CHALLENGES AND OPPORTUNITIES FOR HIGHLY ELECTRIFIED HEAVY DUTY VEHICLES

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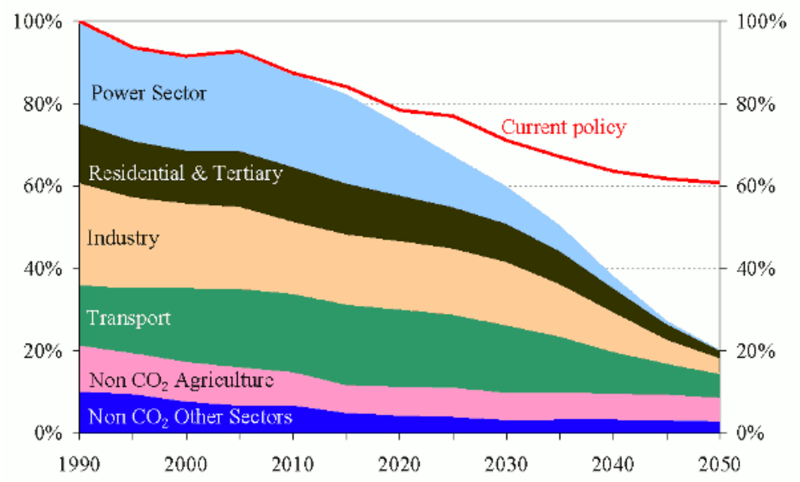
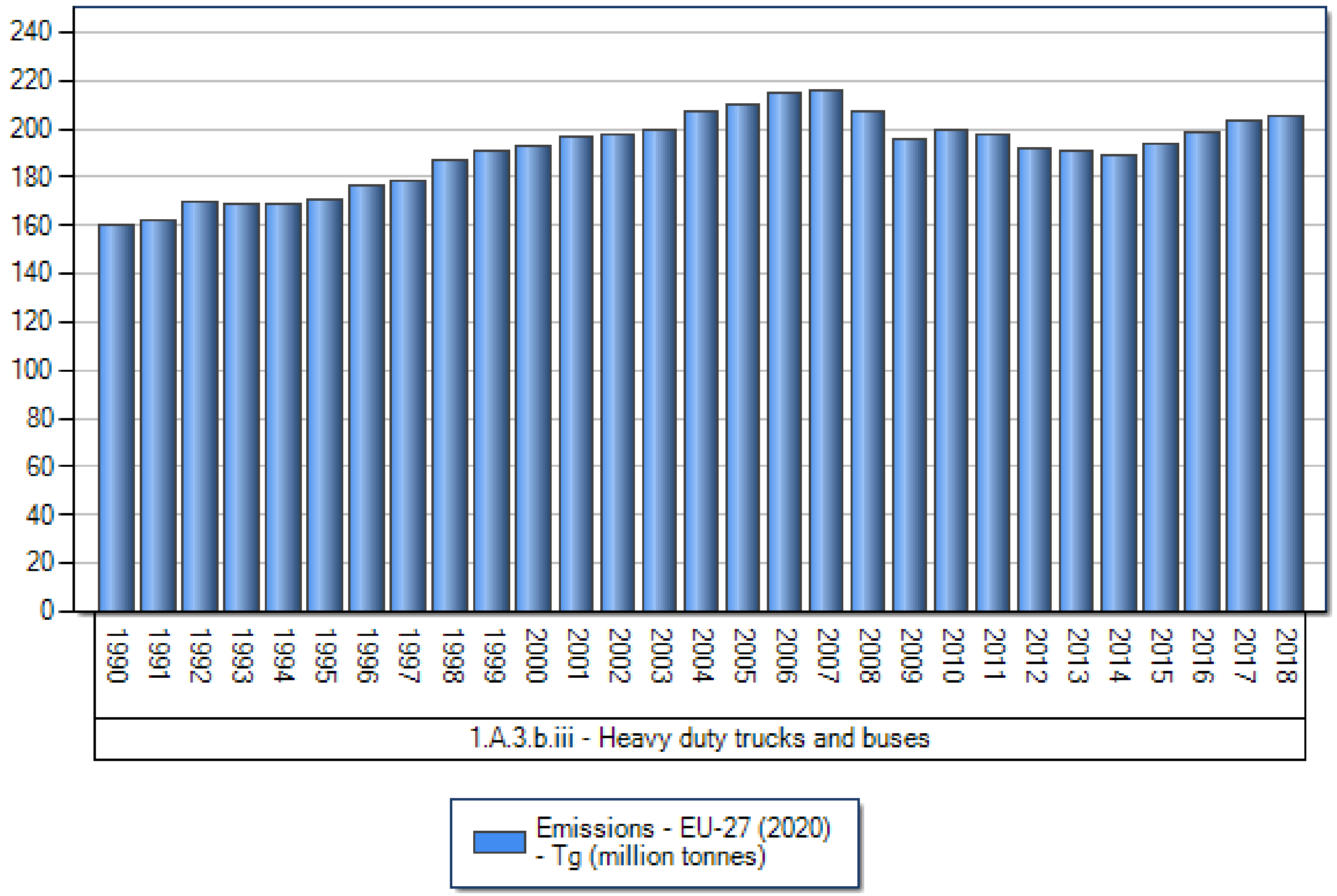
DECARBONISATION OF HEAVY-DUTY VEHICLE TRANSPORT: ZERO-EMISSION HEAVY GOODS VEHICLES 28 OCTOBER 2020

THE CHALLENGE TOWARDS 2050

The EU has set itself a long-term goal of reducing **all** greenhouse gas emissions by 80-95%, when compared to 1990 levels, by 2050.





The challenge:

- Transport includes rail, shipping, aviation, road, etc.
- Road transport is set to increase, even if CO2 from transport ~50%
- The actual CO2 (/km) improvement needs to be ~80-95%
- New energy vehicles selling at volume by 2035-2050
- Technology ready by 2025-2030
- Accelerated R&D 2020-2025!

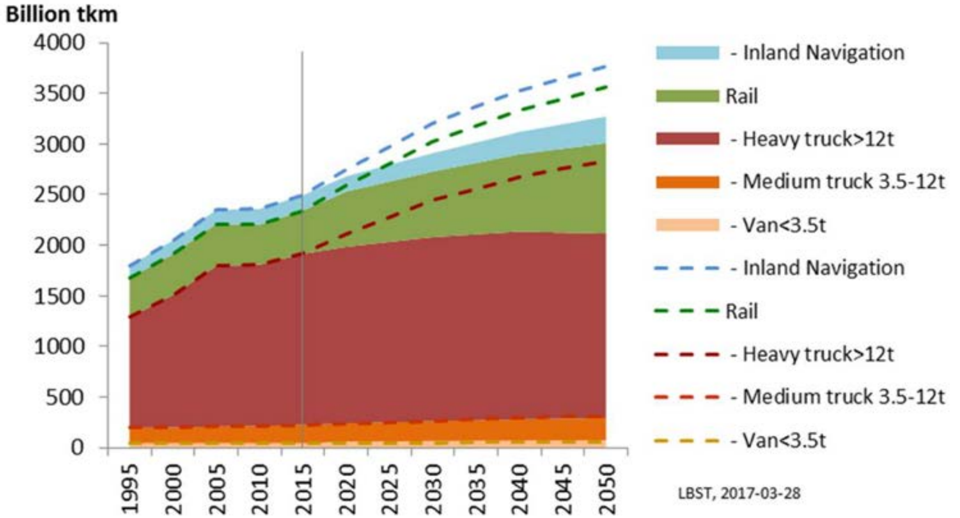
Source: Data viewer on greenhouse gas emissions and removals, sent by countries to UNFCCC and the EU Greenhouse Gas Monitoring Mechanism (EU Member States). https://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer

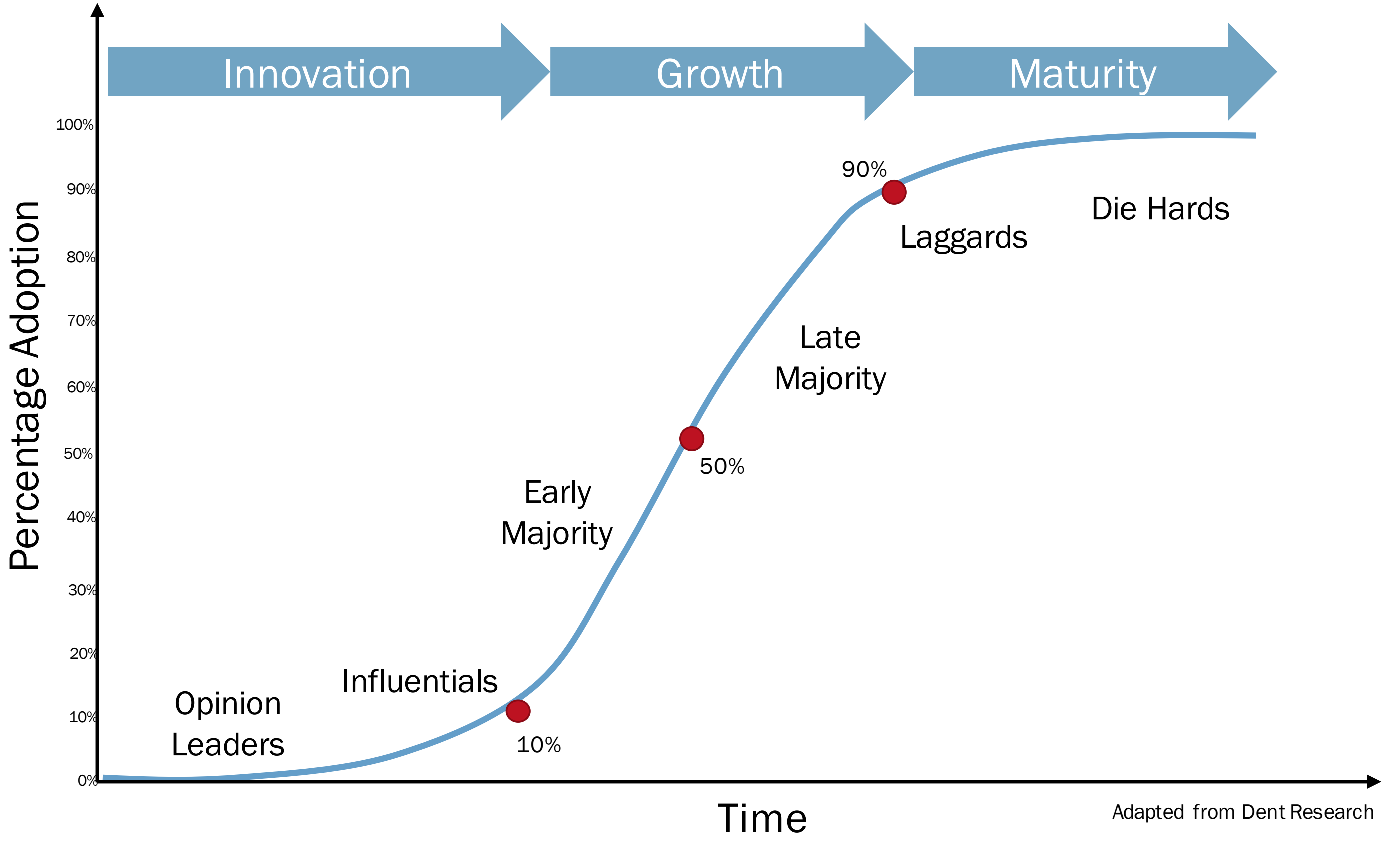
https://ec.europa.eu/clima/sites/clima/files/strategies/2050/images/targets.png
Src: https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/2050-energy-strategy

How (collectively) are we going to achieve this?

THE CHALLENGES FOR HEAVY DUTY: SHORT-TERM TARGETS, SLOW DEPLOYMENT

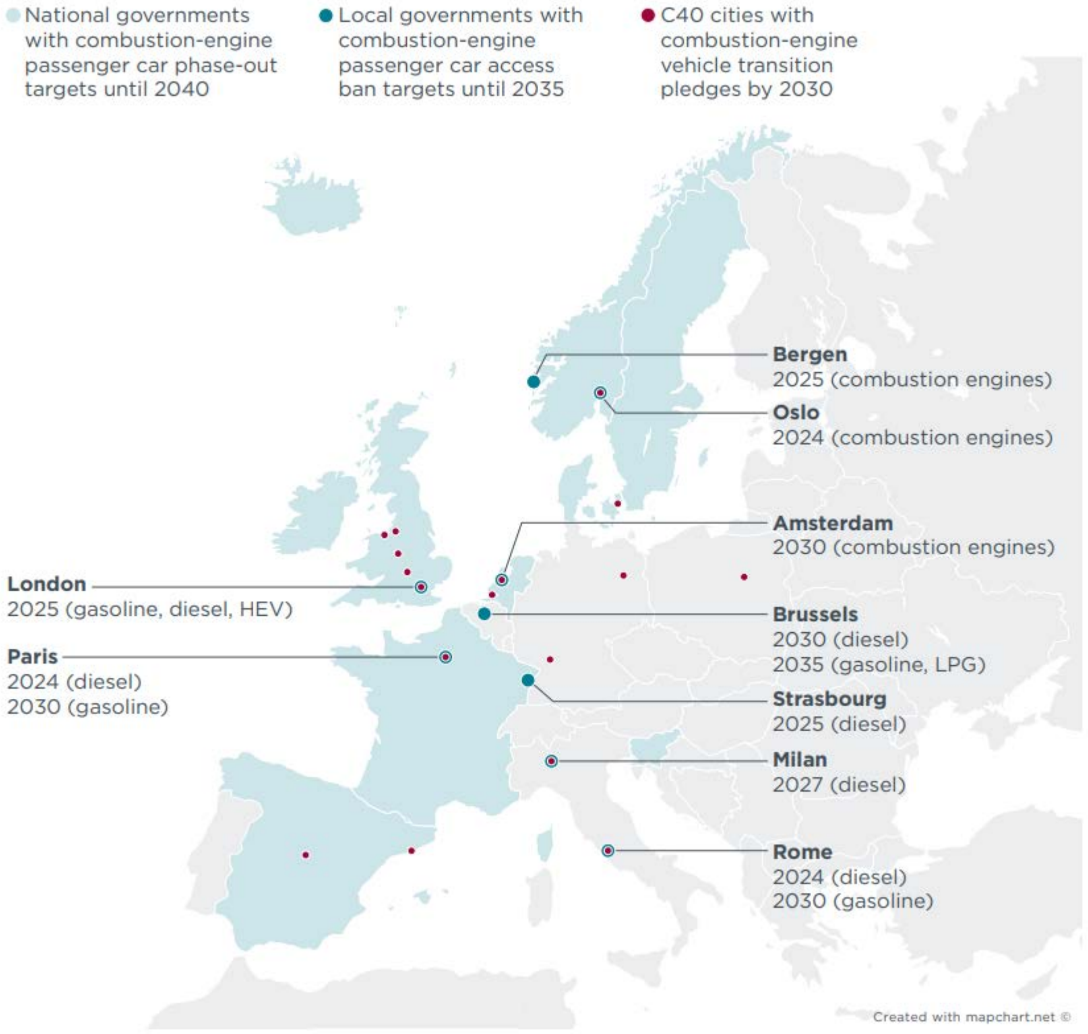
- Heavy Duty sector expected to increase towards 2050
- VECTO introduced May 2018, first declaration year 2019:
  - 15% reduction CO2 by 2025
  - 30% reduction CO2 by 2030
- Typical vehicle development cycle can be ~5-7 years
- Adoption curve can be more gradual
- The next 30 years to 2050 potentially requires more dramatic changes than the last 30 (i.e. since 1990)





ZERO EMISSIONS

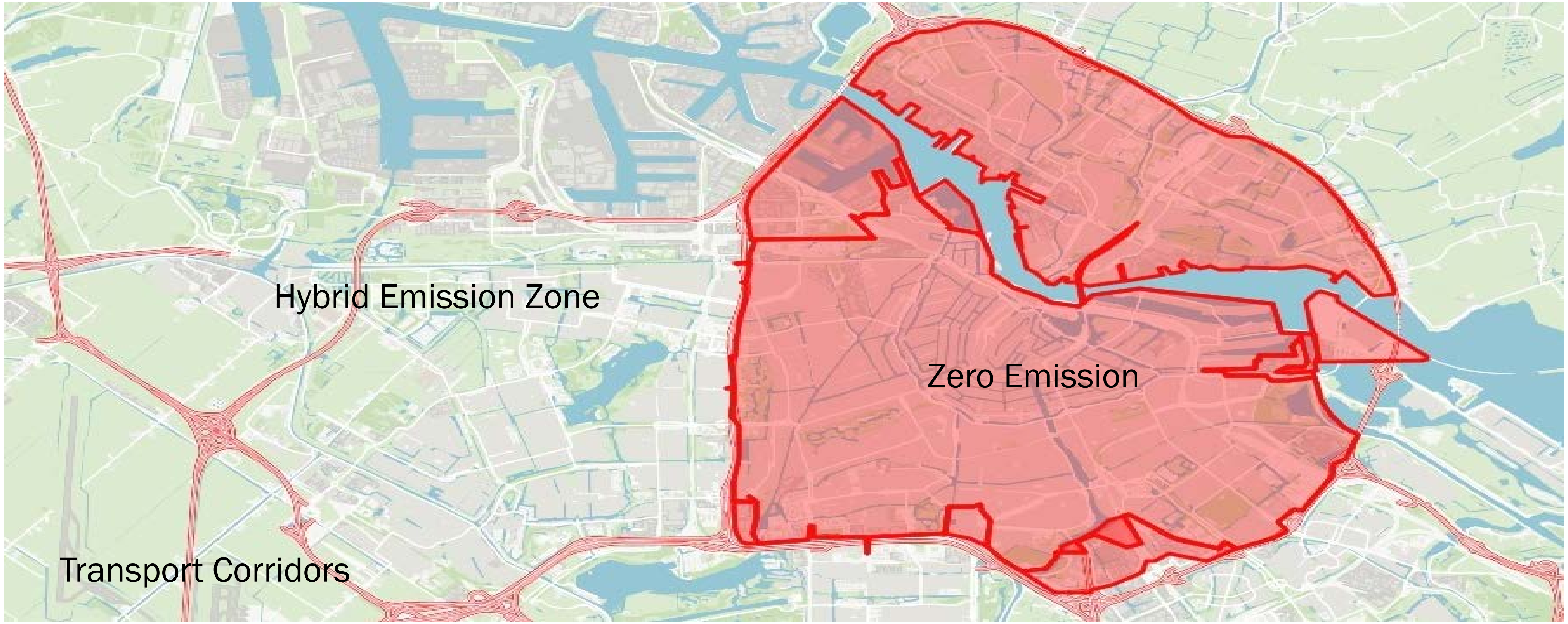
- Zero emission vehicles commonly interpreted as BEV or FCEV
- Under the Green Vehicles Directive [DIRECTIVE (EU) 2019/1161], a **zero emission heavy duty vehicle** is one emitting <1g CO2/km, but allow current levels of pollutants
  - Several OEMs[1,2] view that hydrogen combustion vehicles would therefore qualify as zero emission as a bridging technology
- National governments and city policy focus bans on pollutant emissions (i.e. zero tailpipe emissions), potentially to include all combustion engines (main focus on cars, but also including HD)
- For heavy-duty, some solutions exist around potential geofencing technologies; such as via PHEV
- In-Service Conformity still has some artefacts relating to PHEVs
- One potential scenario is a H2ICE PHEV gradually replaced with FCEVs or BEVs as fuel cell / battery technology improves further
  - Flexible solution with deployment of future charging/fuelling infra
  - More moderate technology step from combustion engines



https://theicct.org/sites/default/files/publications/Combustion-engine-phase-out-briefing-may11.2020.pdf

[1]https://www.volkswagenag.com/en/news/2020/10/MAN-presents-Zero-Emission-Roadmap.html
[2]https://www.daf.com/en/about-daf/sustainability/alternative-fuels-and-drivelines/hydrogen

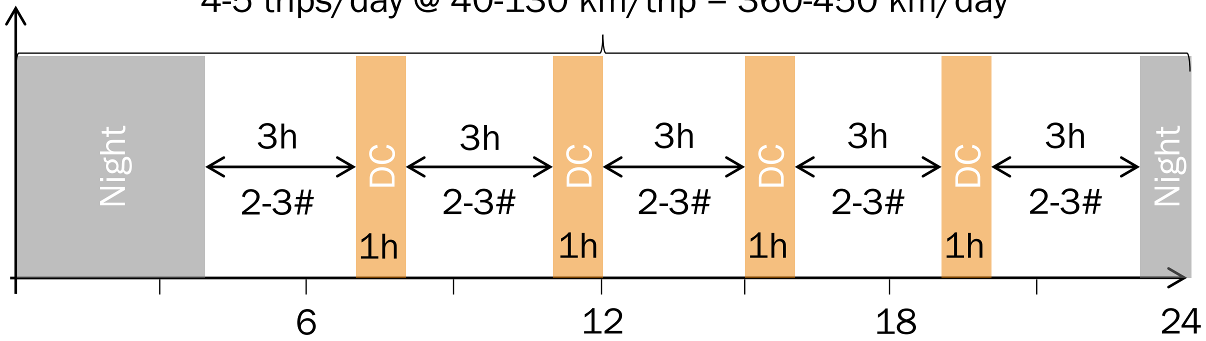
CITY OF THE FUTURE

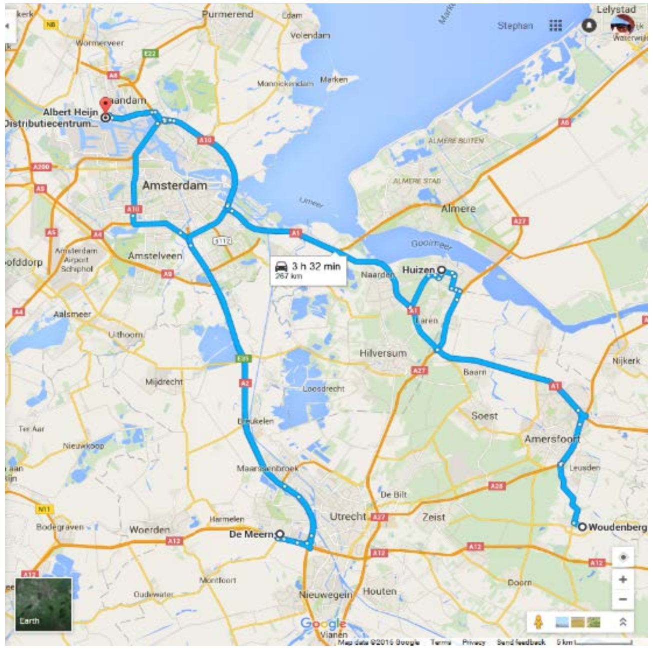


- Zero-emission zones supported through charging infrastructure
- Inter-zone require mixed functionality
- Various vehicle configurations, but key is on modularity and standardisation

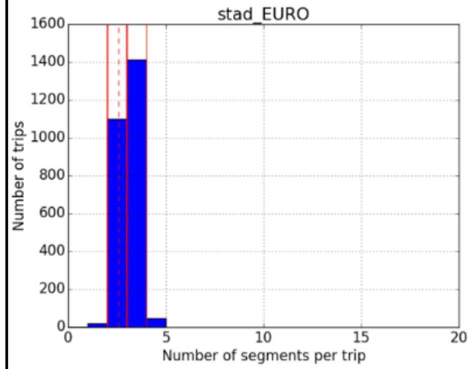
END USER REQUIREMENTS

4-5 trips/day @ 40-130 km/trip = 360-450 km/day

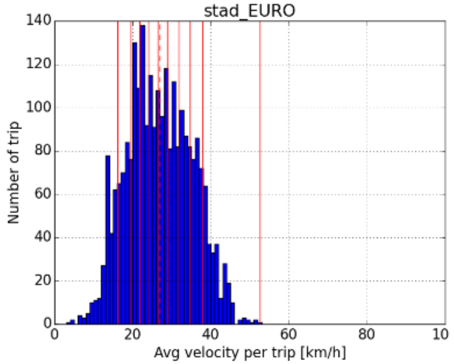




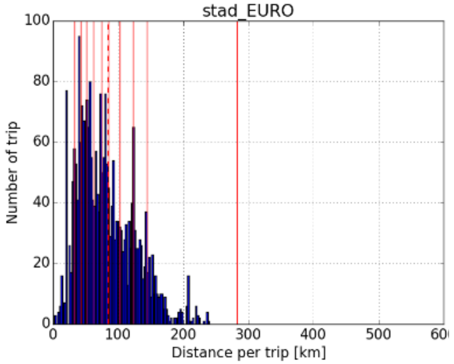
Speed in km/h [segment / trip / day]	35 / 25 / 17
Loading in kg [90% / middle / average / low]	14580 / 11246 / 2770 / 0
Typical usage Diesel [l/100km]	27-29 (+ 9.5)
Typical useage LNG [kg/100km]	23-24 (+ 9.5)
Typical useage Electric [kWh/km]	1.26-1.27 (+ 0.25)

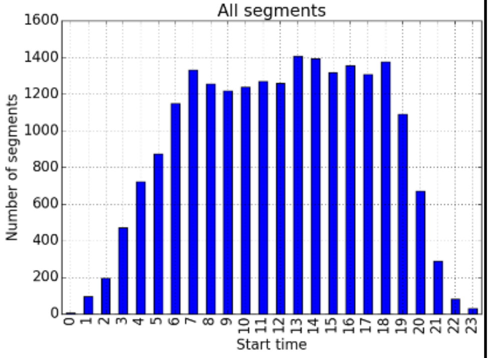


2-3 [stops/trip]



30 [km/h] ⟶ 3 [h] ⟵ 90 [km]

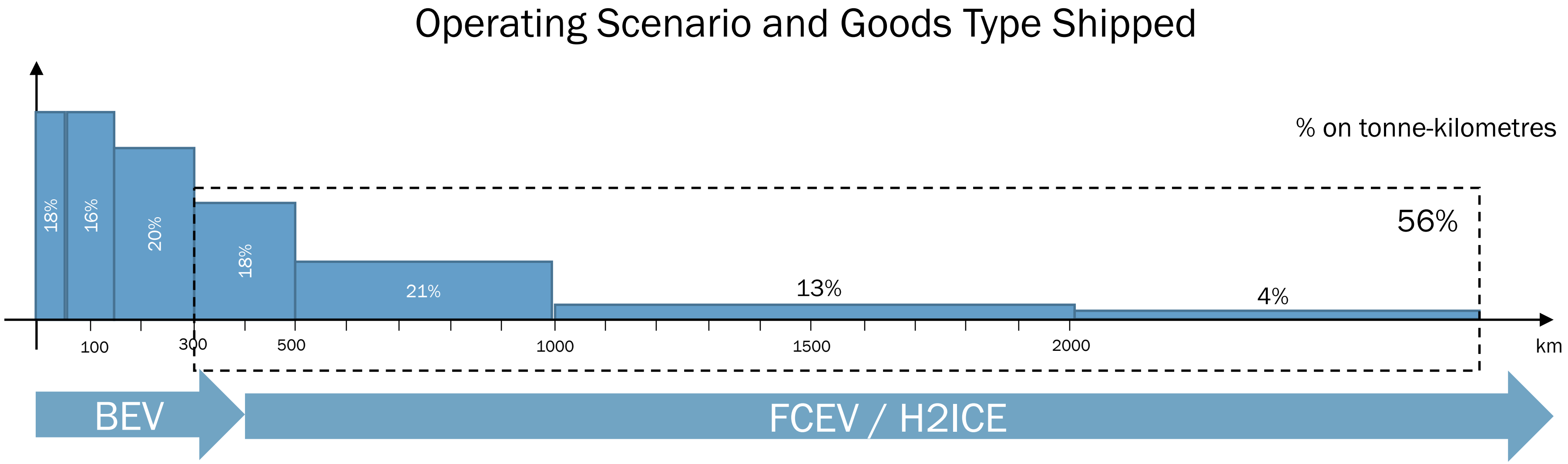




0 – 24 [h]

DISTRIBUTION AND LONG HAUL TRUCKS

For the distribution of journey lengths, ~56% of tonne-kilometre freight are covered by ~300km or more (ref ALICE) for EU – sizing of battery packs towards the application can mean that a choice needs to be made

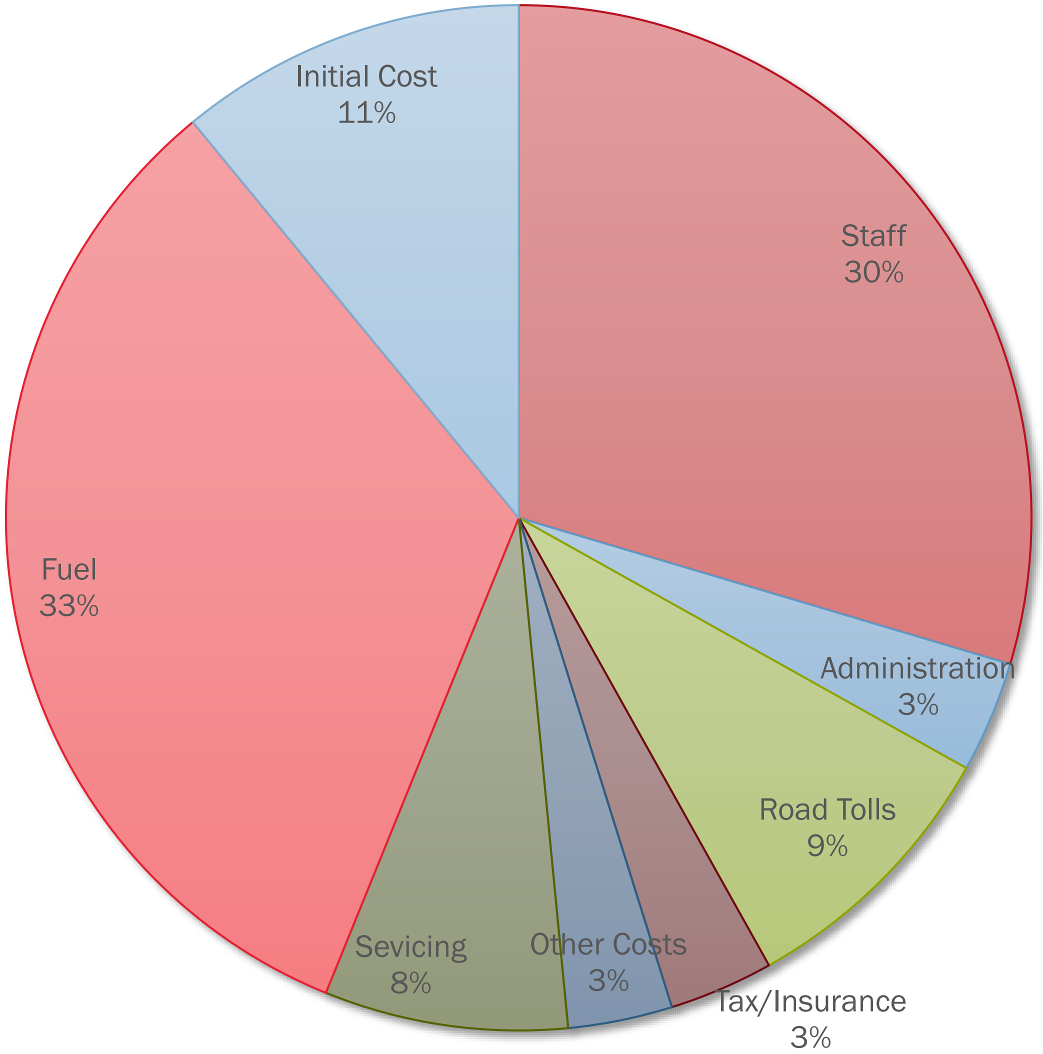


Decisions are based on:

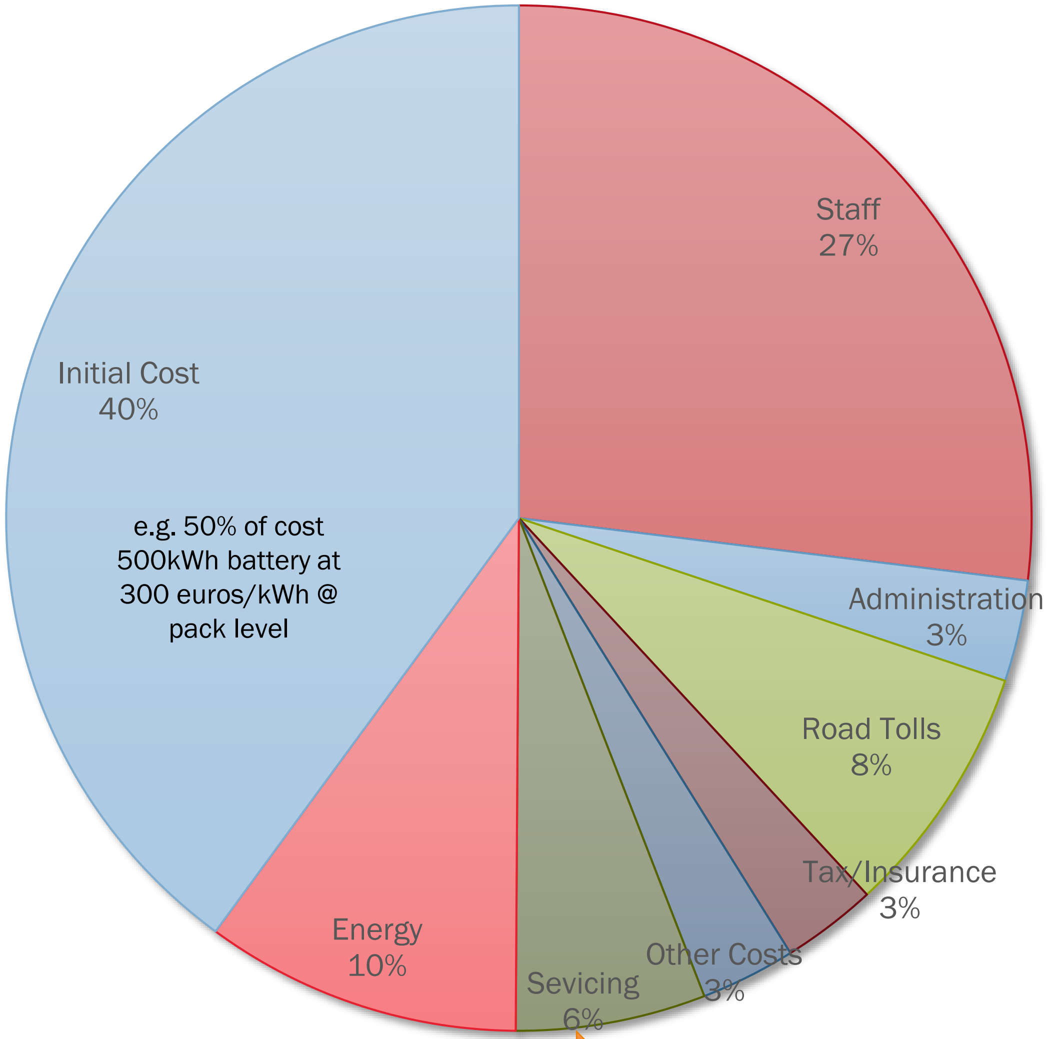
- BEV vs. FCEV transition is shifting based on technology/cost and availability of charging infrastructure
- Vehicle payload and energy density (i.e. loss of cargo due to vehicle weight)
- Payback period for the original technology and vehicle costs
- Functional and operational requirements incl. repeatability of operation

TOTAL COST OF OWNERSHIP (CONVENTIONAL VS. BEV)

Conventional Vehicle



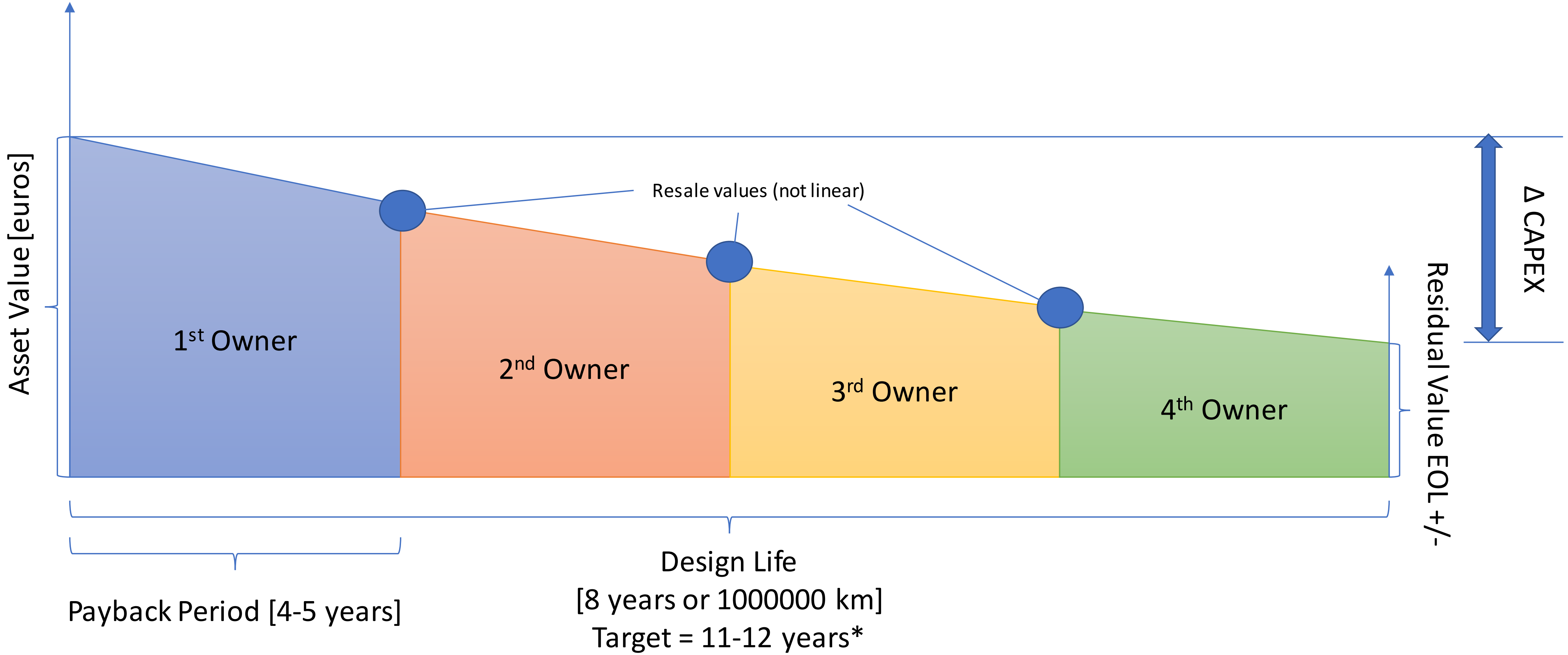
Battery Electric Vehicle



CAPEX increases, OPEX decreases, TCO Comparable for 300km Regional Distribution

Note: Subsidies / cost of infrastructure not included

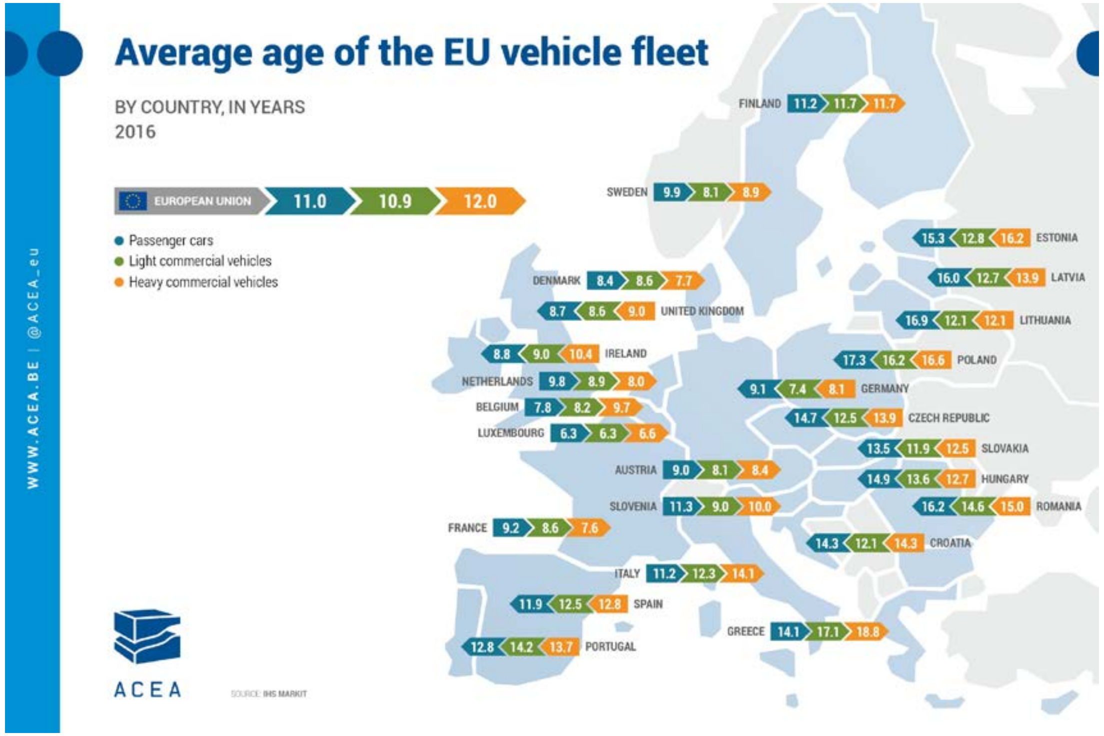
COST MODELLING: PAYBACK PERIOD, VERSUS LIFETIME

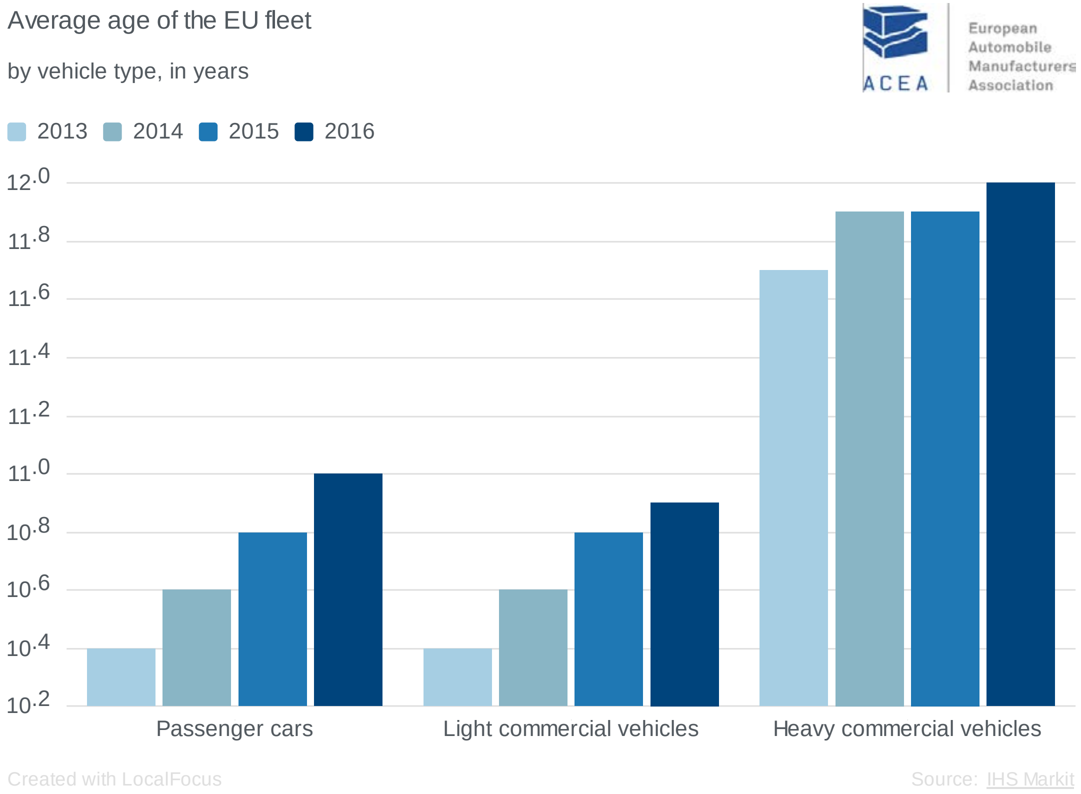


*ACEA HD average lifespan is 11-12 year for EU

All values take at NPV (e.g. 4%)

ANTICIPATING VEHICLE LIFETIME





- Improved product quality and reliability caused an upward trend in vehicle lifetime
- Vehicle lifetime for BEV and FCEV is still not fully understood -> advances in battery and fuel cell durability may shift the depreciation rates / product lifetime
- Tesla engineers now claim a 2 million mile battery (3.2M km), although heavy duty usage still remains to be proven; and many questions remain on determining the remaining useful life/residual value

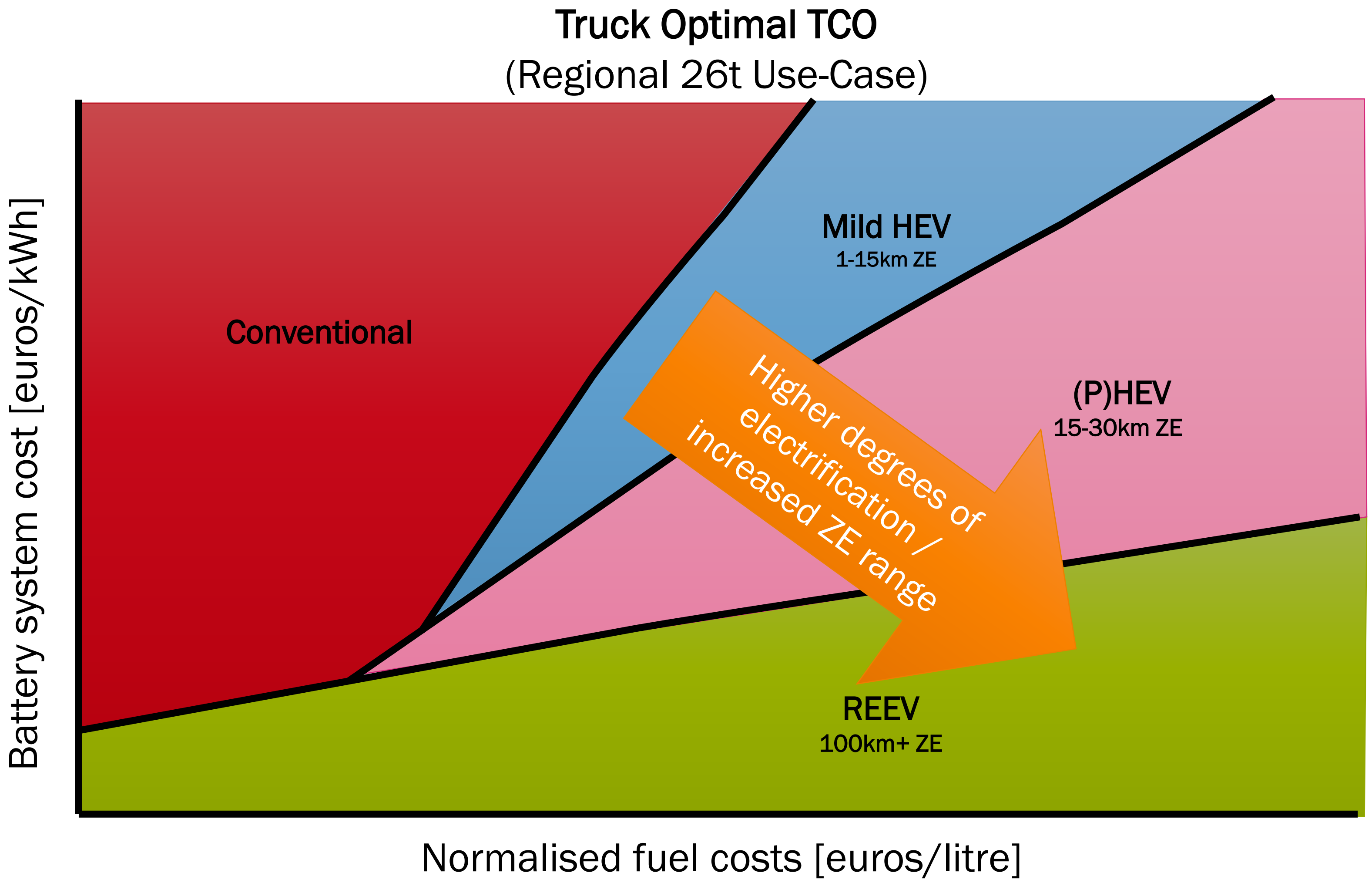
IMPACT FOR HEAVY DUTY VEHICLES ON BATTERY/FUEL COST

Cost and energy density of batteries directly influencing cost of ownership:

- Strong relationship with decisions on infrastructure
- Platforms need to be robust to changing battery technology
- Business cases different to several years ago; studies are rapidly outdated

Sensitivity to assumptions is important where technology is rapidly changing – difficult to compare studies

Evidence-based models from independent technology-agnostic viewpoint are paramount!



NEW TECHNOLOGIES WITHIN LOGISTIC PLANNING

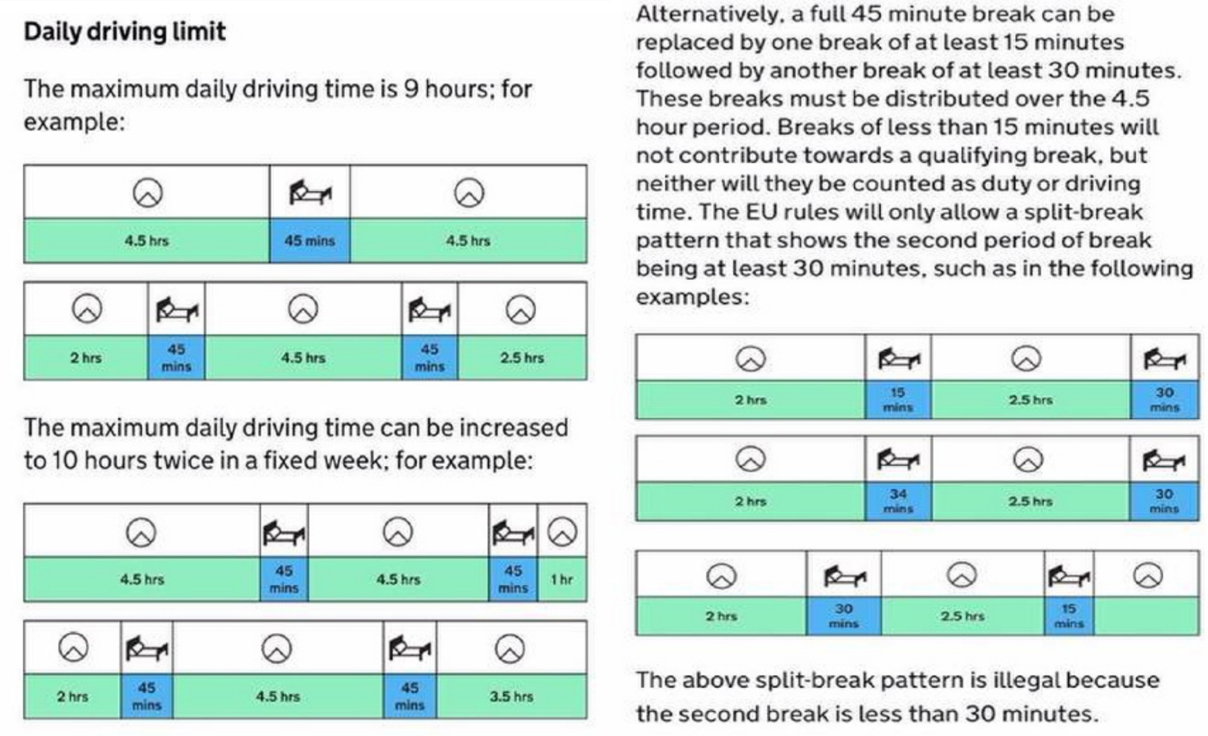
For many applications, the cost of the driver outweighs the cost of the fuel/energy

Increasing the **transport efficiency** (payload, passengers) or automation can help shift the balance away from driver cost towards energy efficiency (e.g. slower vehicles)

Longer-heavier vehicles with distributed electrified propulsion could yield significant cost and energy savings (ref AEROFLEX) as a flexible solution to different transport assignments

Any operational time lost quickly undermines new technologies. Combining charging events with loading/unloading or mandatory breaks (i.e. **opportunity charging**) has economic advantage and influences positioning of charging infrastructure

High power fast charging has economic advantages; the impact on the grid can be offset through localised storage



Also see:

AEROFLEX

https://aeroflex-project.eu/

DEFINING NEW GENERATIONS OF ELECTRIC/ELECTRIFIED TRUCKS

1st Generation of Electrified Trucks

- Largely conversion of existing platforms to include electric powertrain. Placement of components and systems based around on practical integration design decisions.

2nd Generation of Electrified Trucks

- Higher levels of integration of the electric powertrain within truck. More significant charging capabilities. Inclusion of integrated e-axle technologies. Higher degrees of optimisation.
- Optimisation frameworks to balance between topology, sizing, and control become important methodologies [ref ORCA]

3rd Generation (Native) Electrified Trucks

- Clean sheet design for truck, optimised placement of battery pack and innovations in terms of transmission, improved topology and sizing of components.
- For FCEVs, optimal balancing between the fuel cell, battery and electric powertrain

Also see:

ORCA
FURTHER GREENER BETTER

https://h2020-orca.eu/

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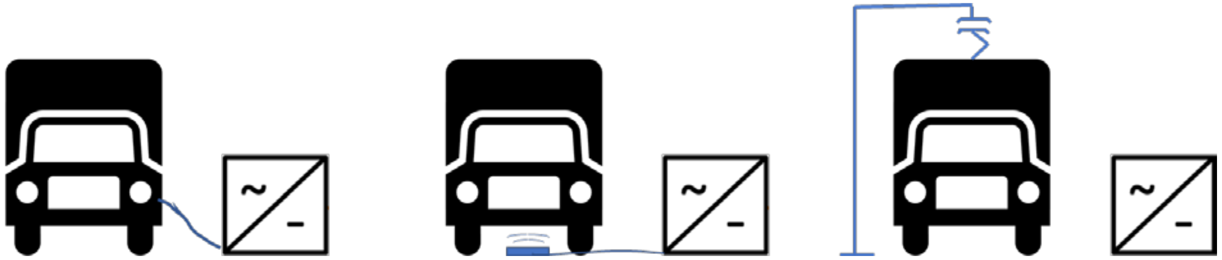
CHARGING INFRASTRUCTURE AND METHODOLOGY

- Focus on fast charging using interoperable solutions (between truck and bus)
- Use of existing standards (OCPP 1.6 and IEC-61851 / 15118)
- Higher power levels:
  - Depot charging (50kW)
  - Continuous/Dynamic charging (50-100kW)
  - Opportunity charging (150-200kW)
  - Fast Opportunity Charging (300kW+)
- Charge strategy (power, frequency) and CCCV vs. advanced charging schemes
- Optimisation beyond single vehicle level => considers **specific cases** of fleet operation via toolsuite for transport solution



Trade-offs:

- Battery size and configuration
- Battery chemistry
- Battery lifetime
- Infrastructure cost/availability
- Range and performance

Can be used in combinations with hydrogen refuelling (FCEV / H2ICE PHEV)

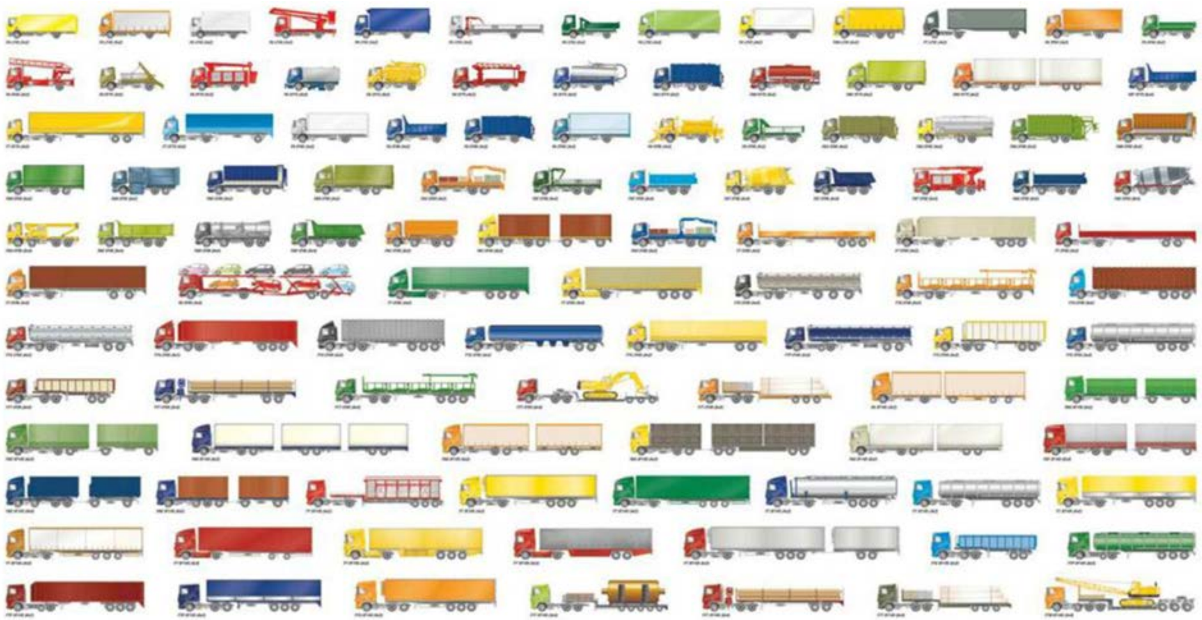
Also see:

ASSURED

https://assured-project.eu/

BENEFIT THROUGH MODULARITY AND OPTIMISATION

- Heavy duty vehicles come in a wide range of configurations and transport assignments
- Benefits in component modularisation and standardisation
- Additional inclusion of LD/MD components and technologies
- TCO across OEM fleet will vary based on application/mission:



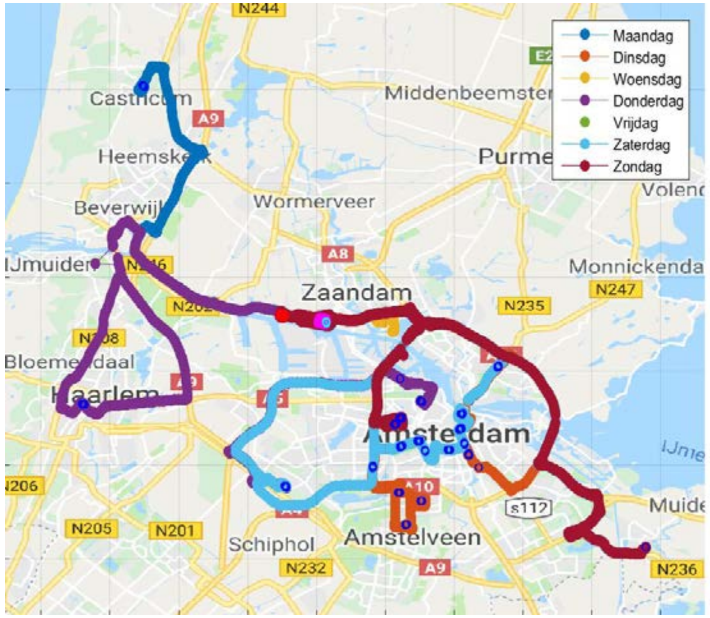
- More transient operation = higher electrification potential
- Higher electrification 'profit' via improved fuel reduction/lifetime

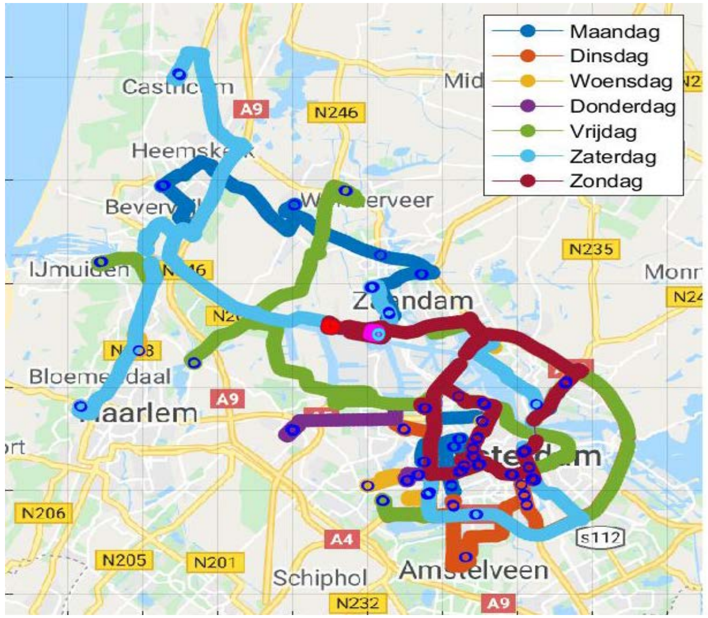
  ⇒ Higher km vehicles benefit more
  ⇒ Lifetime considerations important

⇒ TCO optimised through both hardware and use
⇒ Common design tools and assessment methods
⇒ Standardised electric architecture

THE USE OF BEV TRUCKS: THE LEARNING CURVE

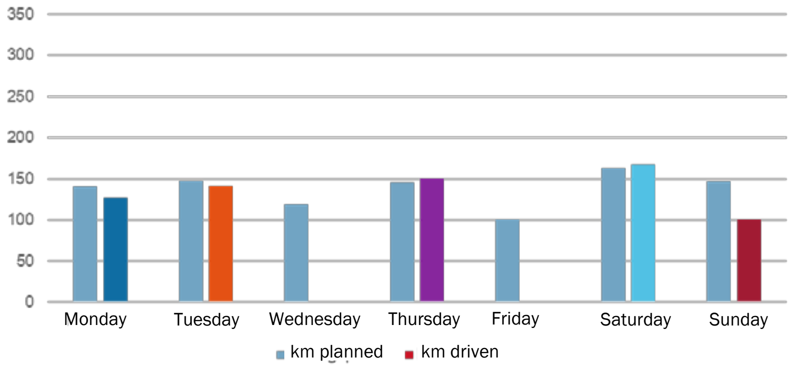
AN EXAMPLE OF THE DEPLOYMENT WITHIN LESS THAN A YEAR



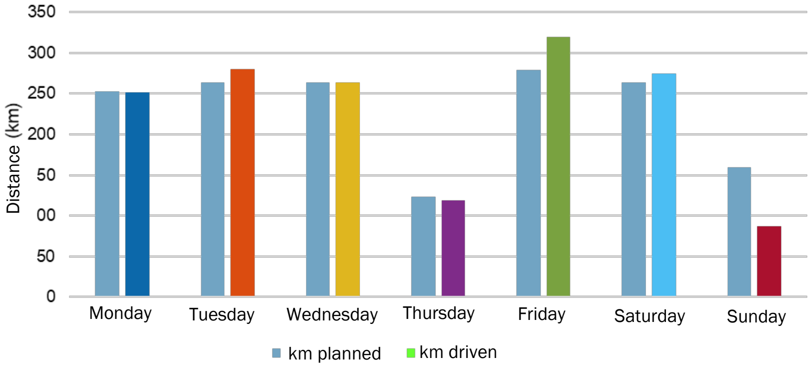


Distance

Week 37 - 2019



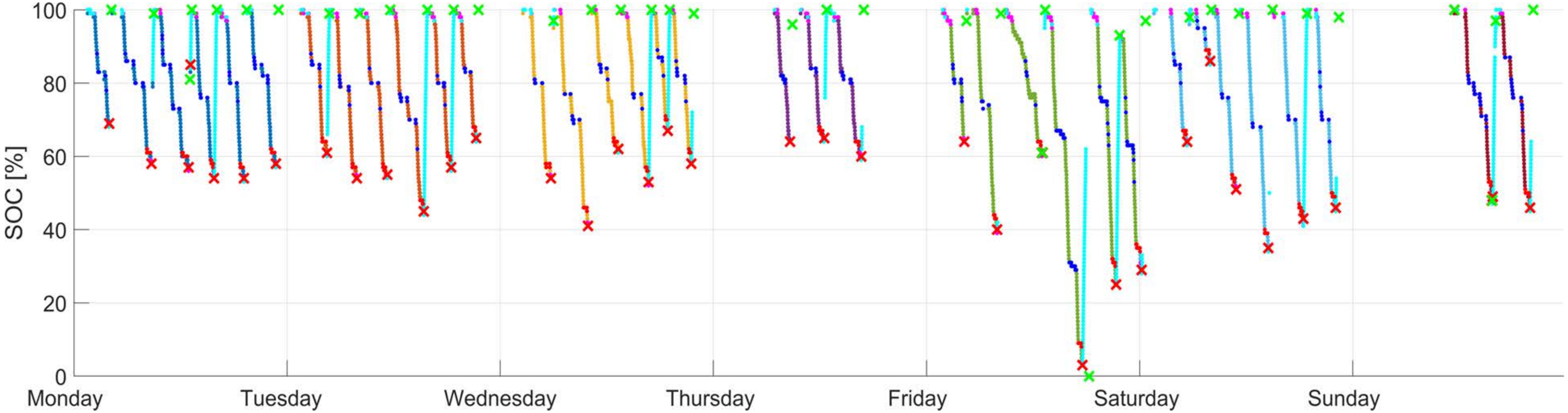
Week 22 - 2020



THE USE OF BEV TRUCKS: THE LEARNING CURVE
WHY IS THE EFFORT NOW SO MUCH MORE INTENSIVE THAN BEFORE?

- Fast(er) charging: from 150 to 300 kW saves approx. 2x in time lost
- Getting used to drivers: driving behavior, type of (short!) journeys, loss of time charging
- Experience/tools among planners: known which journeys can be made at which SOC
- Currently trouble-free operation with trucks and chargers
- Weekly update with monitoring data: continuous learning and refinement

This adjustment is therefore a matter of years rather than months!



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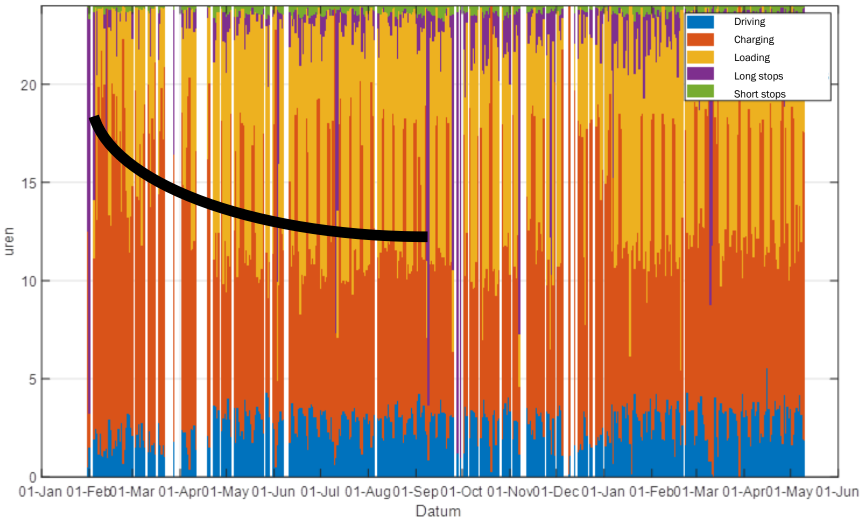
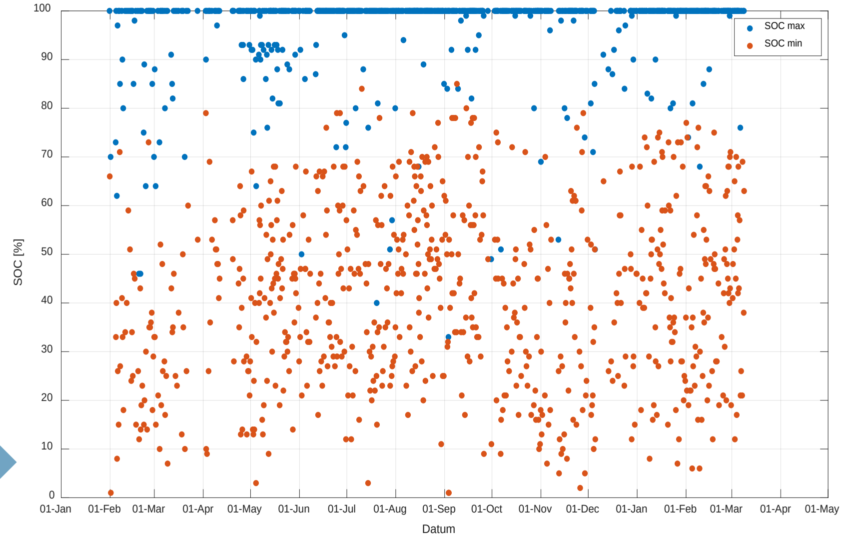
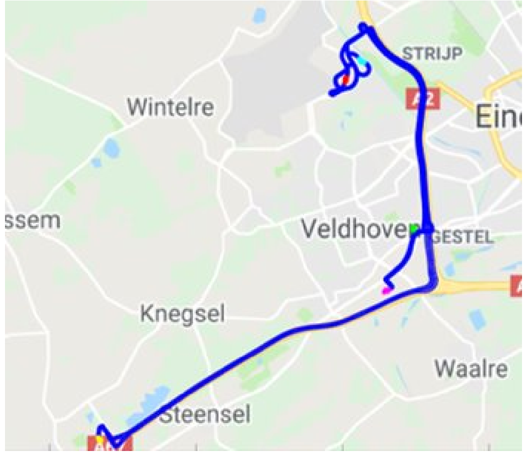
THE SAME E-TRUCK, COMPLETELY DIFFERENT OPERATION
WHAT IF THE OPERATION IS PREDICTABLE AND THE RIDES SHORT

- Go through learning curve here too
- > 50,000 km driven, 7 days / week
- This e-truck is now used almost identically to a diesel truck
- And allows the planning to discharge much deeper
- Optimisation is possible:
  - Small fleet
  - Very predictable rides
  - Short trips only
  - Drivers were already used to short journeys
  - Charging at the dock, so usually no time wasted







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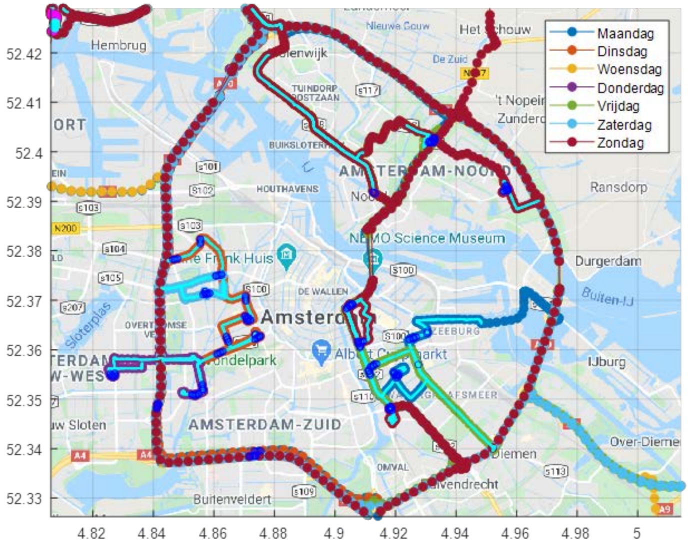
NL DKTI project funded by RVO

THE FIRST EXPERIENCES WITH (P)HEV
LONGER JOURNEYS, ZERO EMISSIONS

- Hybrid: in this case means electric support AND fully electric driving as desired
- Manufacturer is part of the project and the vehicles are prototypes: learning together
- Vehicles only just entered operation, mainly used on long journeys to cities
- First experiences: drivers positive, often electrically driven, a lot of effort possible
- Next steps: updates to vehicles, more variety in journeys, testing electrical range
- Needed: coordination with regard to access to ZE zones -> geofencing, enforcement



Light blue drawn: zero emission mode (instruction drivers: mainly inner-city electric)

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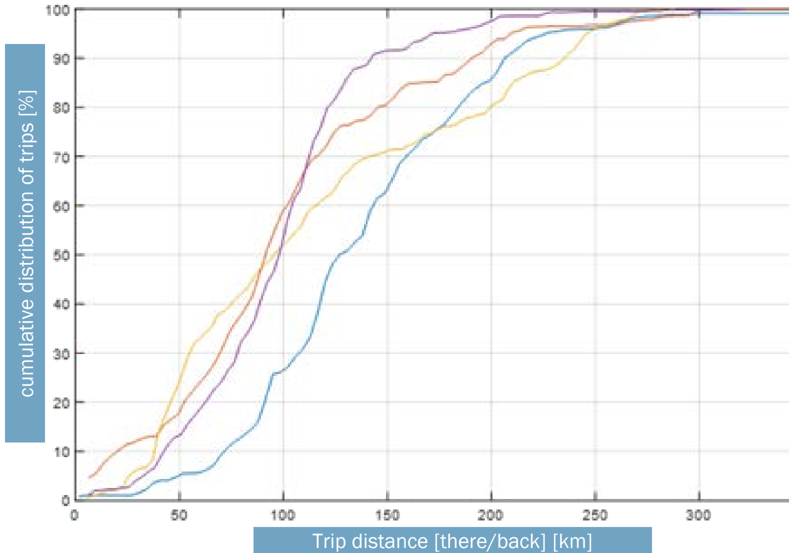
PRESENTATION SUMMARY
THE ROUTE TOWARDS UPSCALING

- TNO continues to develop, test, analyze and learn together in all current projects, working with a wide range of OEMs/end users and policy; broad stakeholder discussion is key
- In many projects it is time for an upscaling analysis with the first generation of vehicles
- Many of our projects are linked to the impact of further upscaling on:
  - Which trips are possible with current and future ZE trucks?
  - What investments are involved, both trucks and especially charging infrastructure?
  - The choice of investing in charging infrastructure or using public charging?
  - The use of flexible (mobile) charging/refueling infrastructure?
- Insight into logistics is crucial
- Uniform policy needed for snowball effect

An upscaling analysis requires even more cooperation and an open mind: much is still unclear, there will be several sustainable solutions, the role of fuel / charging infrastructure is crucial. An open dialogue with stakeholders such as governments helps with this.



THANK YOU FOR YOUR ATTENTION

FOR QUESTIONS OR FURTHER DIALOGUE:

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