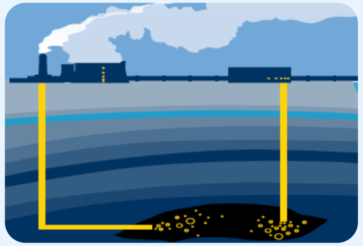

Accelerating the Shift to Zero-Emission HGVs
Zemo Webinar

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Element Energy was commissioned by The Climate Change Committee to develop zero tailpipe emission uptake trajectories for the UK

Introduction

- This study aimed to develop trajectories for zero-emission (ZE) HDV uptake from 2020 to 2050 for the UK
- The study followed on from a study the year before by Ricardo about infrastructure requirements for zero tailpipe emission HGVs and the Ricardo study findings were used by the CCC to develop the fuel prices and infrastructure rollout rates used in our study
- The study included a review of existing evidence regarding the vehicles and infrastructure, a review of progress in other European countries and the potential impact on UK choices, analysis of zero-emission powertrain packaging onto existing vehicle chassis, and a Total Cost of Ownership (TCO)/vehicle suitability analysis to decide uptake trajectories
- The study looked at 5 trajectories:

1. **Trajectory 1:** HRS are deployed as the only public recharging/refuelling option for HDVs, all BEV are excluded from this trajectory
2. **Trajectory 2:** Mega-chargers are the only public recharging/refuelling option for HDVs, all FCEV are excluded from this trajectory
3. **Trajectory 3:** ERS is the only public recharging/refuelling option for HDVs, both BEV and FCEV with depot recharging/refuelling are deployed alongside ERS
4. **Trajectory 4:** All 3 public recharging/refuelling options are deployed, alongside depot recharging/refuelling
5. **Trajectory 5:** All 3 public recharging/refuelling options are deployed, alongside depot recharging/refuelling, but at an accelerated rate compared to Trajectory 4. Manufacturers are also assumed accelerate production of ZE HDVs under this trajectory.

ZE: Zero-Emission. HDV: Heavy Duty Vehicle. HGV: Heavy Goods Vehicle. BEV: Battery Electric Vehicle. FCEV: Fuel Cell Electric Vehicle. ERS: Electric Road System

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A wide range of policies are needed to support the transition to zero-emission HGVs

Policy Summary

The range of vehicle policies needed is expected to include:

- Large scale **commercial demonstrations** to provide information for operators about how zero-emission HDVs will work for them.
- **Information campaigns** to inform HDV operators about zero-emission HDVs.
- **Aggregation and clustering of zero-emission HDV orders** to encourage supply, reduce costs and facilitate infrastructure rollout.
- **National fiscal measures** to make zero-emission HDVs more cost competitive.
- **Local fiscal and operational measures** to make zero-emission HDVs more competitive.
- Support to ensure **battery/fuel cell lifetimes** meet operators' requirements.
- Flexibility in **HDV weight and size restrictions** to allow zero-emission powertrain to be packaged on the vehicles.

The range of infrastructure policies needed is expected to include:

- **Fiscal support for early infrastructure providers** to help overcome the first mover disadvantage of installing infrastructure when the equipment costs are high.
- **Planning support** to ensure infrastructure can be built to the tight timeframes required.
- Infrastructure such as ERS will only be built once on a particular road meaning the infrastructure operator has a monopoly and could easily over charge operators for the service as vehicle operators have little choice but to use the infrastructure available. **Policy oversight will therefore be required on prices to ensure a fair fuel price** is set and high prices do not lead to a delay in zero-emission vehicle rollout.

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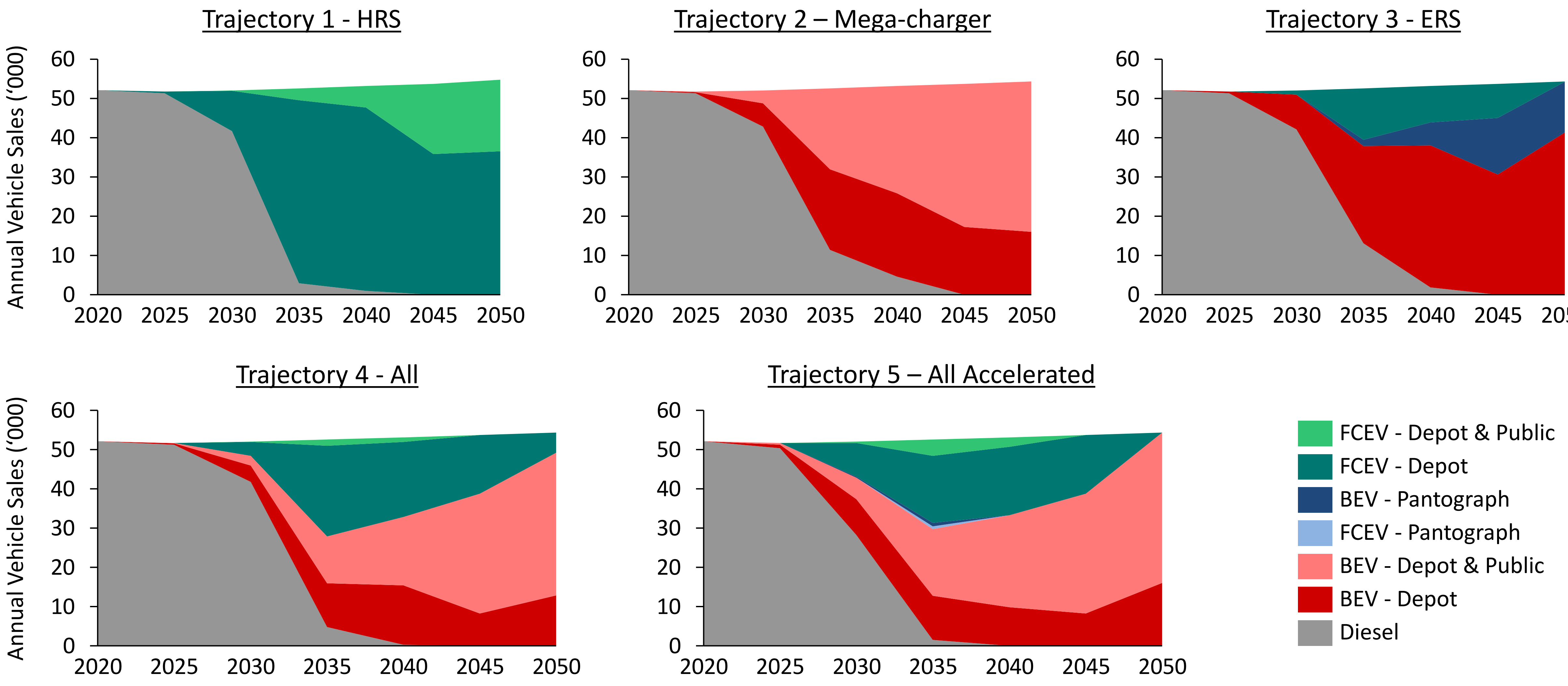
The technology mix and timeline for HGV decarbonisation is very uncertain with a number of outcomes possible given the correct government and industry support

Key Findings

- Hitting TCO parity in 2030-2035, when ZE HGV sales need to grow to dominate the market, requires a **lot of fiscal policy support for ZE HGV** and disincentives for diesel HGVs. Policy support per vehicle can be reduced by ensuring excellent public infrastructure coverage, which in tern requires some technology certainty (aggregated orders, and vehicle and infrastructure packages can help to deliver this)
- ZE fuels are assumed cheaper per km than diesel meaning **the further vehicle drive per year the better the TCO**. This conflicts with the more challenging technical requirement to make these vehicle ZE but this can be overcome through good public infrastructure
- The winning ZE technology is very dependent on fuel price which is heavily impacted by infrastructure utilisation. **Early progress with one technology**, which builds industry confidence and increases infrastructure utilisation, **could lead to one technology dominating the market**
- However, with sufficient infrastructure spending **a mixed fuel approach could deliver decarbonisation earlier**
- Earlier delivery of ZE HGVs, outside of cities, is strongly influenced by when public infrastructure becomes available
- **Operators who are flexible** and are able to change working patterns to accommodate shorter range ZE HGVs (putting shorter range ZE HGVs on a limited number of shorter routes, incorporating public recharging/refuelling into the daily work pattern etc.) **will see significant costs savings**
- The **optimal ZE HGV TCO**, where early wins could be achieved, is found in **operations where the daily mileages are not extremely high but annual mileages are high** because the vehicle is used most days of the year and for a consistently medium mileage each day

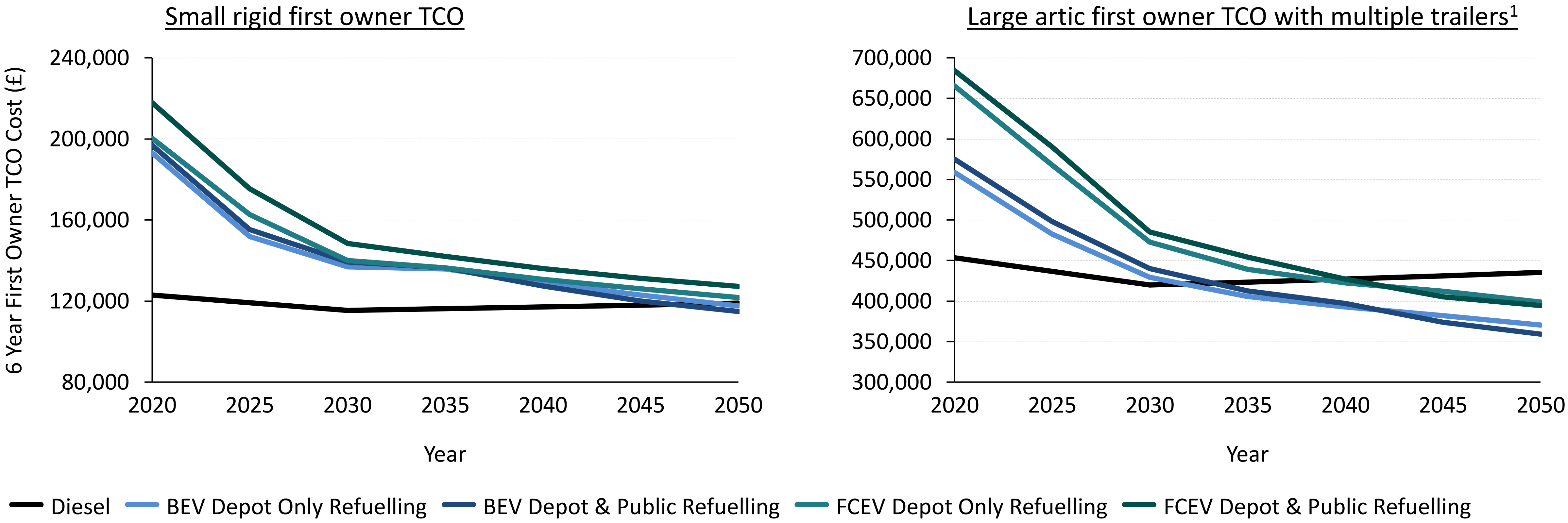
All the scenarios are designed to meet net-zero. This requires all barriers to be removed to allow 100% ZE sales between 2035 and 2040



Higher annual mileage ZE HGVs have a better TCO but are much more challenging technically. Public infrastructure is the deciding factor in early TCO competitive ZE HGVs

Small rigid versus large artic TCO comparison

- The TCO for short annual mileage HGVs can be challenging as fuel savings are small. Longer annual mileage vehicles benefit more from fuel cost savings but the public infrastructure must be in place to facilitate this



1: Zero-emission long haul artic HGVs are assumed to refuel twice a day once in depot and once at a public refuelling site

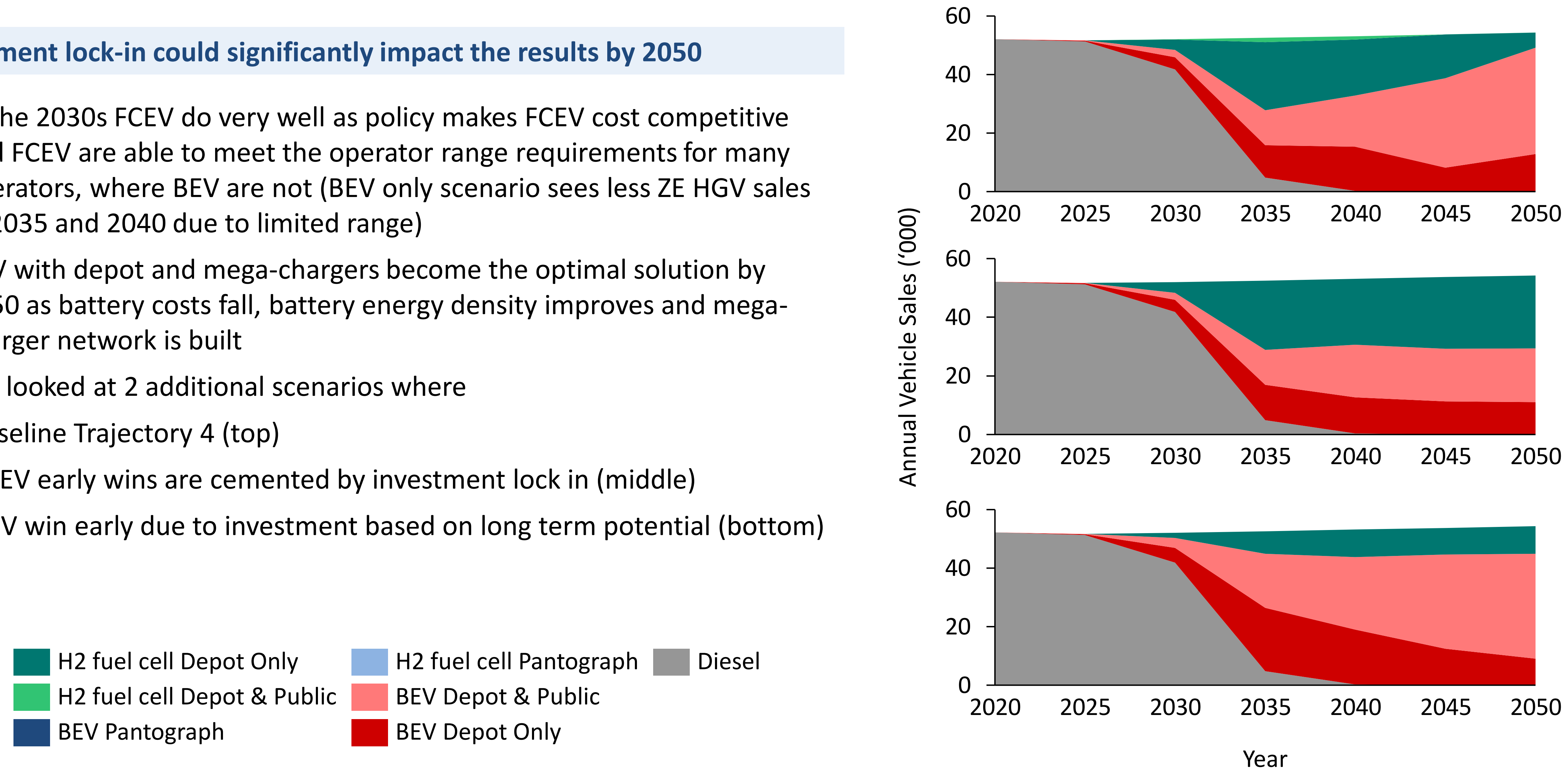
Battery electric trucks with depot and public mega-chargers is the cost optimal solution in 2050 but is outcompeted in the 2030s

Investment lock-in could significantly impact the results by 2050

- In the 2030s FCEV do very well as policy makes FCEV cost competitive and FCEV are able to meet the operator range requirements for many operators, where BEV are not (BEV only scenario sees less ZE HGV sales in 2035 and 2040 due to limited range)
- BEV with depot and mega-chargers become the optimal solution by 2050 as battery costs fall, battery energy density improves and mega-charger network is built
- We looked at 2 additional scenarios where

Baseline Trajectory 4 (top)

1. FCEV early wins are cemented by investment lock in (middle)
2. BEV win early due to investment based on long term potential (bottom)



Fuel costs are a key deciding factor in TCO competitiveness and are heavily impacted by infrastructure utilisation

Infrastructure utilisation

- The use of the public refuelling network is constrained in the study by when it is built and its utilisation, which decides the fuel price and therefore the uptake of these vehicles. This especially impacts ERS which has the widest utilisation range as it could charge diesel hybrid vehicles and could displace depot charging for some users
- However, it is possible to imagine alternative futures where infrastructure utilisation is very different, directly impacting fuel prices and the success of a given technology

Current Modelling Approach

- Pure diesel vehicles shift directly to pure zero-emission vehicles
- Infrastructure utilisation is limited for a long time while zero-emission vehicle numbers ramp up
- A lot of depot refuelling is built to support vehicles before public infrastructure is rolled out
- The final infrastructure network in 2050 onwards is over specified to meet peak demand on a daily basis but also at a given point in the trajectory
- Overall ERS never takes off because low early utilisation increases fuel costs which reduce demand etc.

Alternative Approach

- The introduction of plug-in hybrid vehicles or diesel vehicles with pantographs, as an interim solution, can help to bring fuel costs down through increased public infrastructure utilisation
- As these vehicles don't rely 100% on public infrastructure over specification of the infrastructure can be avoided further increasing utilisation on the remaining infrastructure
- For example, with BEV ERS needs to be supported by depot charging until the ERS network is complete. By having diesel vehicles with an ERS connection as an intermediate step ERS utilisation could be increased and some depot infrastructure avoided, increasing the long term utilisation of the ERS and decreasing the fuel price

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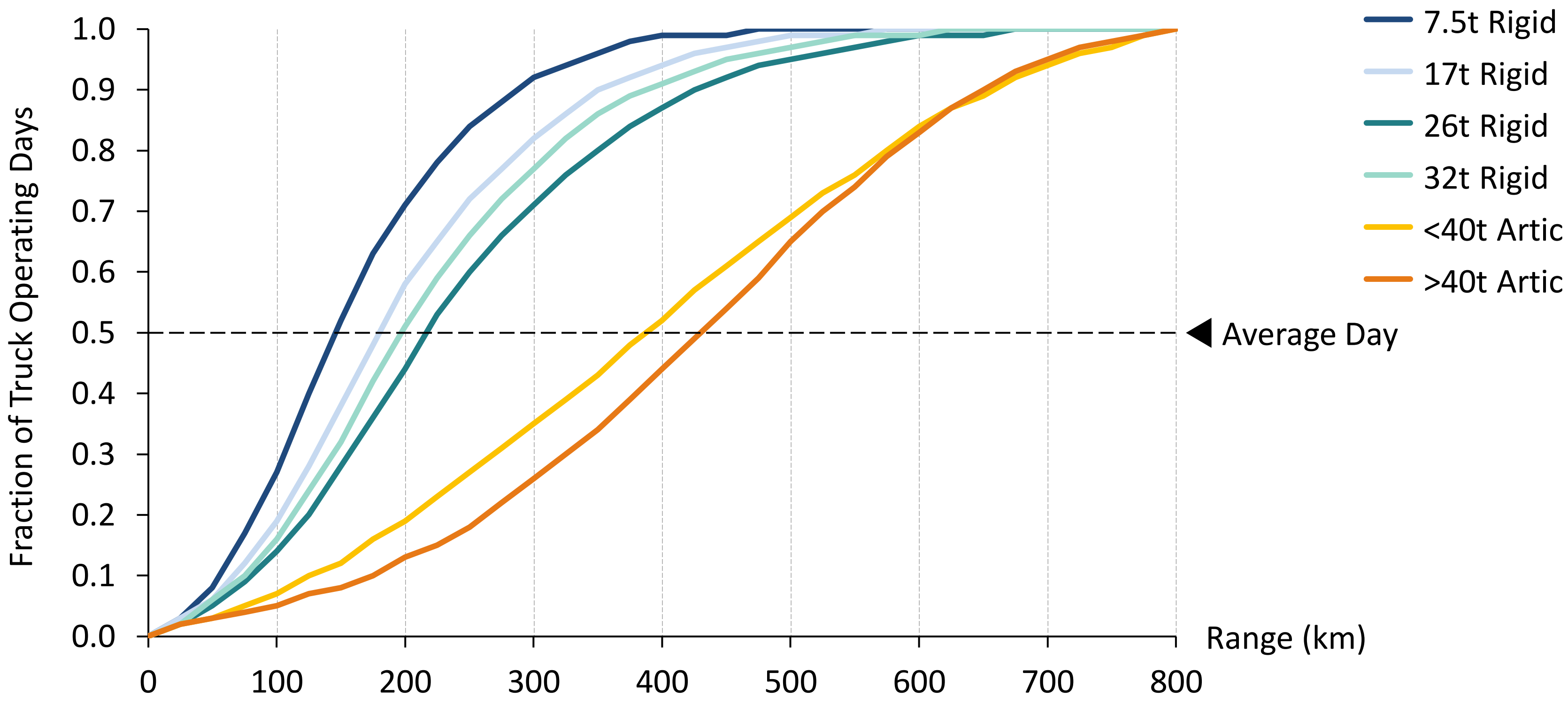
The TCO analysis assumes all HGV users of a certain size of vehicle drive the same daily mileage and therefore want the same spec trucks

Future work

- Due to the limited size of the project we were only able to model 1 daily range requirement for each vehicle size in each 5 year period
- In the early years shorter range models are assumed but by 2030 the zero-emission HGVs are assumed to cover all operators needs
- In reality OEMs are expected to offer many different battery/hydrogen tank sizes, motor/fuel cell sizes, payload capacities etc. for different users of a certain vehicle size
- Increased tailoring of the product to exact user needs is expected to be a key area where OEMs try to compete
- Further analysis in this area could offer better early TCO opportunities for ZE HGVs



There are some future trends not considered in the modelling presented here which could impact the outcomes

Future Trends

- The **growth of zero-emission HGV sales across Europe** will have a major impact on UK choices. The EU market has more larger vehicles which tend to cover longer distances to move across and between countries. This means the optimal solution for the UK and Europe may be different but alignment benefits everyone
- In the long term **vehicle automation will have a major impact on the optimal zero-emission technology choice**. This analysis assumes HGV driver have to stop every 400-430km for driver breaks and that this is an opportunity for refuelling. This reduces the range requirements of the vehicles but increases the requirements for good infrastructure coverage. This solution was selected as it is the cost optimal solution and the cost savings are so large they are likely to offset any operational barriers. However, further vehicle automation in the long term should be considered when designing a zero-emission HGV industry today. Locking in rest stops through vehicle/infrastructure choice today may be a sub optimal long term choice when vehicles may not need rest breaks in the future

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This was a relatively small study and so a number of assumptions had to be made

Modelling assumption and limitations

- The model was designed to provide enough fiscal policy support so that long range ZE HGVs are cheaper, on a TCO basis than diesel in 2035. If this level of fiscal support were already in place many operators could see that ZE models are cost competitive today. The model limits ZE HGV uptake in the 2020s due to OEM supply, and beyond 2030 for long range vehicles, due to public infrastructure rollout rates (taken from Ricardo analysis for the CCC)
- The model's decision making process in each 5 year period is independent of the previous 5 year period meaning the model shows the cost optimal solution for an operator making a purchase decision at each point, not always the most realistic solution given technology lock in due to existing investments
- The fuel prices used in the model were calculated based on the infrastructure analysis completed by Ricardo. Without iterations between infrastructure rollout, vehicle uptake and fuel demand it is difficult to come to a consistent fuel price
- When we spoke to DfT last year they were confident that an additional 2t allowance would be given to ZE HGVs and so this has been included in our packaging assumptions
- The packaging analysis assumes no loss of payload is allowed which will not be the case for all operators
- Only one daily range requirement could be modelled for each vehicle size. This means the vehicles modelled will be over specified and have a higher CAPEX than will actually be the case for many operators who predictably drive shorter distances each day