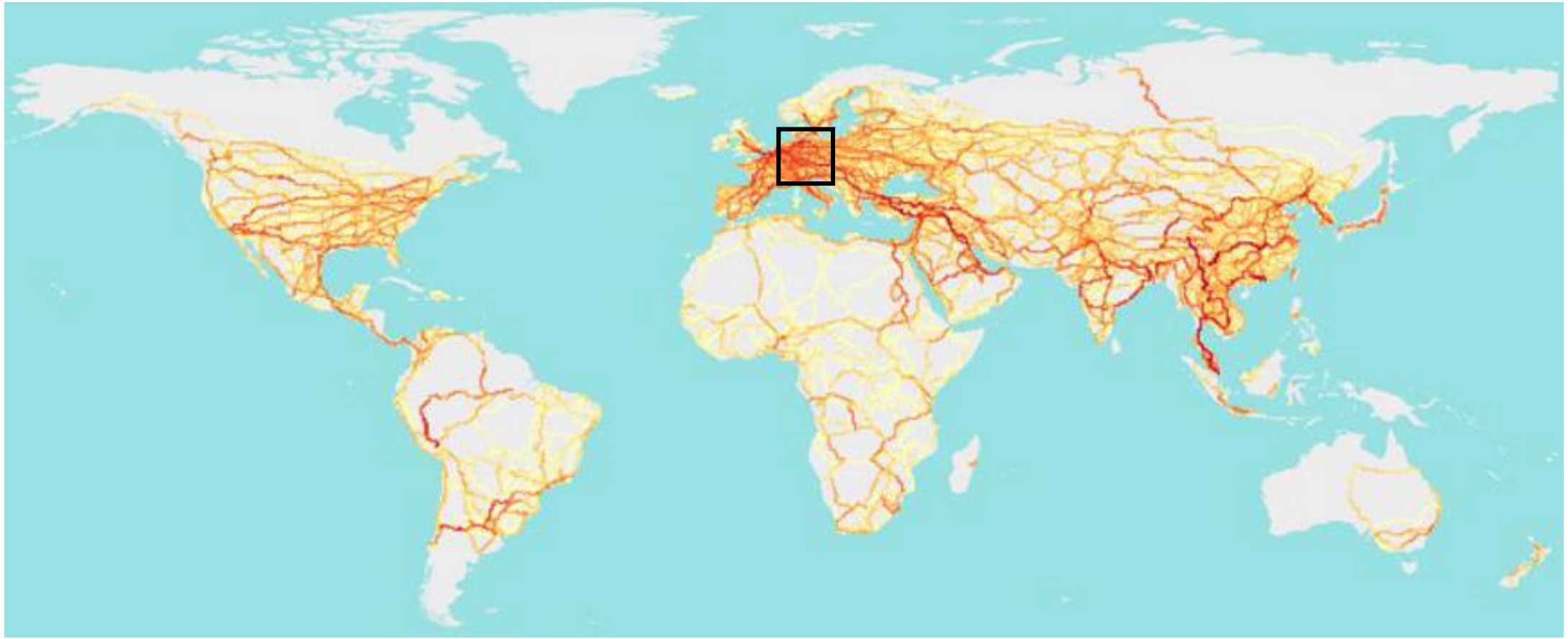
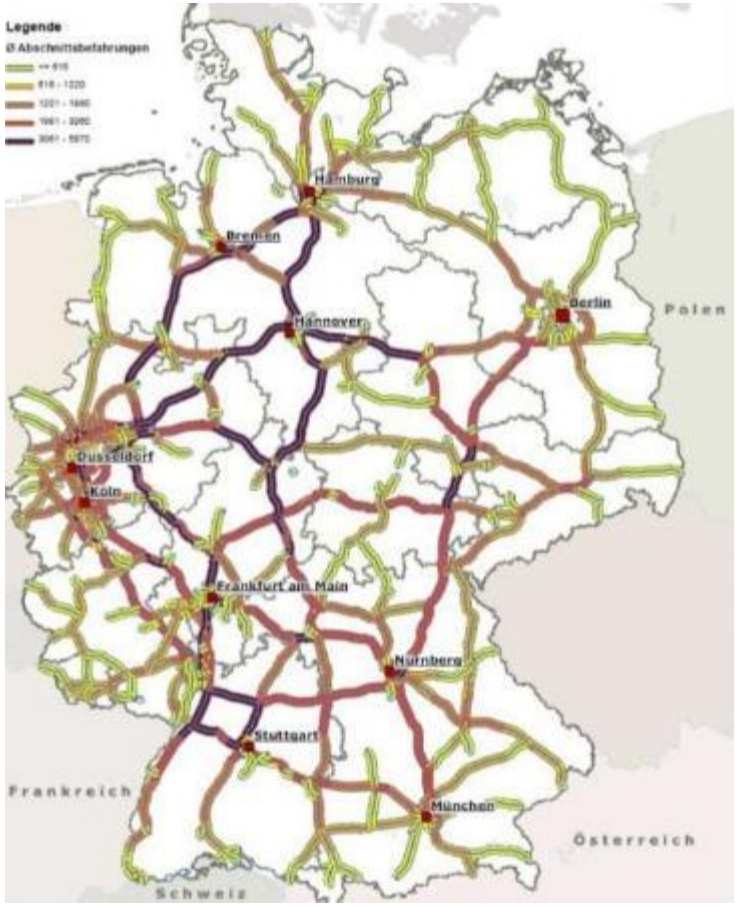
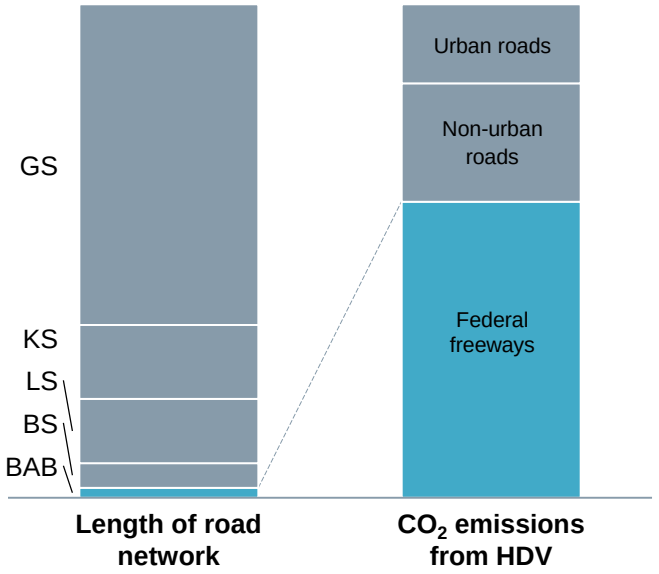


Source: ITF - Transport Infrastructure Needs for Future Trade Growth (2016) page 31

Long haul road transport is highly concentrated to the highway network, as illustrated by German data





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)

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

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. The most intensely used **3,966 km** handle **60%** of all ton-km on the BAB
3. **89%** of truck trips after leaving the highway are **≤50 km**

Source: BMVI website. Study available here

The use case logic is analogous to railway:
- Use direct electrification wherever possible
  - Catenary on busy routes
  - Battery on less busy and short routes
- Elsewhere efuels can play a role

Siemens eHighway

Electrified road freight transport – contributing to a sustainable transport sector

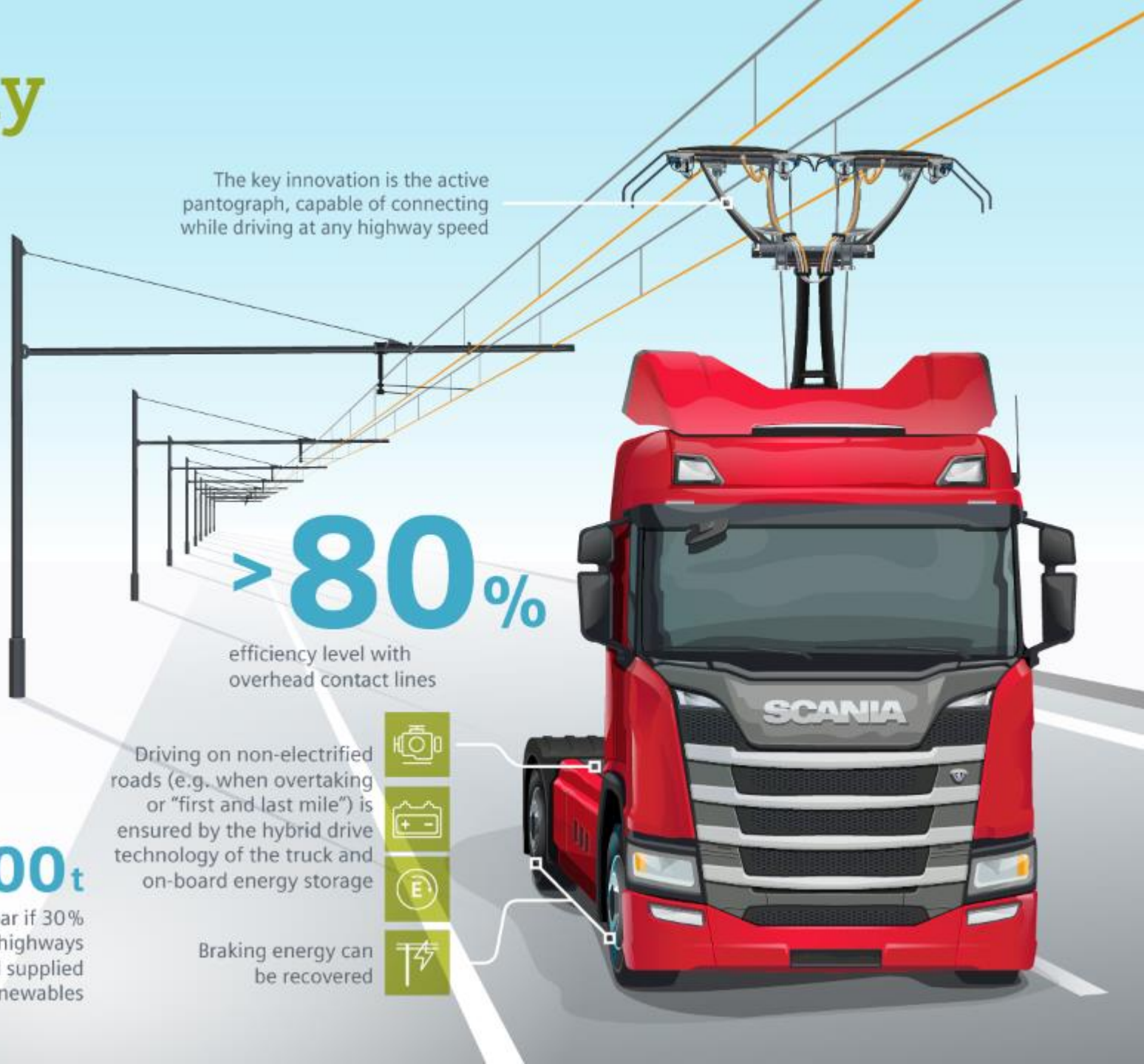
4,000 km
network of contact lines on German autobahn is recommended by the Federation of German Industries (BDI) as a cost-effective decarbonization measure

11 %
of expected truck toll revenue (Lkw-Maut) would cover the investment in a 4,000 km network

16,000 €
of fuel savings can be achieved by a 40-ton truck driving 100,000 km on the eHighway (based on 1.25 €/l diesel and 0.15 €/kWh electricity)

80 %
of heavy duty trucks would have an economic incentive to switch to contact line, given that the busiest 4,000 km of autobahn are electrified

> 7,000,000 t
of CO_2 savings per year if 30 % of truck traffic on German highways is electrified and supplied with renewables



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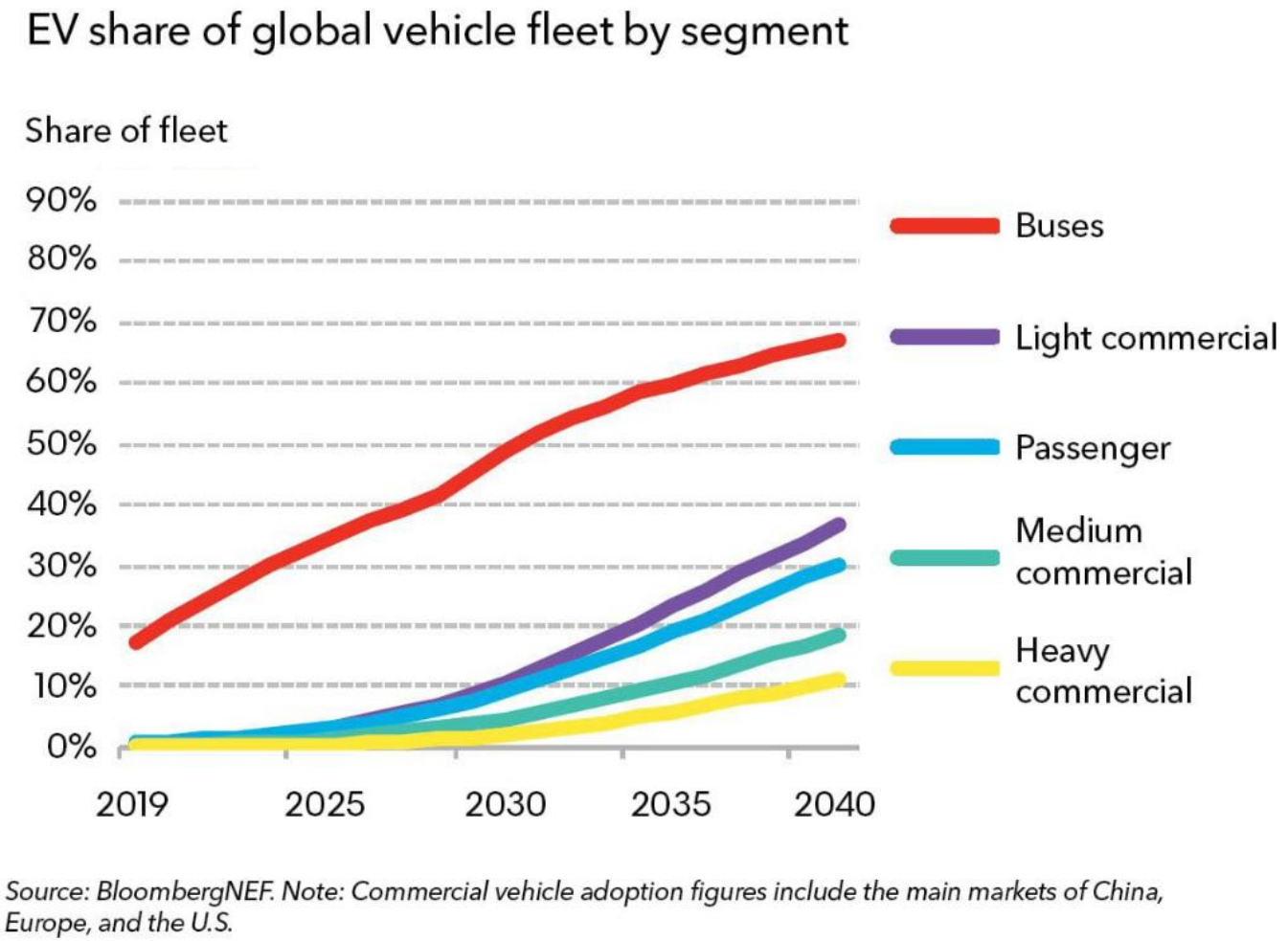
Outlook for battery trucks in heavy duty truck segment not very encouraging in the coming decades



Source: BloombergNEF. Note: Commercial vehicle adoption figures include the main markets of China, Europe, and the U.S.

Source: BNEF EV Outlook 2019

IEA Global EV Outlook 2019

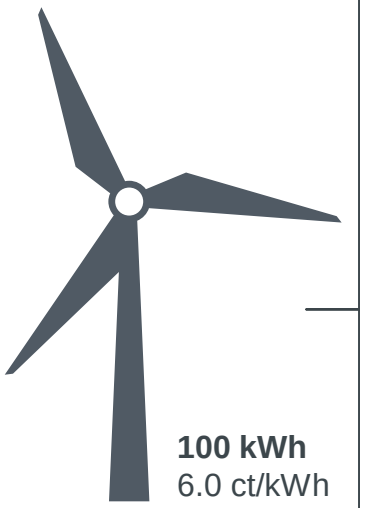
"Electric trucks reach 0.9 million units in 2030 in the New Policies Scenario and 3.3 million in the EV30@30 Scenario, corresponding to 1% and 3% of the total truck stock. The penetration of electric heavy trucks is higher in medium size than in heavy truck segments."

Source: IEA Global EV Outlook 2019

Battery leaders' perspective

Countries leading battery technology development (i.e. Japan, South Korea and China) are not pushing in this direction. Instead they are looking for alternative solutions for the trucks handling the majority of freight (tkm).

Zero emission trucks are possible with renewable energy, but efficiency varies greatly



100 kWh
6.0 ct/kWh

Pathway	Range Cost per km	Efficiency WTW
Electric Road Systems e⁻ → Grid (incl. catenary) → e⁻ → eTruck (Catenary-Hybrid) 96 kWh; 1,6 kWh/km	**60 km** 19 ct/km	**77%**
Hydrogen e⁻ → Electro-lysis η = 70% → H_2 → H_2-network[1)] → H_2 → CH_2- fuel station → $C.H_2$ → Fuel cell truck 2 kWh; 5 kWh 93 kWh; 65 kWh 15 ct/kWh; 65 kWh 18 ct/kWh; 65 kWh 20 ct/kWh; 2.7 kWh/km	**24 km** 55 ct/km	**29%**
Power-to-Gas e⁻ → Electro-lysis η = 70% → H_2 → Methanation η = 80% → CH_4 → NG-network[1)] → NG → CNG-fuel station → CNG → Gas-truck 2 kWh 98 kWh; 69 kWh 15 ct/kWh; 55 kWh 19 ct/kWh; 55 kWh 20 ct/kWh; 55 kWh 22 ct/kWh; 3.2 kWh/km	**17 km** 70 ct/km	**20%**

1) Including storage
Source: German Ministry of Environment

ICCT* sees electrification with contact lines as crucial for reaching deep decarbonization of HDVs

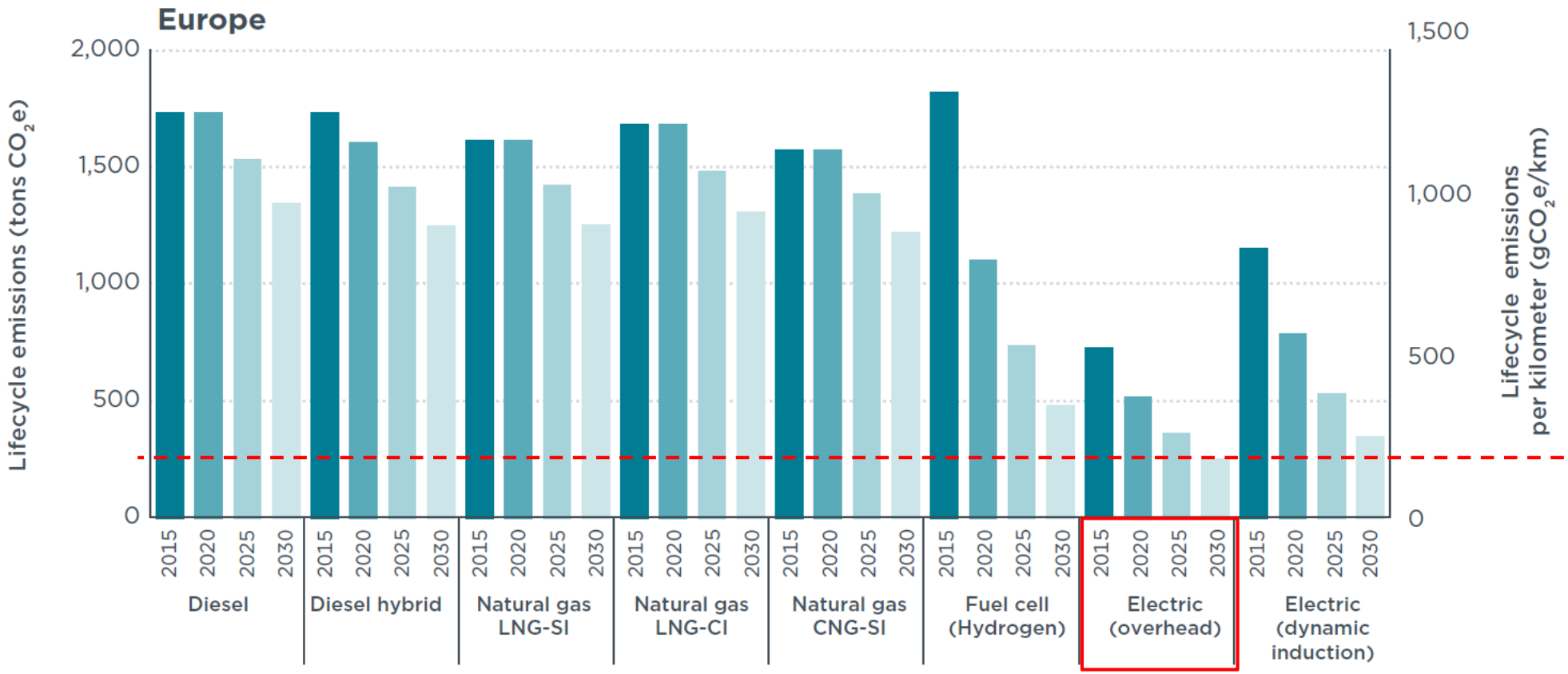


Figure 6. China, Europe, and U.S. lifecycle CO_2 emissions over vehicle lifetime (left axis) and per kilometer (right axis) by vehicle technology type.

- Greatest reductions in GHG emissions in all time periods

Source: ICCT - Transitioning to zero-emission heavy-duty freight vehicles (2017) page 26

* ICCT = International Council of Clean Transportation

System cost assessment shows that efficiency of energy supply plays a far greater role than vehicle and infrastructure costs

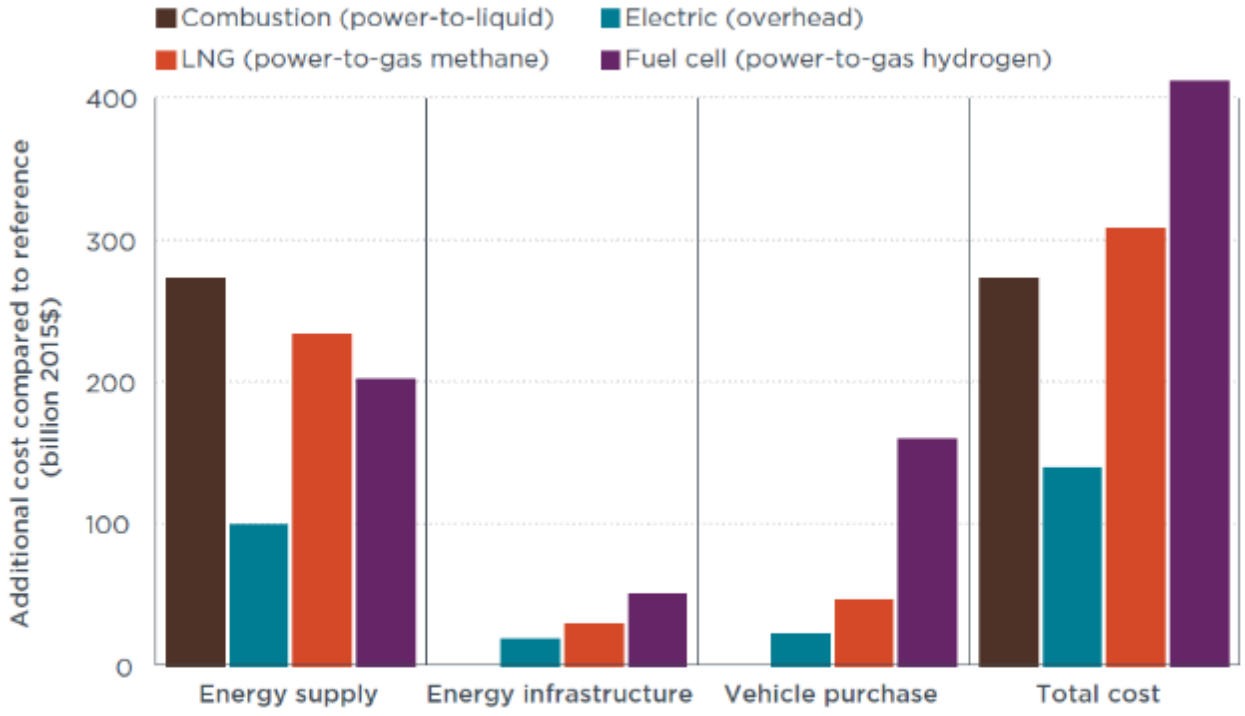


Figure 5. Additional cost for four different greenhouse gas reduction scenarios compared to the reference case (all fossil fuel use) for the long-haul heavy-duty freight transport sector in Germany (based on Kasten et al., 2016).

- Business case for zero emission need to assess several factors, in addition to vehicles
- It is equally important to assess cost of refueling (quickly).
- Especially cost of energy appear to impact total system cost significantly

- **Contact line trucks are the cheapest way to decarbonize the German road freight sector!**
- **Importance of superior energy efficiency will only grow in future**

Key assumptions:

- Length of electric network: 4,000 km; Infrastructure costs: 2.2 million €/km; Maintenance 2.5% of investment per year
- Additional vehicle costs: per today 50,000 € / truck; per 2050 19,000 € per truck; share of direct electric traction: 60% in 2050

Source: ICCT - Transitioning to zero-emission heavy-duty freight vehicles (2017) page 23

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

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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

Project homepage: ELISA

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

Quelle: Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit / Grafik: DVZ

Project homepage: FESH

Federal State of Baden-Wuerttemberg
Tender published Nov 2018
Track length / Amount of trucks: 5-6km / 5
Customer's targeted start of Demonstration: 2020

Project homepage: eWayBW

Field trial near Frankfurt: Infrastructure construction with minimum disruption, delivered on time and on budget

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Many pictures available at: https://mobil.hessen.de/verkehr/elisa/baustellen-news

Maintenance & Operation
For electric and road infrastructures

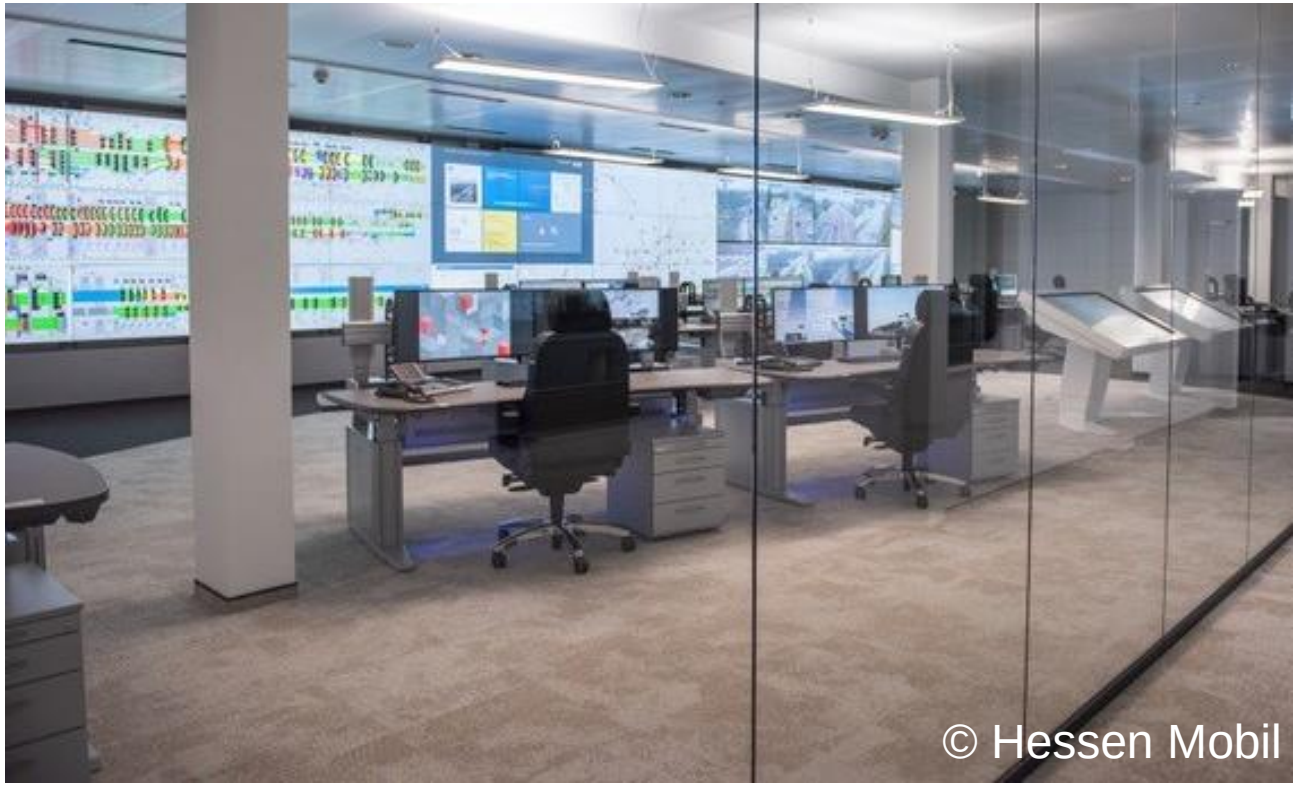
Many similarities to already known aspects of poles, guard rails and contact lines.

Maintenance of road infrastructure

- Ploughing of snow
- Grass cutting
  - Once a year

Maintenance of electrical infrastructure

- Long lasting (cf. road surface)
- Visual inspections



Integration into Traffic Control Center

Scania will deliver 15 trucks for German field trials
This represents the third generation of eHighway trucks

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Latest Scania truck and third generation of pantograph

See Scania press release

Private data on geographical distribution of truck energy consumption

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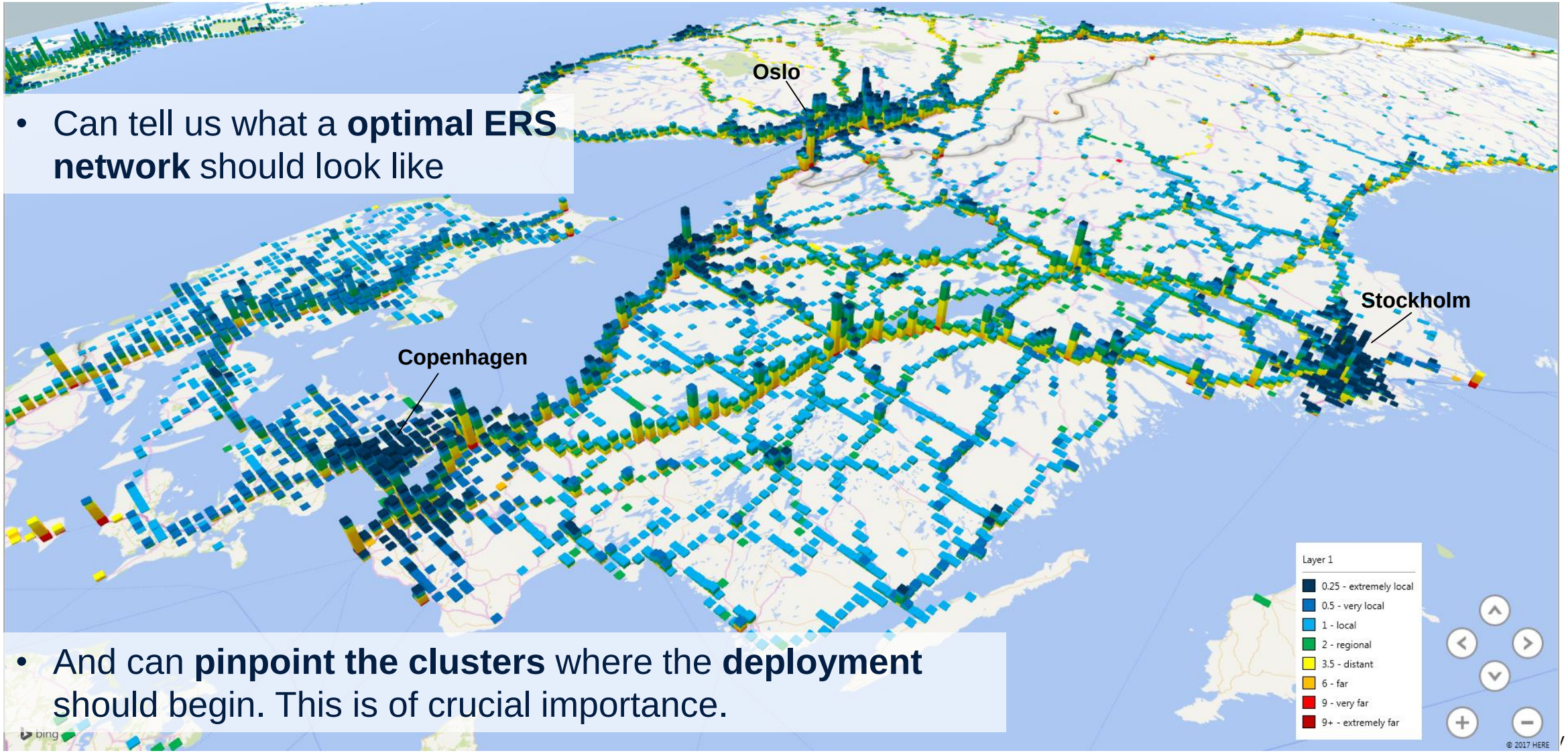
Map of Scandinavia



- Can tell us what a **optimal ERS network** should look like
- And can **pinpoint the clusters** where the **deployment** should begin. This is of crucial importance.

Independent institutes in Germany have identified early shuttle applications and how to scale up to a full system

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Selected recommendations

- Suitable first applications are on routes around Hamburg, in Ruhr area and southern Germany
- With a comprehensive network of catenaries it is possible that 65% of the vkm by heavy duty trucks could be commercially viable to switch to catenary-trucks
- Using electricity with a carbon footprint of 412 g/ kWh this would help reduce the total GHG emissions from heavy duty trucks in Germany by 17%
- Without a transparent development plan for the infrastructure the risks of faced by OEMs and trucking companies during the transitions are too big

Identified routes based on freight goods flow suitable for catenary systems usage

#	Name	BAB	Distance
1	Essen/Gladbeck – Dreieck Heumar	A3/A2	85 km
2	Düsseldorf – Kreuz Kamen	A46/A1	81 km
3	Neckarsulm - Stuttgart	A81/A6	57 km
4	Hamburg – Lübeck	A1	49 km
5	Krefeld – Köln	A57	45 km
6	Schwerte – Lüdenscheid-Süd	A45	32 km
7	Essen – Dortmund	A40	26 km
8	Kreuz Kamen – Hamm-Uentrop	A2	23 km
9	Pfaffenhofen – München	A9	20 km
10	Bremen – Hamburg	A1/A261	81 km

Source: IFEU, PTV – *Roadmap OH-Lkw Potentialanalyse 2020-2030* page 22 and 30

German Transport Ministry is supporting overhead contact line shuttles as part of their climate action plan

- The German federal transport ministry (BMVI) support was listed among recently announced measures for transport decarbonization.

- Road freight is the area where 1/3 of the CO_2 savings are expected to be achieved, making it biggest contributing segment to the overall reductions from transport

5 Nutzfahrzeuge	CO_2-arme Lkw auf die Straße bringen	CO_2-Flottenregulierung (auf EU-Ebene)	**17-18 Mio. Tonnen**
		Kaufprämie für Nutzfahrzeuge mit alternativen Antrieben	
		CO_2-Differenzierung der Lkw-Maut	
	Tank- und Lade-infrastruktur ausbauen	Infrastrukturaufbau und -förderung (z.B. Wasserstofftankstellen, Mega-Charger, Oberleitungen auf Pendelstrecken)	

- German government's climate action plan calls for 1/3 of truck traffic to be electric or using eFuels by 2030. Supporting this goal is an infrastructure plan including for catenary systems

Source: BMVI website and Government plans (announced on Oct 09, 2019)

A European and harmonized solution could take shape already today - enabling zero emission trucking on TEN-T corridors by 2050

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UK

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

Sweden

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

Germany

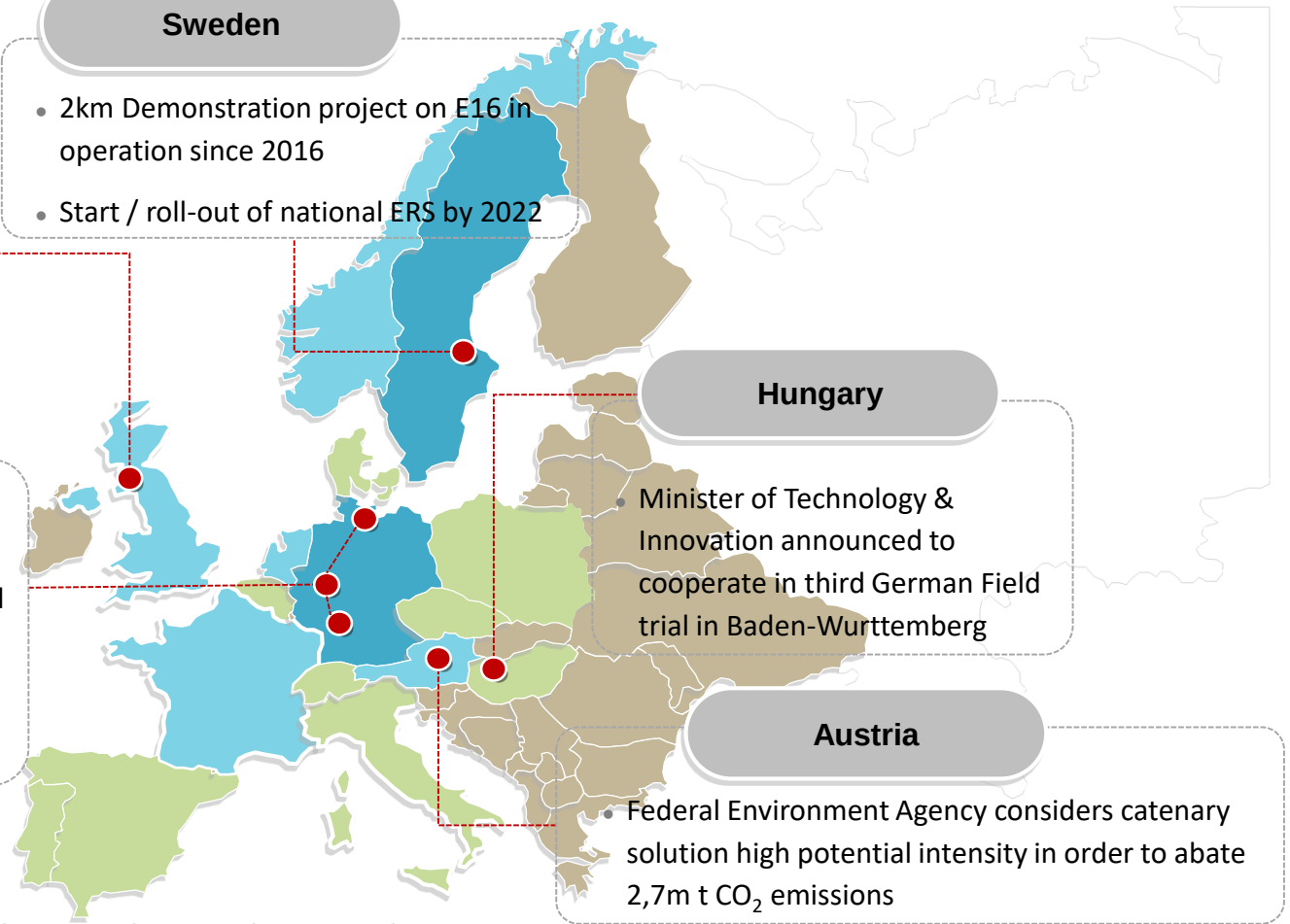
- 2018-2022: Three fields trials on motorways A1 and A5 and national road B462 publicly funded by BMU € 45,3m
- Extension of catenary network part of climate protection program 2030

Hungary

- Minister of Technology & Innovation announced to cooperate in third German Field trial in Baden-Wurttemberg

Austria

- Federal Environment Agency considers catenary solution high potential intensity in order to abate 2,7m t CO_2 emissions



Interest in catenary solution exists

Study with regard to catenary solution for HDV exists or under preparation

Catenary solution: demo / field trial realized or in preparation

International

- USA:
  UC Davis study outlines advantages of catenary solution compared to alternative propulsion solutions for trucks
- China:
  Deputy's Minister for Transport showed serious interest into the technology
- India: Minister for Road Transport & Highways Nitin Gadkari proposes plan to electrify India's highways with catenary system


SPEDITION
SCHANZ
CAPAROL
SCANIA

Back ups –
Sector coupling

eHighway offers efficient and low cost electricity supply, thanks to smooth load profiles and high connection voltage

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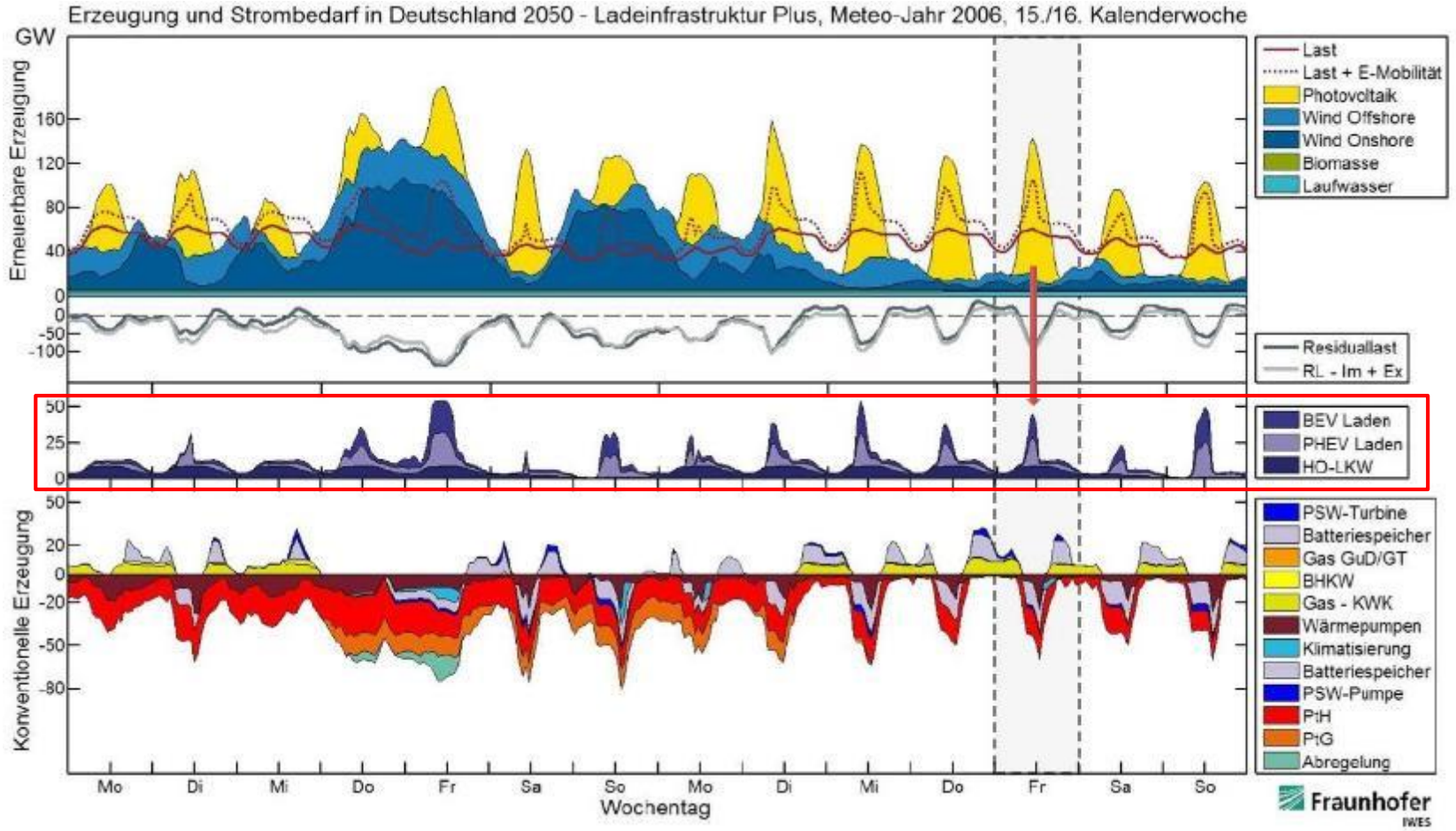
Detailed load profiles from BEV, PHEV and eHighway, and supply though conventional and renewable generation in Germany



- **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

Back ups –
Experiences so far and outlook

ADAC Motorwelt positive to the field trial

The *Allgemeiner Deutsche Automobil Club* (ADAC) has 18m members and is Europe's largest car club.

MEINE REGION

Hessen
Rheinland-Pfalz
Saarland

Kassel
Koblenz
Frankfurt
Mainz
Trier
Neustadt
Saarbrücken

Umweltfreundlich unterwegs: Auf der 5 km langen Teststrecke auf der A5 werden Leitungen montiert, die die Hybrid-Lkw über den „Pantografen" mit Strom versorgen

Aufstellen der **229 Strommasten** am E-Highway

Beim Überholen fährt der Stromabnehmer ein, der Lkw nutzt den internen Akku oder Dieselmotor

Oberleitung auf der Autobahn

Der Startschuss für den E-Highway auf der Autobahn A5 ist gefallen: Bis 2022 soll getestet werden, ob sich der Betrieb von Oberleitungs-Lkw rechnet

Pendler zwischen Darmstadt und Frankfurt kennen es bereits – Urlauber, die in den Sommerferien die A5 nutzen, werden sich mitunter wundern. Zwischen Langen/Mörfelden und Weiterstadt sieht es auf der Autobahn aus wie auf einer Bahntrasse. Auf einer Strecke von fünf Kilometern verlaufen in beiden Fahrtrichtungen über dem rechten Fahrstreifen Oberleitungen. Doch statt von Zügen sollen die Stromleitungen künftig von Hybrid-Lkw genutzt werden.

Die Anlage ist Teil der Teststrecke des Projekts Elisa (Elektrifizierter, innovativer Schwerverkehr auf Autobahnen), bei dem bis Ende 2022 ein realitätsnaher Probebetrieb mit insgesamt vier Oberleitungs-Lkw stattfinden wird. Anfang Mai wurde die Strecke das erste Mal von einem dieser Brummis mit ausfahrbarem Stromabnehmer (Pantograf) befahren. Das Ziel: Erfahrungen und Daten für einen flächendeckenden Betrieb zu sammeln, um den CO_2-Ausstoß des nach wie vor wachsenden Schwerlastverkehrs zu reduzieren. Der Grund: das Erreichen der selbst gesteckten Klimaziele. Denn eine Verlagerung auf die Schiene ist unrealistisch. Der Güterverkehr fährt bereits jetzt am Limit, und neue Strecken zu bauen ist im dicht besiedelten Deutschland nicht so einfach. Zudem kann nicht jeder Supermarkt an einen Bahnhof angeschlossen sein. „Wir sehen die Erprobungsphase sehr positiv", so Wolfgang Herda, Verkehrsexperte des ADAC Hessen-Thüringen. „Vorausgesetzt, der Strom kommt dauerhaft aus erneuerbaren Energiequellen, könnten diese Laster künftig CO_2-neutral unterwegs sein."

Die Vision: Lkw fahren in Ballungsgebieten elektrisch

Auf viel befahrenen Verkehrsachsen könnten Lkw künftig rein elektrisch mobil sein und während der Fahrt ihre Batterien laden. Die Technologie bietet gleich mehrere Vorteile: Alle Fahrstreifen der Autobahn bleiben nutzbar, durch die oberirdische Installation lässt sich die Anlage leicht warten, und die Technik ist seit Jahrzehnten bewährt. Entlang der Teststrecke wurden während des Baus 229 Masten errichtet. Sie nehmen die beiden Fahrdrähte über der rechten Spur auf. Auch an Schildern oder Brücken muss die Stromversorgung nicht unterbrochen werden. Die Drähte werden an diesen Stellen einfach abgesenkt.

Vorerst jedoch wird getestet, ob sich der Betrieb rechnet und ob sich dadurch auf diesem Autobahnabschnitt der Verkehrsfluss ändert. Mit Einschränkungen ist nicht zu rechnen, denn die Oberleitungs-Lkw können problemlos überholen. Der Pantograf fährt dann ein, und der Lkw nutzt seinen internen Akku oder Dieselmotor. Kehrt der Laster auf die rechte Spur zurück, fährt der Stromabnehmer automatisch wieder aus. Neben dem Strom für die Fahrt wird gleichzeitig der Akku geladen. Das System hat für die Spediteure einen großen Vorteil: Im Gegensatz zu rein akkubetriebenen Lkw kann das Speicheraggregat kompakter gebaut werden und somit Gewicht und Kosten sparen. Werden längere Strecken ohne Oberleitung zurückgelegt, springt der interne Dieselmotor wieder an.

Die Teststrecke wurde bewusst gewählt. Mit mehr als 130.000 Fahrzeugen pro Tag (zehn Prozent Schwerverkehrsanteil) in einem Ballungsgebiet und dem Flughafen als Verkehrsdrehkreuz in der Nähe bietet sie ideale Bedingungen. „Wenn es hier funktioniert, funktioniert es überall", so Herda. Auch mögliche Gefahren wurden bedacht. Sollte eine der Leitungen reißen, schaltet das System automatisch die Stromzufuhr ab. Dass Leitungen oder gar einer der Strommasten durch einen Unfall auf die Fahrbahn geraten, ist nahezu ausgeschlossen. „Die Masten sind durch eine Betonwand so abgesichert, selbst Lkw können diese bei einer Kollision nicht beschädigen", erläutert Dr. Achim Reußwig, zuständiger Projektleiter Elisa bei Hessen Mobil.

Weniger Lärm und Vibrationen durch elektrisch fahrende Lkw

Die fünf Kilometer lange Teststrecke soll den Akku jeweils für ca. 60 km Strecke laden. Im Inneren der Lkw-Kabine profitiert der Fahrer zudem von einer wesentlich geringeren Geräusch- und Vibrationsentwicklung. Für einen flächendeckenden Ausbau müssen jedoch viele Rädchen ineinandergreifen. So gilt es, Rettungskräfte und Polizei in das Konzept einzubinden, um beispielsweise Landeplätze für Hubschrauber zu definieren. Außerdem muss die Stromversorgung sichergestellt sein, wenn in einer möglichen Zukunft mehrere Hundert Lkw am Tag die Strecke befahren sollen.

Vier Speditionen werden ab Mitte 2020 mit den von einem schwedischen Hersteller geleasten Trucks regelmäßig auf der A5 unterwegs sein. Die Kosten des Projekts belaufen sich auf knapp 15 Millionen Euro. Für die Zukunft ist es vorstellbar, rund 30 Prozent des deutschen Autobahnnetzes zu elektrifizieren. „Für die Haupttransportrouten wäre das ein enormer Gewinn", so Herda. „Damit könnte ein Großteil des Güterverkehrs auf deutschen Straßen deutlich umweltfreundlicher abgewickelt werden und seinen Beitrag zur notwendigen CO_2-Reduktion leisten." Davon würden auch die Anwohner profitieren.

Text: Oliver Reidegeld

Fotos: Hessen Mobil (2), Ralph Orlowski

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"We have a very positive view on the field trials" – Wolfgang Herde, Transport expert for the local ADAC chapter

"If it can work here [on the busy A5], it will work everywhere" – Wolfgang Herde,

"The poles are protected by a concrete barrier, and even a truck crash won't damage them" – Dr. Achim Reußwig, Manager for the project at Hessen Mobil

Source: https://www.adac.de/_ext/motorwelt/ADAC-Motorwelt-7-8-2019.pdf

Individual trucking companies are also excited about the technology

"The e-road technology looks very promising and we're very excited to learn more about how it works in practice" - Kerstin Seibert, co-owner of Spedition Schanz.

"I'd read that Spedition Schanz would participate in the pilot project and immediately became interested. Electromobility is an exciting development – that's the future and I want to be part of it." - Thomas Schmieder, truck driver.

Source: https://www.scania.com/group/en/spedition-schanz-pioneers-e-road-transport-in-germany/?sf216389546=1

Back ups –
Economics

ICCT* sees electrification with contact lines as crucial for reaching deep decarbonization of heavy duty vehicles

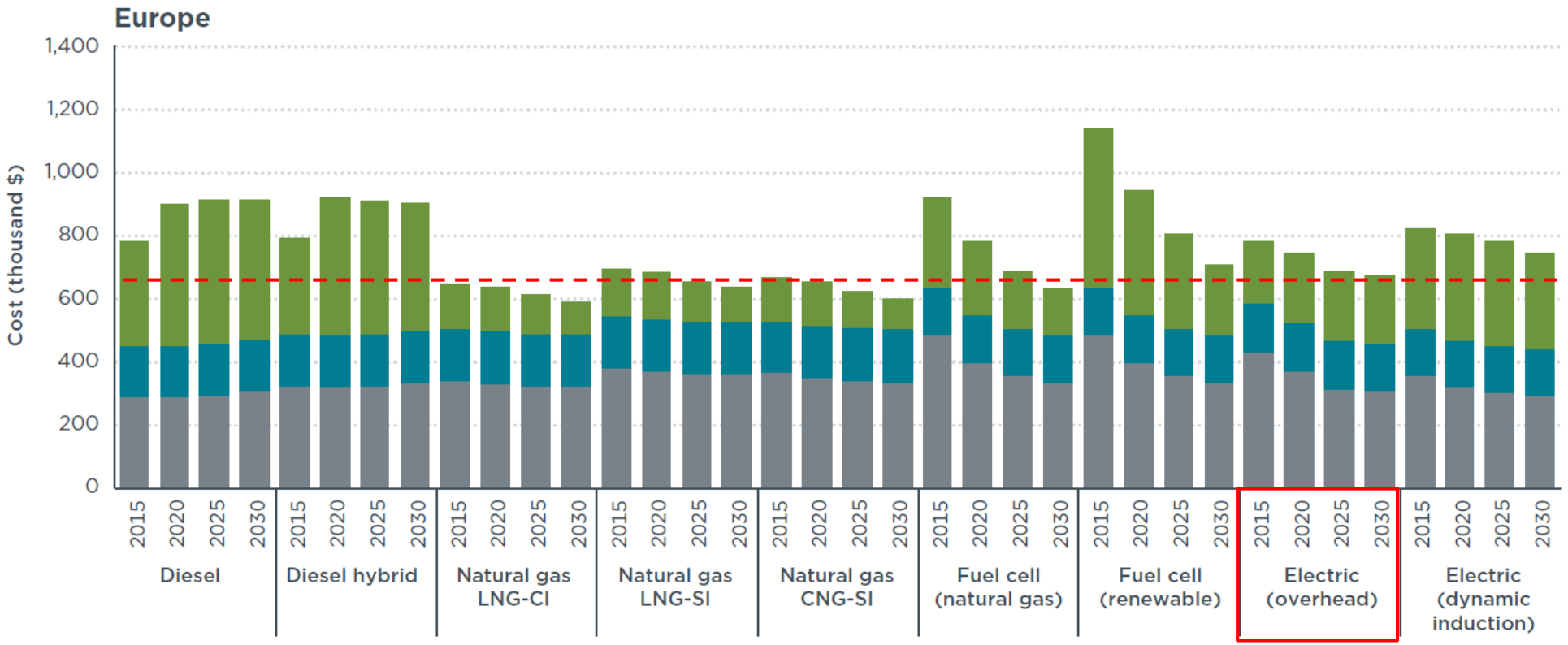

Figure 4. Cost of ownership in China, Europe, and the United States for each long-haul heavy-duty truck technology for a vehicle purchased in 2015–2030 broken down by capital cost, maintenance cost, and fuel cost.

- TCO lower than diesel, and most economical use of renewable electricity

Source: ICCT - Transitioning to zero-emission heavy-duty freight vehicles (2017) page 20

* ICCT = International Council of Clean Transportation

German industry association BDI recommends 4.000 to 8.000 km of overhead catenary lines as a cost-effective climate action for HDVs

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Background

- BDI published in 2018 an independent report looking at **all sectors of the economy**
- It 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

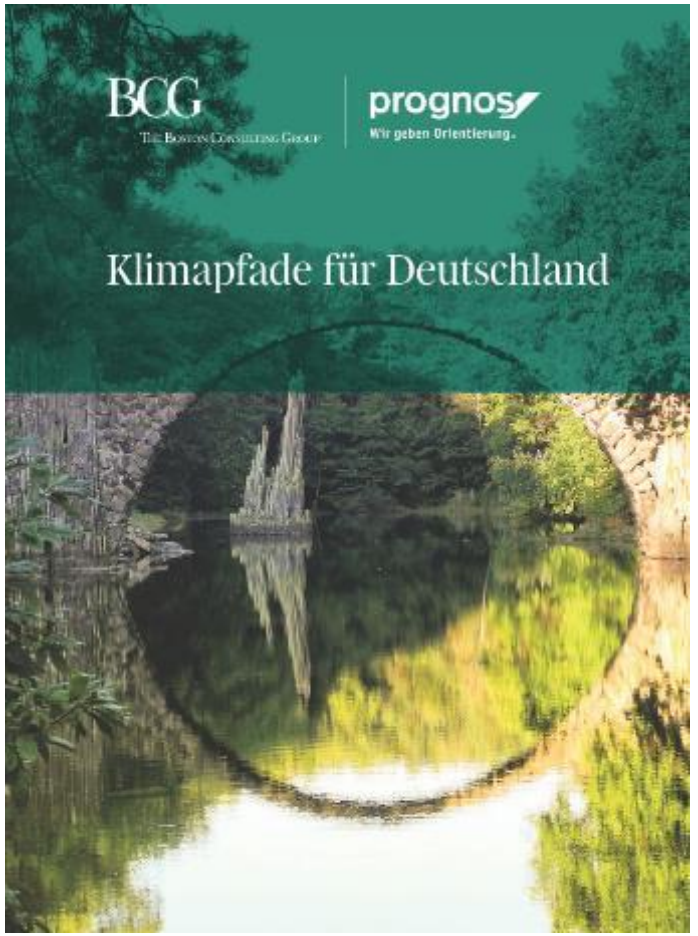
- Reaching **the 80% reduction is possible** by pushing existing technologies to the max. Has economically **positive effects, even if Germany acts alone**.
- Reaching the **95% reduction goal** touches the limit of what can be expected from technology and citizens. **Only in joint action with G20 economies**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

Transport highlights

- Shift to rail leads to an i**ncrease by 88% of ton-km of freight activity on rail** by 2050
- **No additional biofuels** for transport**,** because other sectors will be prepared to pay more
- **PtX only in 95% scenario.** Imported from Middle East & North Africa, and it will still be very pricey

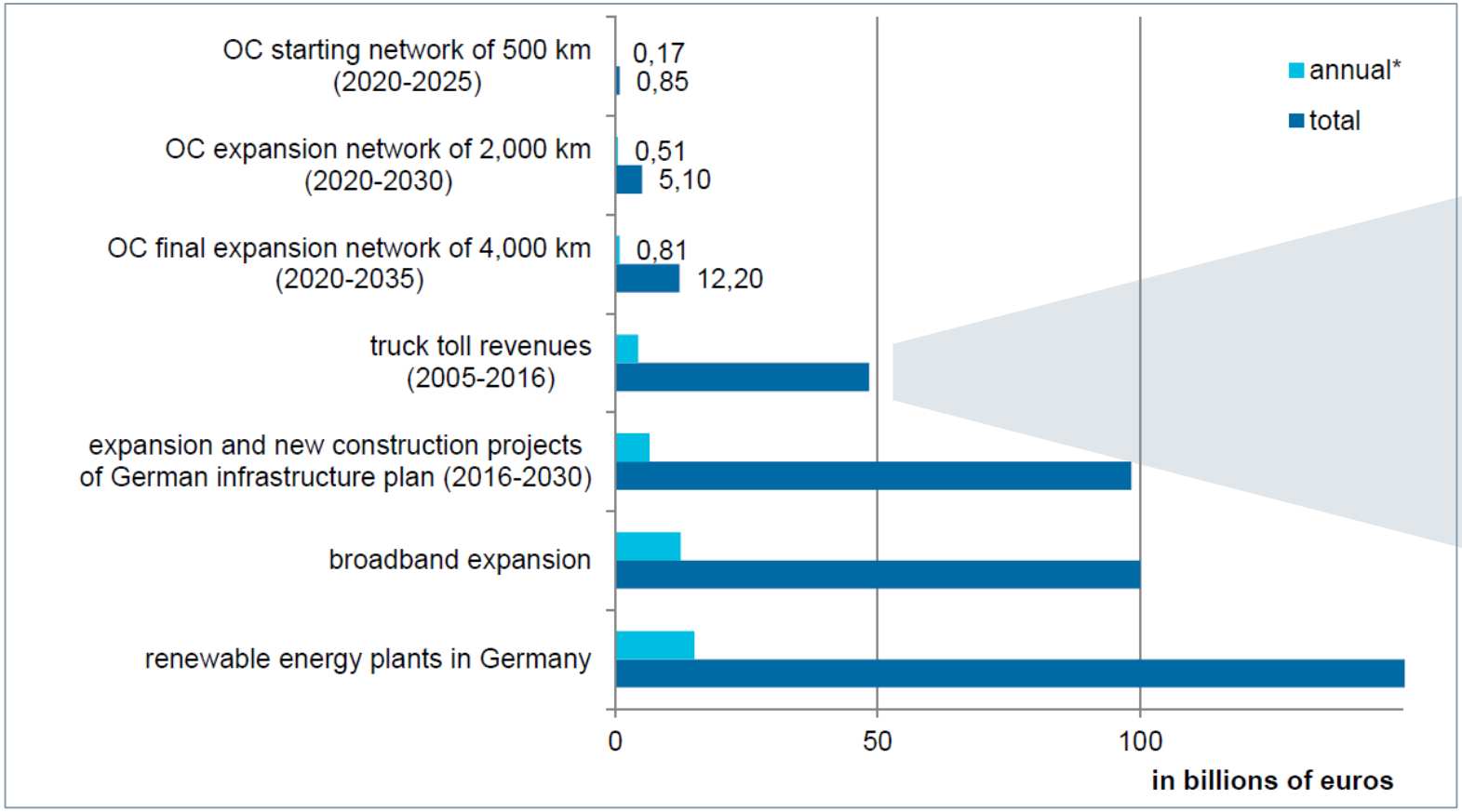
eHighway

- 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 GER 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.



Source: https://bdi.eu/publikation/news/klimapfade-fuer-deutschland/

Investment in eHighway network covering 4.000 km of Autobahn could be financed by 11% of annual expected truck toll revenue



German government changed the toll scheme in 2018 and now **expects annual truck toll revenue to exceed EUR 7.2bn.**

Source: Handelsblatt

*average annual toll revenues or infrastructure investments during the indicated period

**the rising infrastructure costs per kilometer with increasing network expansion (from the start to the final expansion network) are caused by the assumed increasing performance of the infrastructure.

Source: Oeko Institute – StratON Project report (2018) page 12

Translated Table 7 from German Transport Ministry (BMVI) report

Components	Basis for calculations	Costs (EUR/km)
Grid connection point	Ca. 15.000 EUR per connection. At a pattern of a connection point every 3 km leads to 5.000 EUR/km	5.000,--
Feed line from grid connection point to substation along the route	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	250.000,--
Substation	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	600.000,--
Poles	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)	400.000,--
Catenary (contact line)	Ca. 300 EUR per m, e.g. 600.000 EUR per km (covering both road directions)	600.000,--
Guard rails	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)	200.000,--
Planning, Procurement and Project management	Ca. 10% of the investment costs	205.000,--
Total		**2.260.000,--**

Source: BMVI - Machbarkeitsstudie zur Ermittlung der Potentiale des Hybrid-Oberleitungs-Lkw (2017) page 36