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Truck decarbonization race: Who is taking the pole position?

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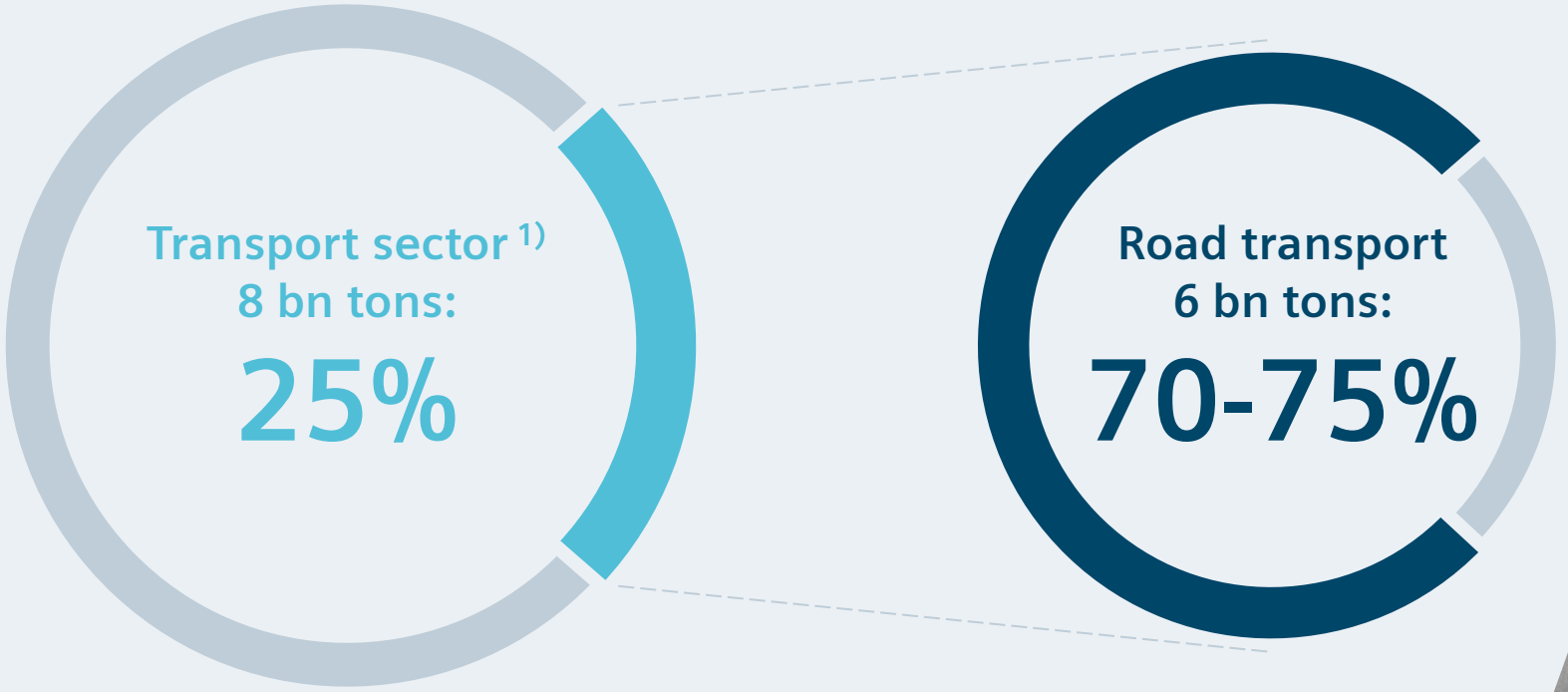
Transportation accounts for roughly 25% of global CO_2 emissions

Global CO_2 emissions 2019: 33 bn tons



1) Rail, aviation, road and others
Source: Climate Watch; IEA; Siemens, European Commission

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Cars, vans and trucks in the transport sector have significant decarbonization goals of ~30-40% until 2030 based on EU regulation

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EU regulation for cars & vans

2020 emission level for new cars in EU: 95 g/km

EU fleet-wide CO_2 emission targets:

- Cars: 15% reduction [1] by 2025; 37.5% by 2030 [2]
- Vans: 15% reduction [1] by 2025; 31% by 2030 [2]

Penalty / tax:
95 EUR for each g/km of target exceedance

EU regulation for trucks

Strict emission targets to be met starting from 2025:

- From 2025 onwards: 15% reduction
- From 2030 onwards: 30% reduction [2]

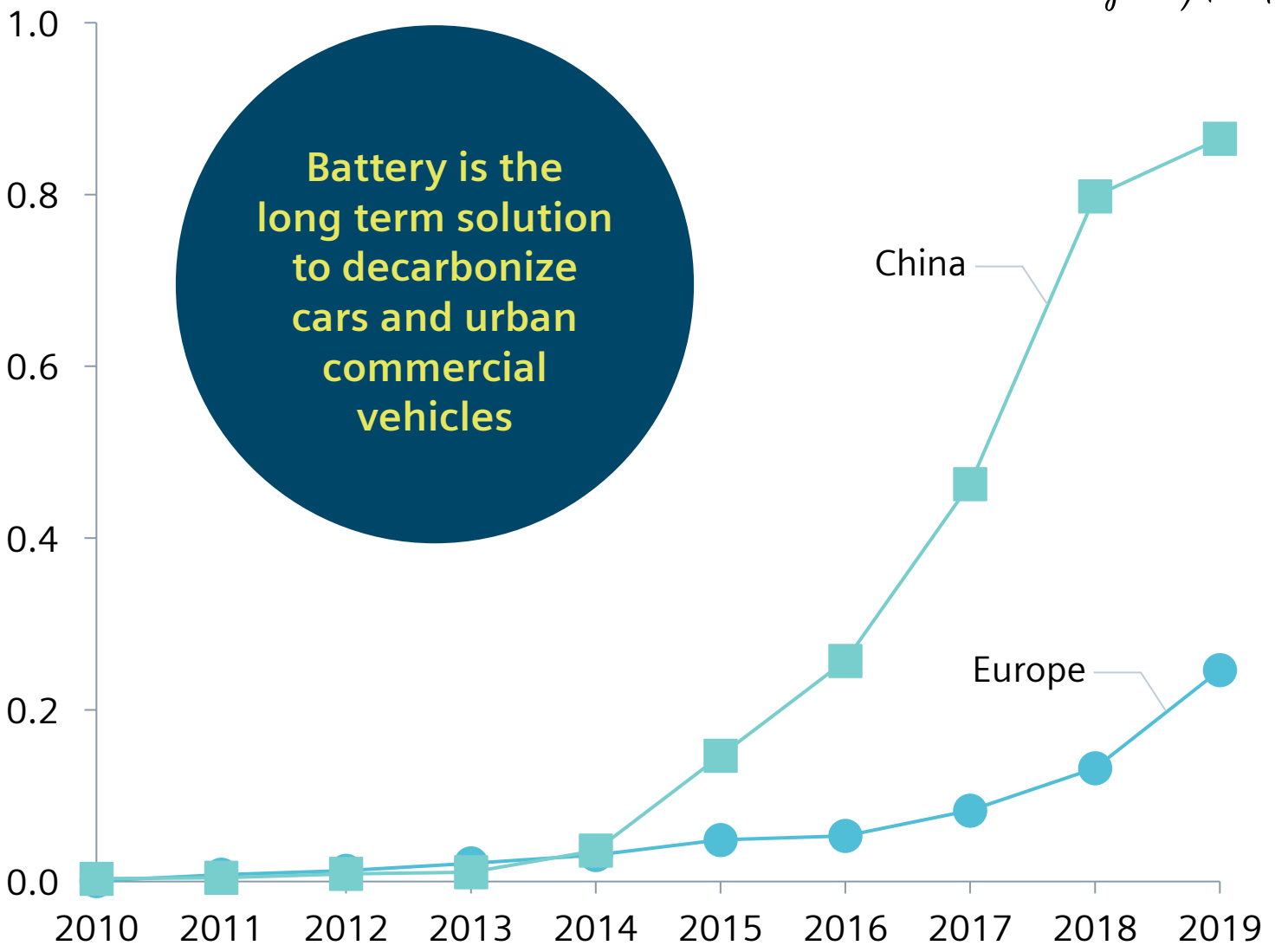
First applied to heavy duty trucks
(65-70% of total CO_2 emissions)

Penalty / tax: 4,250 EUR per gCO_2/tkm in 2025 and 6,800 EUR per gCO_2/tkm in 2030

1) Reference point: 2021
2) Target of European Commission: Zero emissions by 2050
Source: Climate Watch; IEA; Siemens, European Commission

Battery technology will power new cars and urban commercial vehicles …

BEV annual sales, in million units



BEV: Battery electric vehicle; OCL: Overhead Catenary Lines; EV: Electric vehicle
Source: CAAC, Europ. Alternative Fuel Observatory, Siemens, Handelsblatt, NPM

… but leading decarboni-zation approach for trucks remains open

?

Electric:
Tesla plans to deliver their **battery EV truck** "Semi" end of 2021

Overhead Catenary Lines:
Scania supplying 22 **OCL-trucks for Germany,** where the government is electrifying several 100 of km by 2024

Synthetic fuel:
Porsche & Siemens Energy plan to produce up to **55 mio liters** of synthetic fuel by 2024 in Chile

Hydrogen fuel cells:
Hyundai delivered the first of their total of **1600 H_2 medium weight fuel cell trucks** to Switzerland, also **Toyota, Volvo and Daimler** work on H_2 fuel cell powered trucks

Source: CAAC, Europ. Alternative Fuel Observatory, Siemens, Handelsblatt, NPM

Decarbonization of heavy duty trucks will be possible by using different drive train technologies per use case

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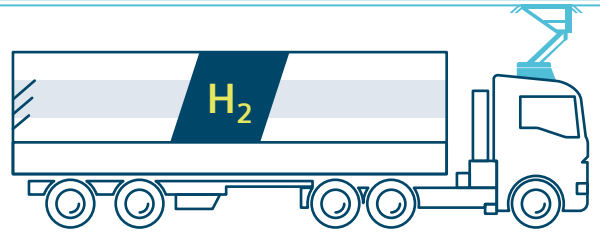
Booster: **Overhead Catenary Lines** (details on next slide)

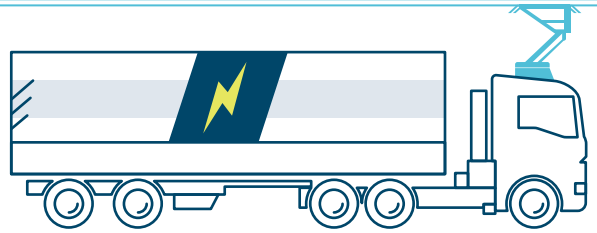


Hydrogen fuel cell power

- \+ High range to mass ratio
- − High operational cost (e.g. due to fuel price, efficiency)

Preferred use case

Best for **long range use case in which electrification is not economical**



Battery electric power

- \+ Technology eco-system proven with light duty vehicles
- − Limited range

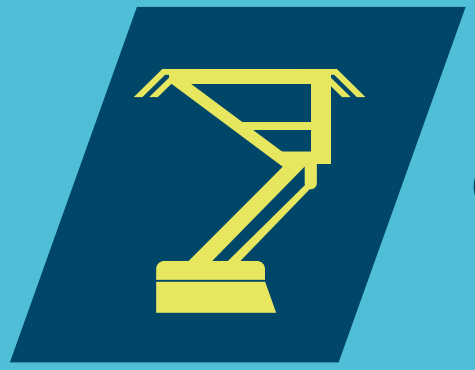
Best for decarbonized **urban distribution use case**

Synthetic/bio-based fuel power

- \+ Available infrastructure, suitable to decarbonize existing fleet [1) 2)]
- − Limited availability of fuels

Best for **existing fleet decarbonization use case**

1) Assuming a hybrid-electric drivetrain truck is used 2) Synthetic fuels require carbon capture technologies for decarbonization
Source: Siemens



Overhead Catenary Lines

All three drive train technologies and their business cases can be "boosted" by charging infrastructure such as "Overhead Catenary Lines" (OCL) on highly frequented routes. The technology works similar to electric trains and reduces the cost per kilometer when in use.

Source: Siemens

Hydrogen is prominent in the press, yet other drive train technologies are also pushed by key market players

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Formed a JV to develop fuel cell systems for heavy-duty trucks
- Daimler consolidated its FC activities
- Volvo to acquire 50% in JV with 0.6 bn EUR
- Series production to be started in the second half of the decade

Daimler Truck AG & Volvo Group

Agreed to jointly develop a heavy-duty FC truck
- Based on modified Hino Profia (adjusted chassis system for FC)
- Using Toyota's latest FC stacks (initially developed for Mirai)
- Length of 12 m, weight of 25 t, range of 600 km

Toyota & Hino Motors

Strong start of hydrogen truck activity in Switzerland
- First delivery of H_2 Xcient trucks, July 2020
- Plans to increase production capacity to 2,000 units per year by 2021
- Announced to spend 6.4 bn USD on hydrogen technology globally by 2030

Hyundai Motors

Committed to the investment of up to 1 bn EUR in the development of truck and bus e-drive-trains; JV with Hino Motors for FC trucks
- E-drives to be used for MAN, Scania, VWCO and Hino
- VWCO received order for 1600 etrucks in Brasil

Traton Group & Hino Motors

SAIC Motor Cooperation

Leading Chinese OEM in FC heavy duty trucks
- Launched FC500 D12 FC trucks, series production planned to start in 2020
- 7 t load capacity, 500 km range
- 3 min refueling time

Hyzon Motors Group

Hyzon Motors is a 2020 spin-off of Horizon Fuel Cell Technologies Pte
- Develop Medium & Heavy duty FC trucks
- Offer trucks from 12-50 t powered by with 400-600 km range
- Hiringa ordered for up to 1,500 trucks by 2026

Tesla, Inc.

Plans on starting production of Tesla Semi end of 2021
- Semi 2.0 announced to have up to 1000 km range
- Semi offered with 480-800 km range
- Weight optimization ongoing to reduce negative impact on load capacity

Siemens Mobility & Scania AB

In R&D partnership to test Overhead Catenary Lines on highways
- First pilot projects in Germany built on motorways, used in regular trucking
- Cost of 3-12 ct/km for technology use
- Germany plans to build-up ~300km of OCL by 2024, with national plans of 4,000 km by 2030 being promoted

Note: FC: fuel cell; OCL.: Overhead Catenary Lines; Synfuels can be used in most of the existing fleet
Source: Siemens, public press releases

Regulatory framework in support of alternative drive train trucks is accelerating across Europe, Americas and Asia

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California
- Requirement for new trucks to be zero emission from 2024 (inc. sales %)
- 40% of tractor trucks sold need to be zero emission by 2032

~10-13 EUR/kg

Sweden
- National plan for 2,000 km of electrified motorways for trucks by 2030

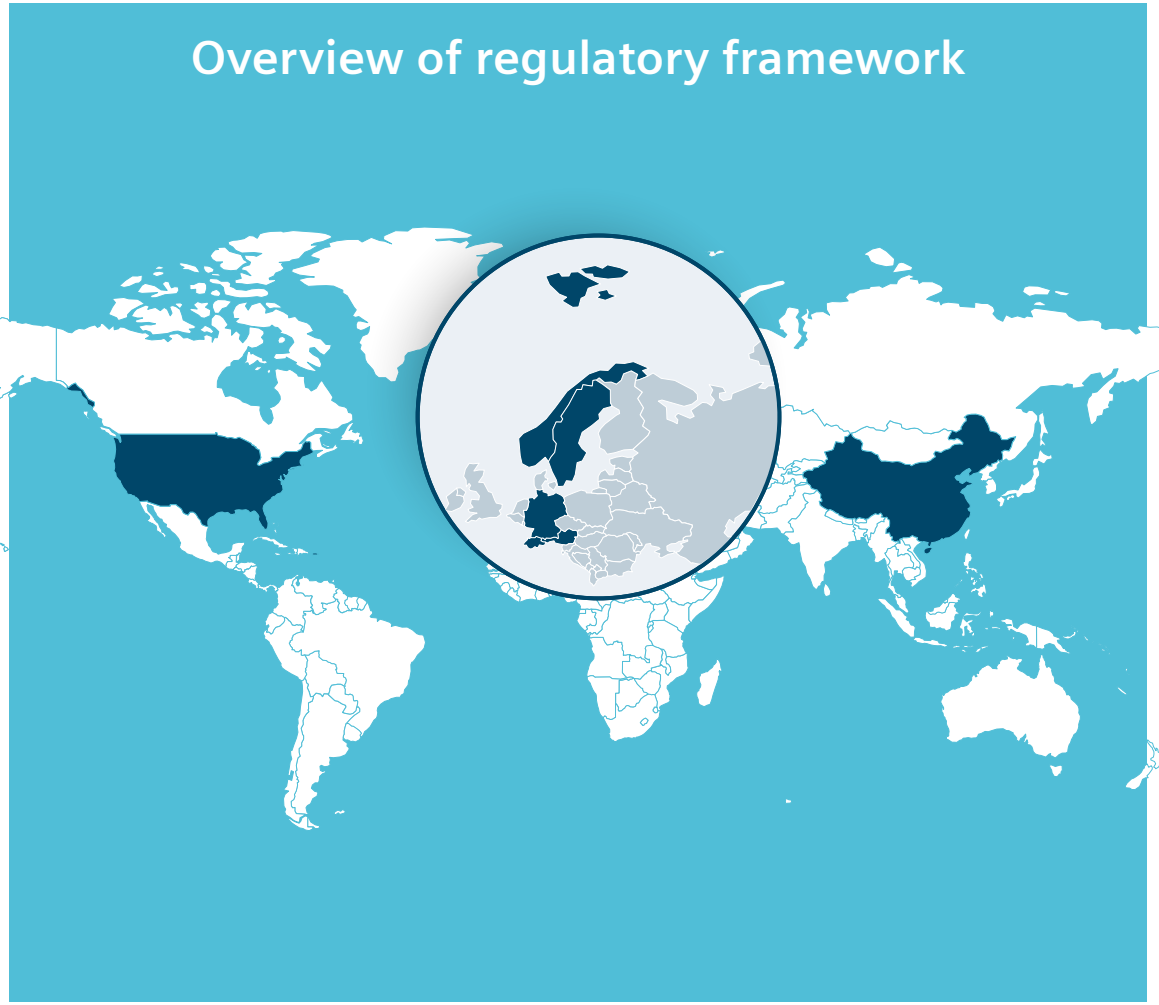
~8-10 EUR/kg

Norway
- Incentive for EVs (including FCV) trucks
- No annual road tax
- Lower highway fares [1)]
- Lower parking fees [1)]

~8-9 EUR/kg

Switzerland
- Vehicles with electrical drive train (including FC) are exempt from heavy vehicle charge

~10-13 EUR/kg



Germany
- 4.1 billion investment in infrastructure for alternative fuel technologies for road transport
- Electric trucks (batt., catenary, hybrid, fuel cell) pay no heavy truck highway fee (~0.2 EUR/km)

~9-10 EUR/kg

Austria
- Lower highway rates [2)] for fully-electric and non-hybrid hydrogen FCV in 2020

~9 EUR/kg

China
- Regional government subsidies for hydrogen fueling stations [3)]
- Subsidies on BEV trucks

~5-8 EUR/kg

South Korea
- For EV (including FCV) trucks, highway fee can be reduced by 50%

~5-6 EUR/kg

Note: Selective regulations only as of February 2021 1) Up to 50% discount 2) ~10-20 EUR ct/km, depending on size (2-axle to 4-axle)
3) Up to 500k EUR per station 4) Based on local prices and hydrogen production mix in Jan 2021
Source: Siemens, public press releases

Hydrogen off-take price [4)]

Also for Overhead Catenary Lines we see government commitments in the market to support the technology role-out

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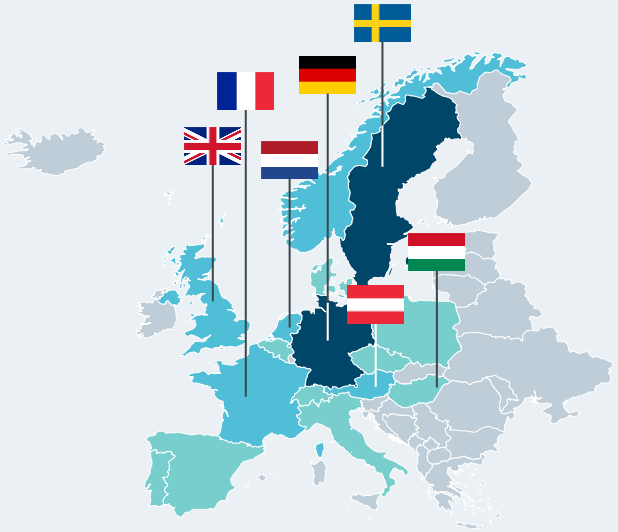
Enabling zero emission trucking government commitments by 2050 [1] (selective)



- Overhead Catenary Lines: Field trial realized or in preparation
- Study with regard to Overhead Catenary Lines for heavy duty vehicles exists or in preparation
- Interest in Overhead Catenary Lines exists

UK
- +20 km Overhead Catenary Lines pilot with 50-150 trucks considered by transport department

France
- Government to government partner-ship on electrified roads with Sweden and Germany
- Ministry leading three working groups for electrified roads: potential, technology and pilot

Netherlands
- Study finds electrical road systems most economical. Stresses linking up with Germany

Germany
- 2018-2022: Three OCL fields trials on motorways A1 and A5 and national road B462
- Shuttle pilots by 2023 and perspective of 4,000 km large OCL network by 2030

Austria
- Environment Agency sees contact lines as highest measure to road freight CO_2 reduction
- Overhead Catenary Lines part of new coalition agreement

Sweden
- Transport minister announced plan for 2,000 km of electrified motorways for trucks by 2030

Hungary
- Transport minster keen on implement-ting pilot project

OCL: Overhead Catenary Lines
1) On Trans-European Transport Network corridors
Source: Siemens, public press releases

To reach decarb goals for heavy duty trucks most economically, alternative drive train technologies have to be combined cleverly

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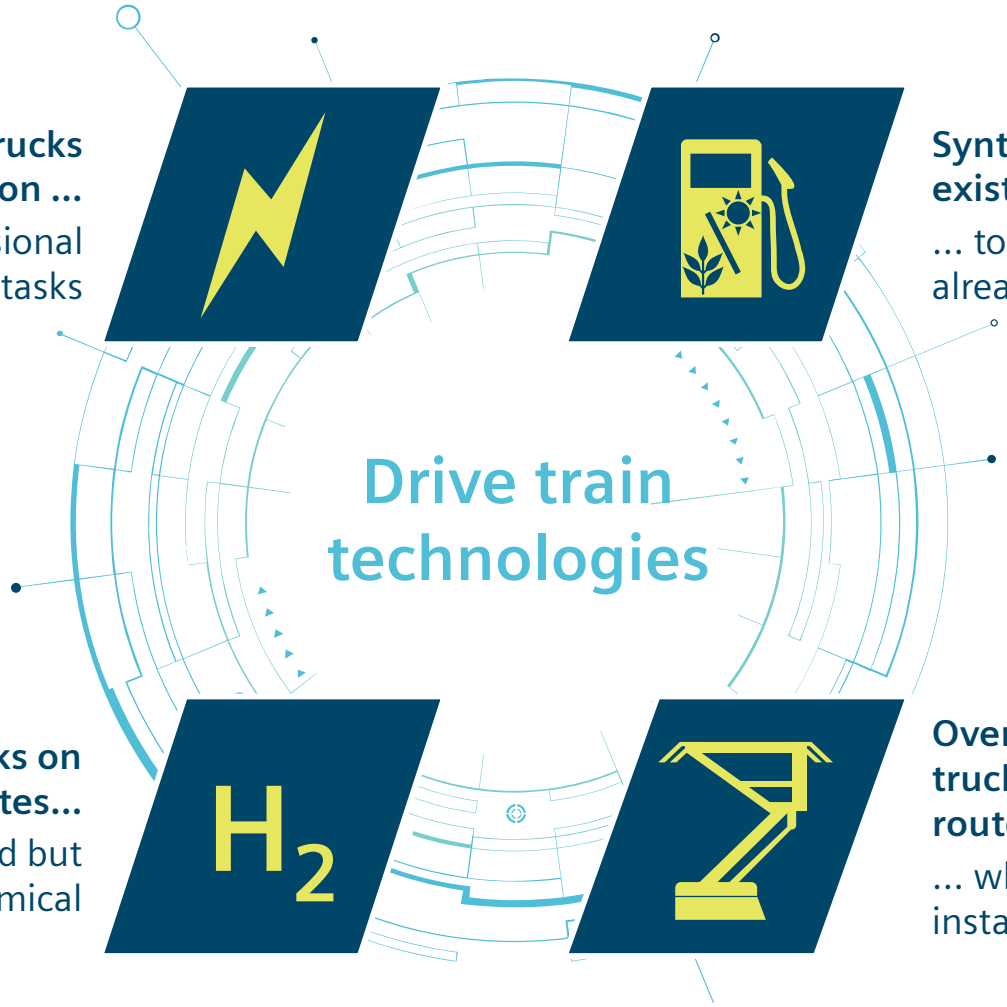
Battery powered trucks in urban distribution ...

... with only occasional longer transport tasks



Synthetic/bio fuel for powering trucks in existing fleets...

... to achieve partial decarbonization of the already existing combustion engines in use

Fuel cell powered trucks on the non-electrified routes...

... where long range is needed but electrification is not economical

Overhead Catenary Lines as add-on for trucks traveling on highly frequented routes...

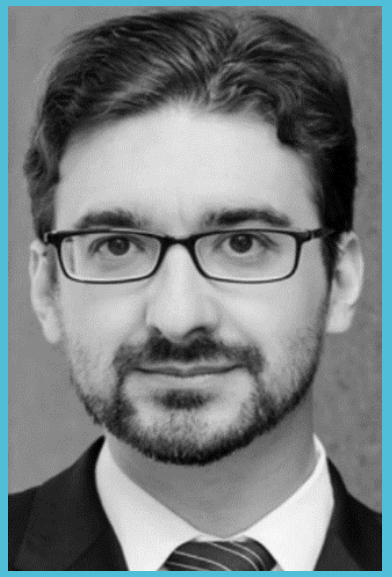
... where the volume of trucks justifies the installation of the infrastructure

Source: Siemens

Siemens Advanta Consulting
Contact us to discuss your decarbonization strategy!

Philipp Grosse Kleimann

Senior Partner
Head of Automotive &
New Mobility



Stefan Kneip

Partner
Energy and
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www.siemens-advanta.com/decarbonization-race