ZEV HDV UPTAKE TRAJECTORIES

# Modelling Assumptions

Sustainability is our business

# About this update report

In 2020, Element Energy conducted a study for the CCC entitled '**Analysis to provide costs, efficiencies and roll-out trajectories for zero-emission HGVs, buses and coaches**', which formed part of the evidence base for the CCC's recommendations to the UK government on setting the 6th Carbon budget (2033 – 2037).

Element Energy was acquired by ERM in July 2021, and in 2024 the CCC commissioned ERM to provide this update report to highlight the key changes in the sector since the original report and modelling work was conducted. The following were identified as key areas to assess for updates, with key details provided in the following slides:

- **Battery cost projections**: Updated for 2024
- **Fuel cell costs**: Updated for 2024
- **Infrastructure build-out – trucks**: Updated for 2024
- **Infrastructure build-out – buses and coaches**: Updated for 2024
- **Fuel prices (electricity, diesel and hydrogen)**: Updated for 2024
- **Daily mileage assumptions:** No updates
- **Vehicle depreciation rates**: No updates

# About the authors

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Project code: 0717515

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This report was prepared for the CCC in March 2024

*This study uses data derived from publicly available sources and incorporates independent modelling and analysis performed by ERM. Modelling inputs and assumptions have been provided/approved by the UK Climate Change Committee.*

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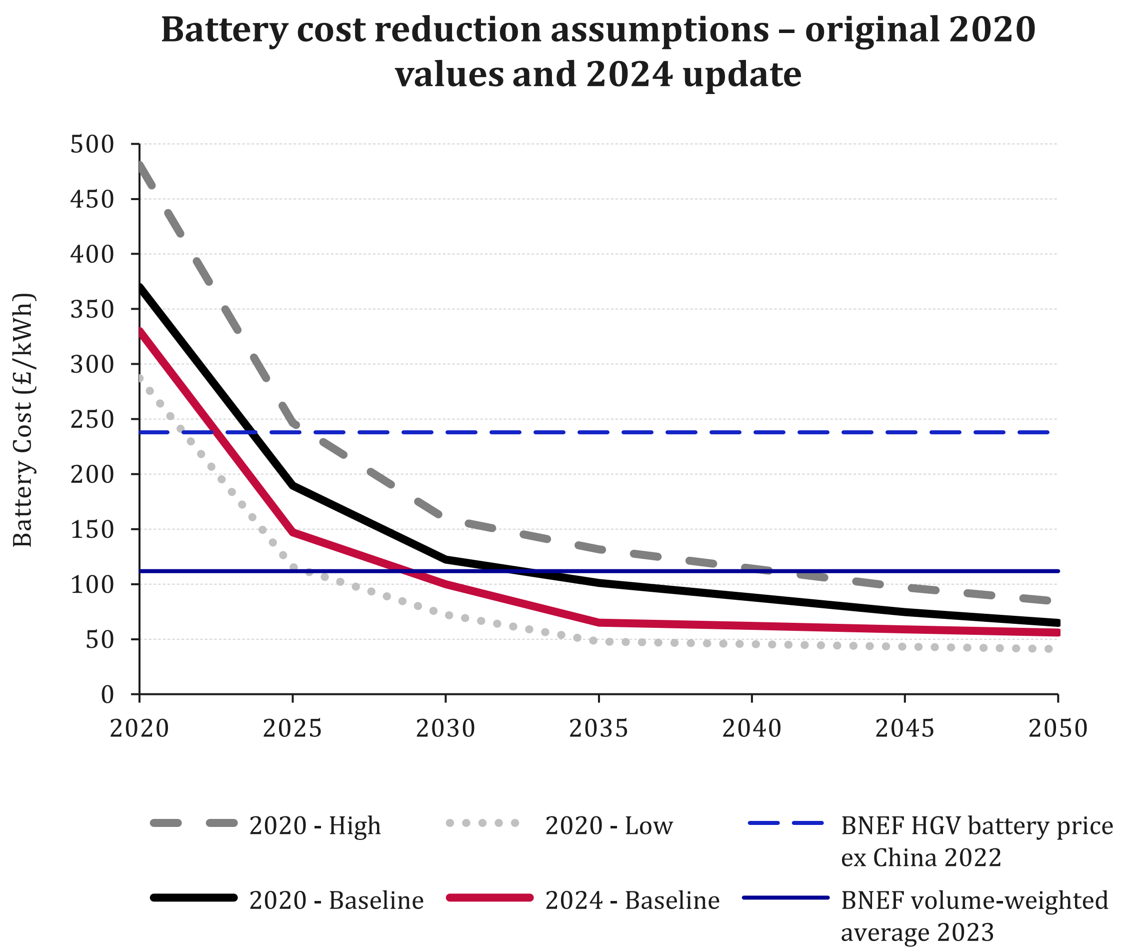
# Agenda

# Battery costs for heavy duty vehicles have fallen more quickly than expected in the 2020 study

Updated for 2024

ERM's new 'baseline' battery cost scenario is now closer to the original 'low' cost scenario, based on the latest cost data

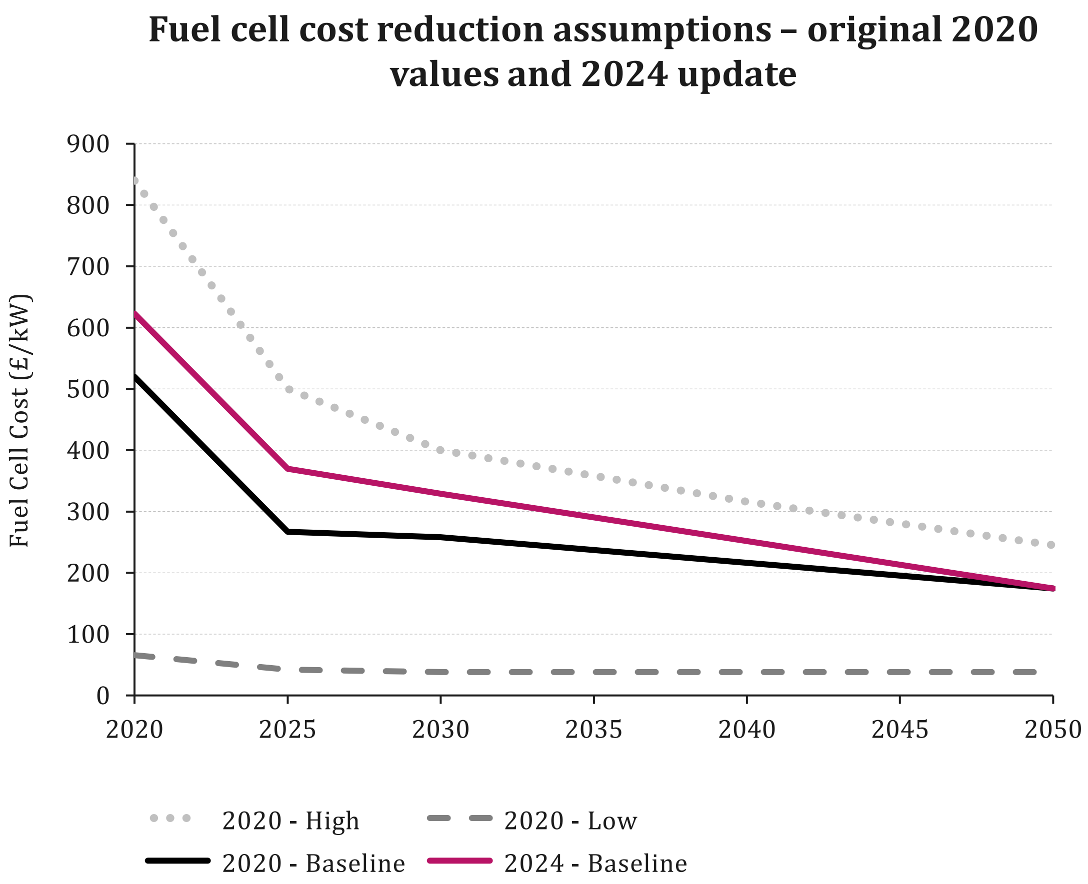



- The chart to the left shows the three battery cost reduction scenarios developed for the original 2020 report, compared to ERM's 2024Q1 projections. In the last few years, battery costs have come down more quickly than expected in the 2020 baseline case
- The new 2024 projection (red line) reflects prices for batteries used in heavy duty vehicles (HDVs – trucks and buses), which are typically higher than for light duty vehicles (LDVs – cars and vans)
- Outside of China, battery prices for HDVs (blue dashed line) are typically 5-years behind batteries for LDVs (blue solid line). This is driven by electric LDVs being produced on a far larger scale than electric HDVs. Over time this difference is likely to fall, particularly as within China they are already achieving parity (see this slide).
- Prices are expected to continue to fall rapidly in the short term, as some HDV manufacturers move towards lower cost chemistries (such as lithium iron phosphate cathodes, LFP), invest in manufacturing capacity and group purchases with LDV production where possible
- Longer term, the rate of price reduction in the baseline falls, with battery prices for heavy vehicles conservatively assumed to continue to be 5 years behind LDV battery prices

# Fuel cell costs have fallen more slowly than expected in the 2020 study

Updated for 2024

ERM's new baseline for fuel cell costs sits between the original baseline and high scenarios




- The chart left shows the three fuel cell cost reduction scenarios used in the original 2020 study. This included a highly optimistic 'low' scenario, which explored the potential for 'light duty' fuel cells produced at scale for LDVs to be used in heavy duty vehicles, with the expectation that they would be cheaper but require more frequent replacement
- Progress on fuel cells has been slower than expected in our 2020 study. The new suggested baseline (red line) increases the near-term cost projections to be in line with the FCH JU's latest cost target for fuel cells for 2024 of €480/kW (£395/kW) in 2024.
- After passing through the FCH JU's 2024 target, the costs then continue to fall at a similar rate to the original projection, achieving the same long-term cost of £175/kW by 2050

1: https://www.clean-hydrogen.europa.eu/knowledge-management/strategy-map-and-key-performance-indicators/clean-hydrogen-ju-sria-key-performance-indicators-kpis_en

# Agenda

Component Costs

**Infrastructure Rollout Rate**

Fuel Costs

Travel Distances & Depreciation

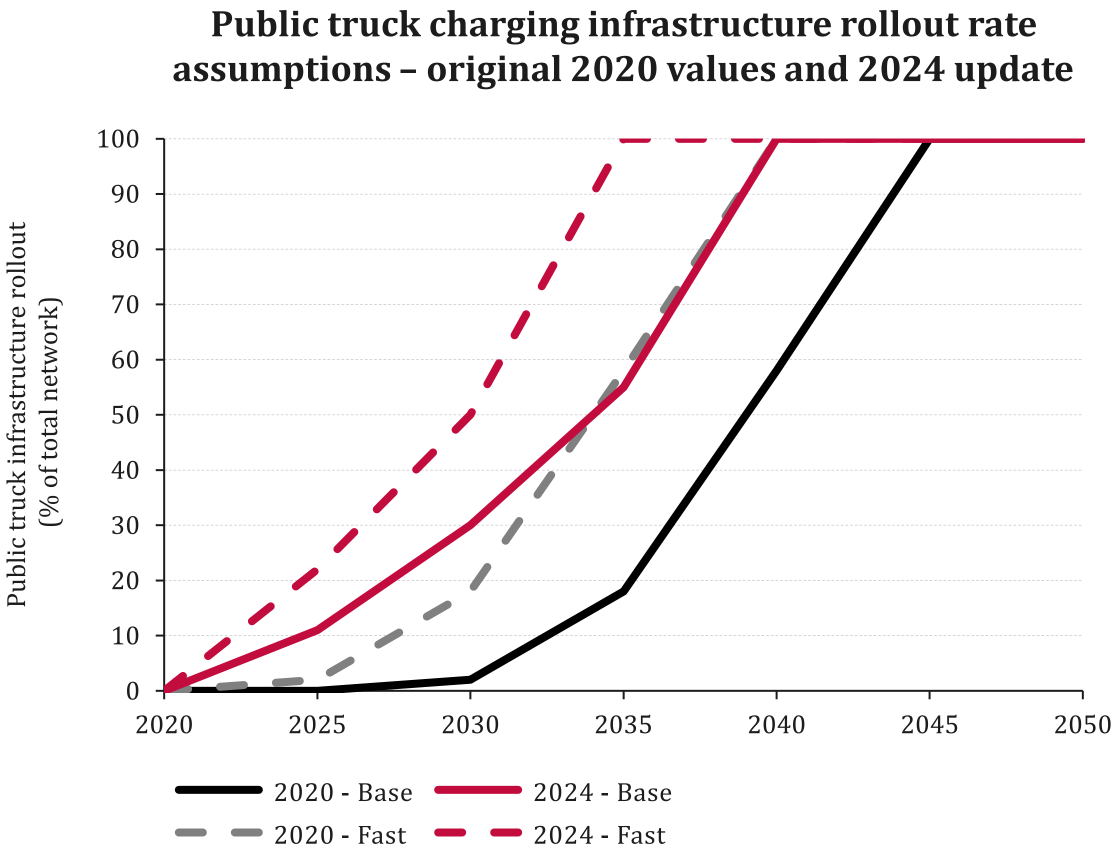
About ERM

Appendix

# ERM now expects that truck charging infrastructure could be rolled out more quickly than originally envisaged in 2019

Updated for 2024

Updated analysis and developments in the market suggest a suitable truck charging network could be deployed 5 years earlier




- The chart shows the assumed build-out rate for public truck charging infrastructure in the original 2020 report (black/grey lines) and the 2024 updated assumption (red lines) which includes an acceleration of the deployment rate

We are now much more confident in the early rollout of truck public charging than we were in 2020. This is because:

- Most HGV movements occur along a small number of key corridors connecting major logistics centres. In fact, ERM analysis suggests that up to 80% of public truck charging demand could be covered by around 50 sites. Thus, a relatively small number of early sites can allow a relatively large proportion of the fleet to electrify.
- We expect the Zero Emission Heavy Goods Vehicle and Infrastructure Demonstrator[1] project alone to build around 25 sites by the end of 2026. Significant numbers of sites are also expected from be built outside of ZEHID from c. 2025 onwards, for example by Milence[2].
- DfT consultation on the Rapid Charging Fund indicated that a requirement for Motorway Service Areas to provide 2 truck chargers per site was considered. If implemented, this would add another 100 sites to the network this decade.

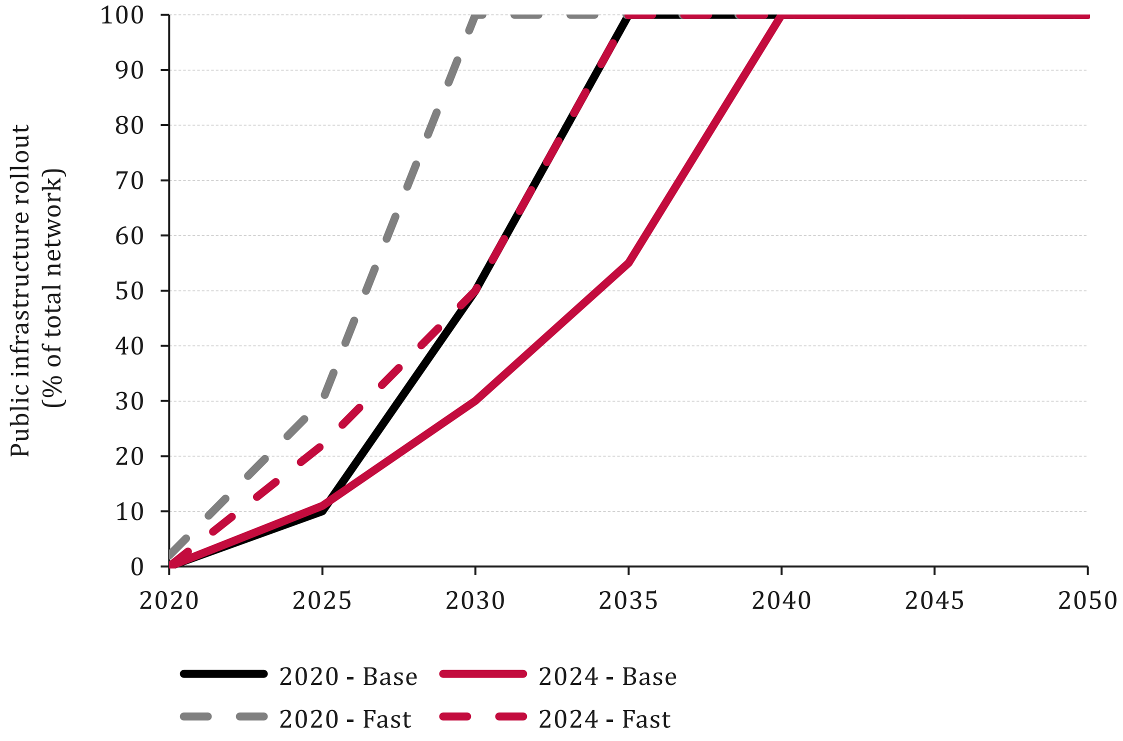
1: https://www.gov.uk/government/publications/zero-emission-heavy-goods-vehicles-and-infrastructure-competition-winners/zero-emission-heavy-goods-vehicles-and-infrastructure-competition-winners
2: https://milence.com/

# Since 2020, more detailed analysis by ERM of UK bus and coach operations suggests infrastructure rollout may be slower

Updated for 2024

Deployment of charging infrastructure for buses is ahead of that for trucks, but significant challenges remain

**Bus and coach charging infrastructure rollout rate assumptions – original 2020 values and 2024 update**




The chart shows the assumed build-out rate for electric bus and coach charging infrastructure in the original 2020 report (black/grey lines), updated for 2024 (red lines). Overall, the build-out rate has been slowed by 5 years.

Most bus charging infrastructure is not currently public, although parts of the sector are keen to make marginal daytime use of local bus infrastructure for other commercial users, which might ultimately include destination charging for coaches. Any en-route charging for coaches is most likely to utilise and thus reflect HGV infrastructure rollout patterns.

Recent ERM analysis has identified that uptake of electric buses in certain segments is likely to be much more challenging than in others, and this slide presents several scenarios for the uptake of ZEBs which are used as the basis for the new infrastructure rollout rates:

- The new **'2024 – Fast'** curve is based on the 'Operator Target' scenario, where 85% of buses are zero emission by 2035 (100% in 2045), aligning with the publicly announced targets of the five major operators.
- The new **'2024 – Base'** curve is based on the 'Risk Minimisation' scenario where 75% of buses are zero emission by 2040, but there is a longer tail out to 2055 before all buses have transitioned.

In both cases, there is likely to be a lag between all sites being electrified (by 2035 or 2040), and all chargers being deployed at those sites, matching any progressive BEB adoption within each site's fleet.

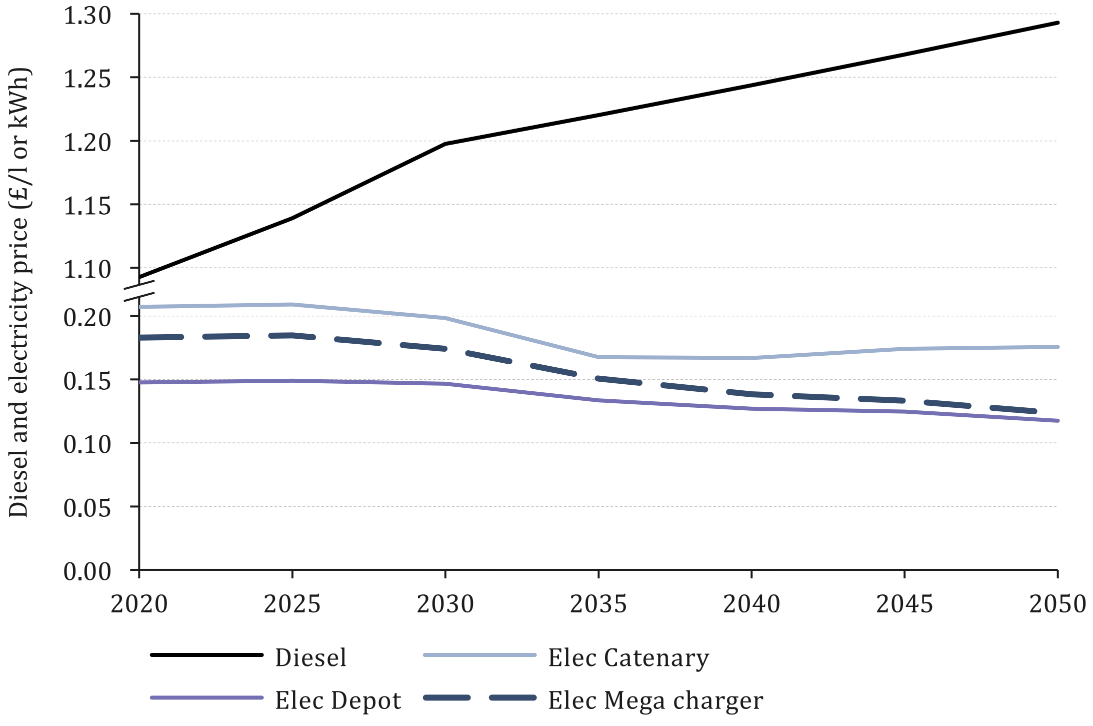
The new curves reflect ERM's much more detailed analysis of the bus market, which highlighted the challenges of decarbonising certain local bus routes, notably interurbans. Solutions are likely to add cost or complexity to decarbonisation, both factors likely to delay rollout.

# Agenda

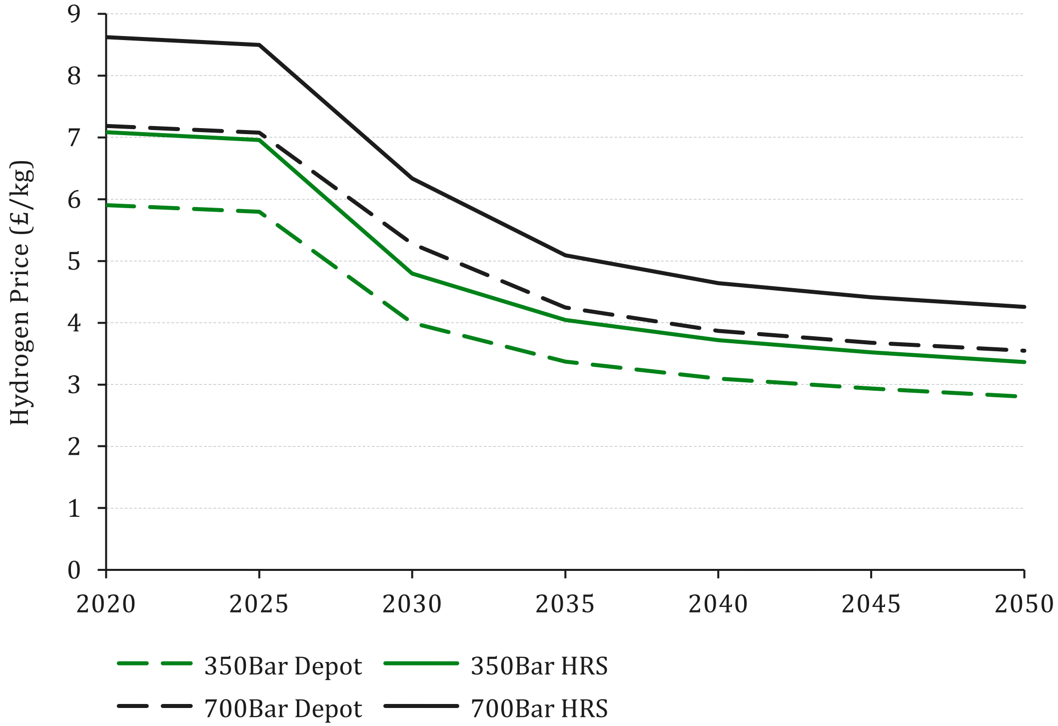
# Recap: Fuel prices have changed significantly since the 2020 report due to factors including Covid and the war in Ukraine

The CCC have provided updated 2024 updates to the fuel price projections shown here from the 2020 report

**Diesel and electricity prices from 2020 study (£ ex. VAT)**




**Hydrogen prices from 2020 study (£ ex. VAT)**

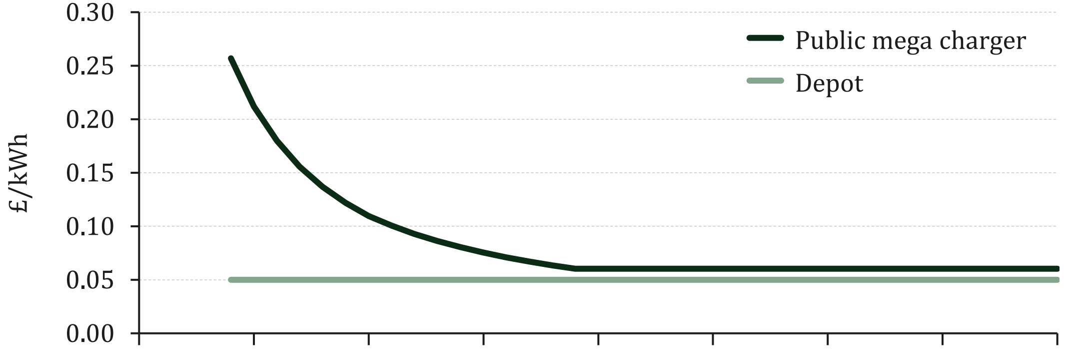



- Diesel prices are currently around 120p/l ex VAT so the previous 2030 projection has already been reached
- Electricity prices have jumped to 20p/kWh and are expected to return to normal by 2030
- Hydrogen prices have jumped to over 20£/kg and are not expected to reach 7-8£/kg until the end of the decade

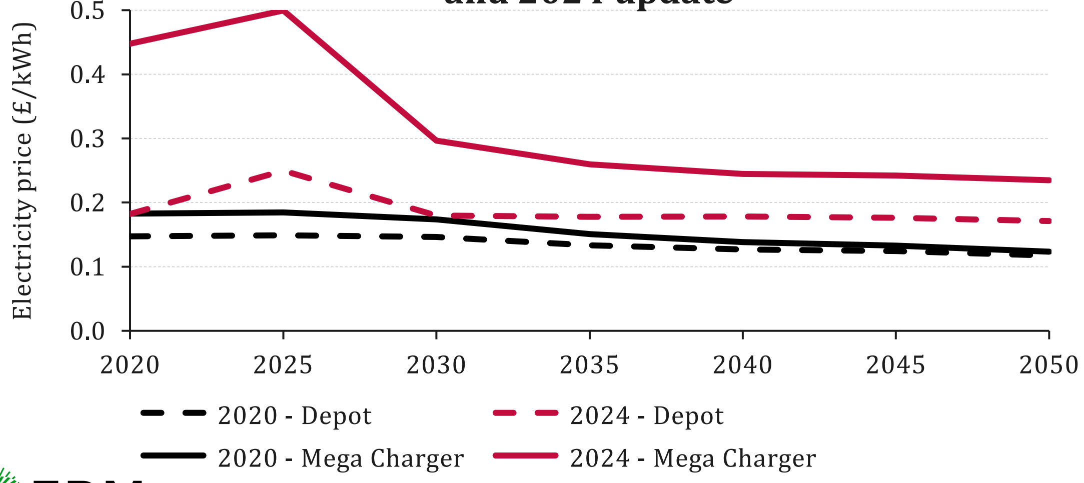
# ERM have updated fuel costs to include the CCC's latest projections and included infrastructure costs more clearly in electricity prices

We assume electricity prices for public truck charging will initially be inflated to ensure a reasonable IRR for early infrastructure

**Public mega charger and depot charger: markup of price at charger above base electricity price (£ ex. VAT)**

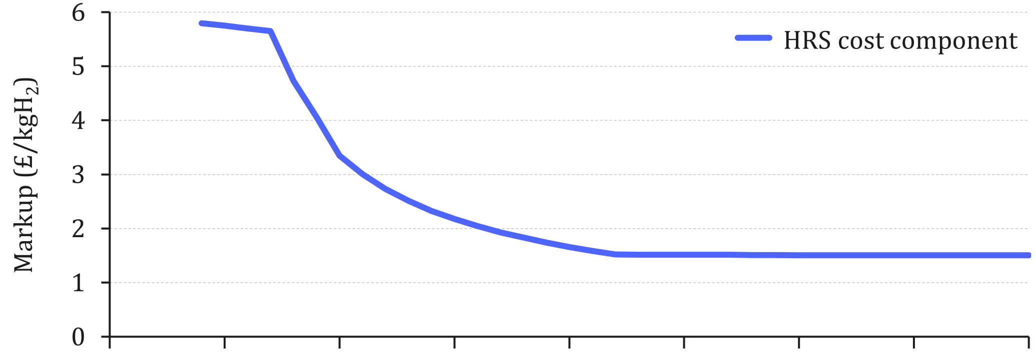


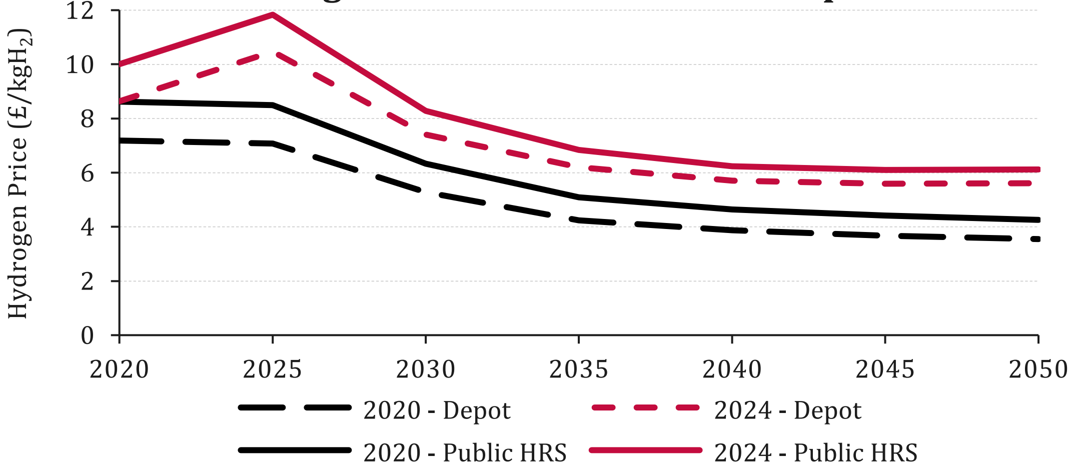

**Electricity price assumptions – original 2020 values and 2024 update**




- The top left chart shows the markup on electricity prices that the operator of a mega-charger would need to charge to earn an IRR of 10% over 15 years
- This curve accounts for increasing utilisation over time as uptake of electric trucks increases – as more electricity is sold, operators will be able to charge less per kWh to recover the investment costs
- We assume that depot infrastructure will be sized to meet the demands of individual fleets, and so costs will be evenly distributed over the infrastructure's lifetime
- The bottom chart shows the original 2020 electricity prices and ERM's suggested updates for 2024. The 2024 updates include updated price projections from the CCC, as well as the additional infrastructure costs
- **Note:** electricity prices do not include any market factors which might mean that operators charge more or less in reaction to competitive dynamics, they only account for paying off the cost of deploying the infrastructure

# Hydrogen prices have not fallen since the 2020 study, and ERM have accounted for infrastructure costs



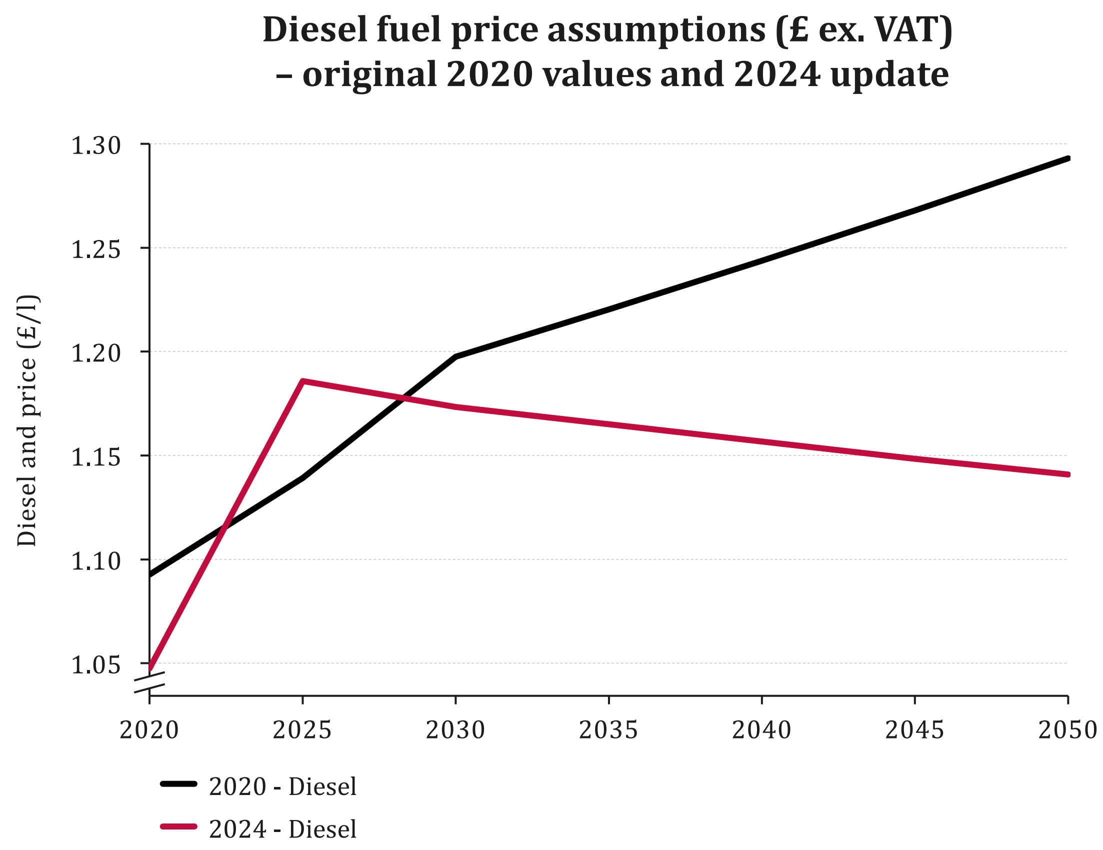




- The top left chart shows the markup on hydrogen prices that the operator of an HRS would need to charge to earn an IRR of 10% over 15 years
- The falling cost of the infrastructure component is based on the same uptake curve of hydrogen trucks as was applied for electric trucks to create the curve on the previous slide. However, the start of the uptake hydrogen trucks is delayed until 2027, as this is the earliest that truck OEMs are planning to release production models (this date might be further delayed)
- The bottom chart shows the original prices from 2020 compared to the updated hydrogen prices ERM proposes, which apply the infrastructure cost to compare to hydrogen price projections from the CCC. Prices are assumed to stay high (~£12/kg) until 2027, when the uptake of hydrogen vehicles at scale begins to reduce the impact of the infrastructure cost component
- **Note:** prices are only shown for 700 bar stations because this is expected to be the dominant pressure for hydrogen HGVs (rather than 350 bar)

# Diesel prices have been updated compared to the 2020 study

Updated for 2024

The CCC has developed their own scenarios for future fuel prices which have been used in the updated modelling




- The chart to the left shows the diesel price used in the 2020 study compared to the updated price in the CCC's latest fuel price scenario
- In the 2020 study, it was expected that diesel prices would gradually climb to ~£1.20/L by 2030, then continue increasing at a slower rate out to 2050. The Ukraine war has led to a short-term spike in diesel prices, briefly nearly reaching the projected 2050 price in early 2024[1]
- As a result, the new CCC scenario now has short-term diesel price assumptions that are higher than those used in the 2020 study (increased from £1.14/L to £1.19/L in 2025). However, in the longer-term, diesel prices are lower in the new scenario

1: Compare latest petrol and diesel fuel prices | The AA

# Agenda

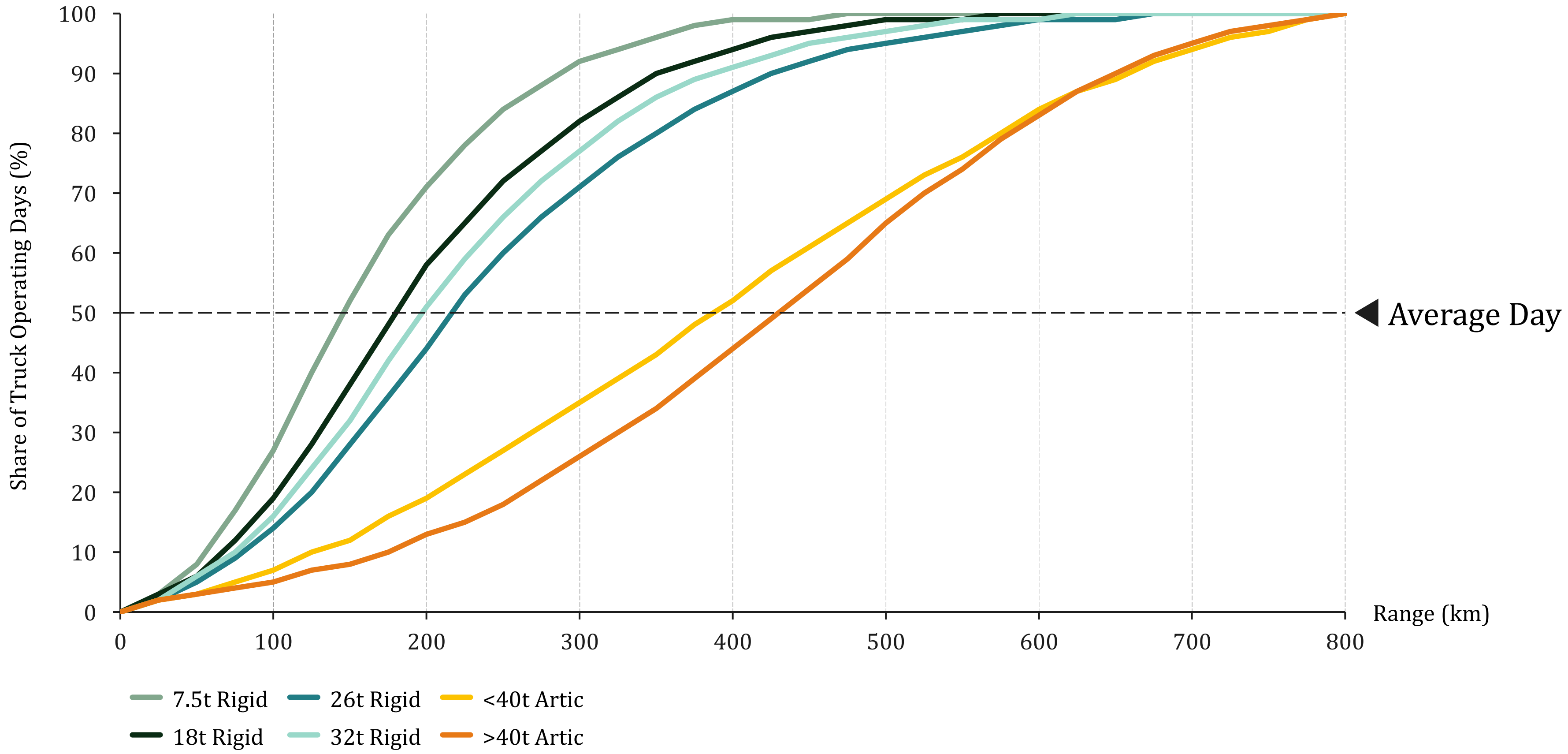
# Below are the range requirements for trucks in the UK. We don't propose to make any changes to these in this iteration of work

Truck operational profiles are not expected to have changed since 2020

Unchanged since 2020

**Daily milage by share of truck operating days for 6 truck weight categories**

*ERM analysis of UK truck telematics data*



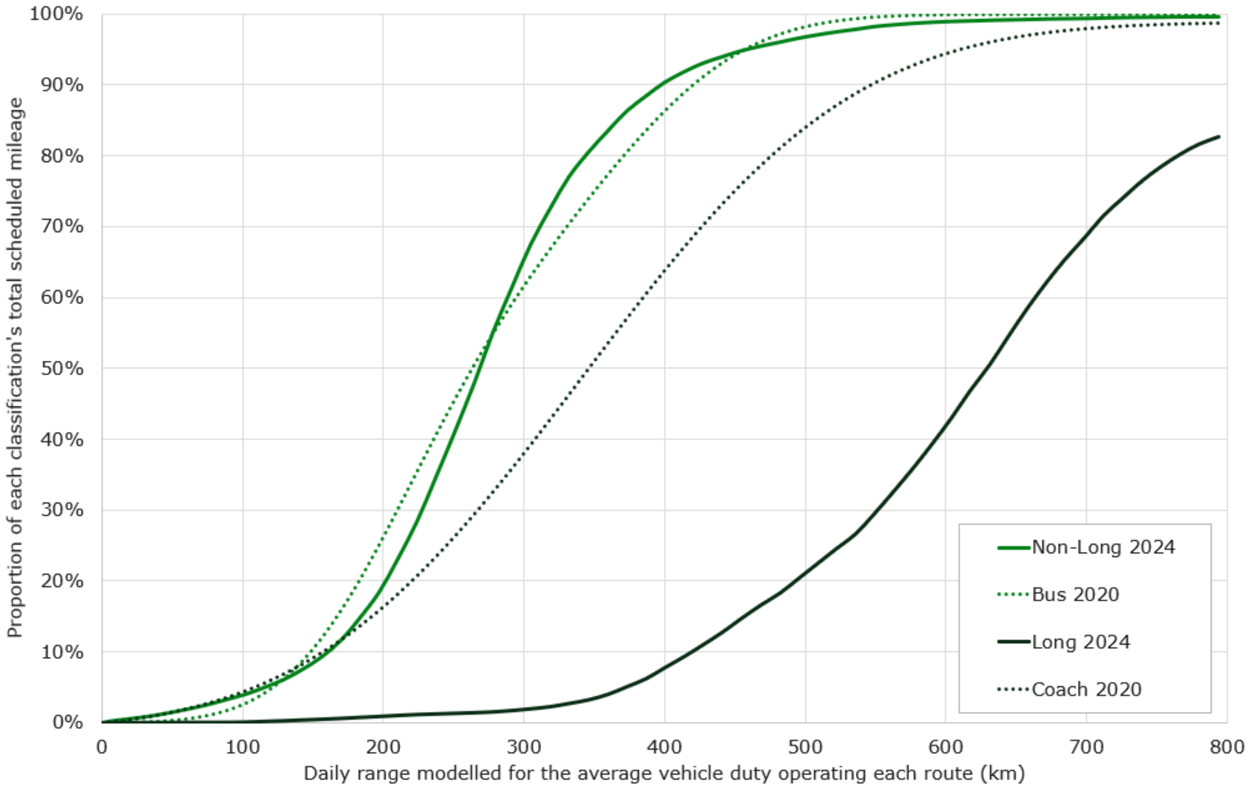
# Below are the range requirements for buses in the UK. We don't propose to make any changes to these in this iteration of work

Unchanged since 2020

Bus is broadly comparable, while 2020's coach reflects coach bodied vehicles more than just scheduled coach which is more intense

**Average daily bus and coach mileage by share of each classification's total scheduled mileage**

*ERM analysis of UK bus and coach operations*




2020's bus curve compares favourably to 2024's non-Long (archetypes mileage weighted) curve, with only a slight change in gradient.

In contrast, 2020's coach curve is most likely a reflection on the wider coach fleet, most of which is used on far less intensive duties, typically group hire and tours.

In practice future ZE coach vehicles are likely to be much more precisely specified for their duties than any one average coach curve might imply.

Unlike local bus, it is not reasonable to assume scheduled coach networks remain unchanged by decarbonisation. The fare, rather than time, sensitivity of most scheduled coach markets may lead operators to compromise existing schedules in favour of more fragmented routes operated within ZE vehicle limitations.

# Depreciation and vehicle lifetime

Unchanged since 2020

Depreciation values are very uncertain for BEV and FCEV so we currently assume they remain the same as diesel as in the 2020 study

| Vehicle Size | Y1 | Y2 | Y3 | Y4 | Y5 | Y6 | Y7 | Y8 | Y9 | Y10 | Y11 | Y12 | Y13 | Y14 | Y15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HGV Rigid <7.5t | 74% | 61% | 50% | 41% | 33% | 27% | 22% | 18% | 15% | 12% | 10% | 8% | 7% | 6% | 5% |
| HGV Rigid <18t | 70% | 58% | 49% | 41% | 34% | 28% | 24% | 20% | 16% | 14% | 12% | 10% | 8% | 7% | 6% |
| HGV Rigid 25/26t | 75% | 63% | 54% | 45% | 39% | 33% | 28% | 24% | 20% | 17% | 14% | 12% | 10% | 9% | 7% |
| HGV Rigid 30/32t | 76% | 65% | 56% | 48% | 42% | 36% | 31% | 27% | 23% | 20% | 17% | 15% | 13% | 11% | 9% |
| Artic 36/38t | 78% | 64% | 52% | 43% | 35% | 29% | 23% | 19% | 16% | 13% | 11% | 9% | 7% | 6% | 5% |
| Artic >40t | 75% | 59% | 46% | 36% | 29% | 23% | 18% | 14% | 11% | 9% | 7% | 5% | 4% | 3% | 3% |
| Single deck bus | 84% | 75% | 66% | 59% | 52% | 46% | 41% | 36% | 32% | 29% | 25% | 23% | 20% | 18% | 16% |
| Double deck bus | 84% | 75% | 66% | 59% | 52% | 46% | 41% | 36% | 32% | 29% | 25% | 23% | 20% | 18% | 16% |
| Coach | 78% | 64% | 52% | 43% | 35% | 29% | 23% | 19% | 16% | 13% | 11% | 9% | 7% | 6% | 5% |

# Agenda

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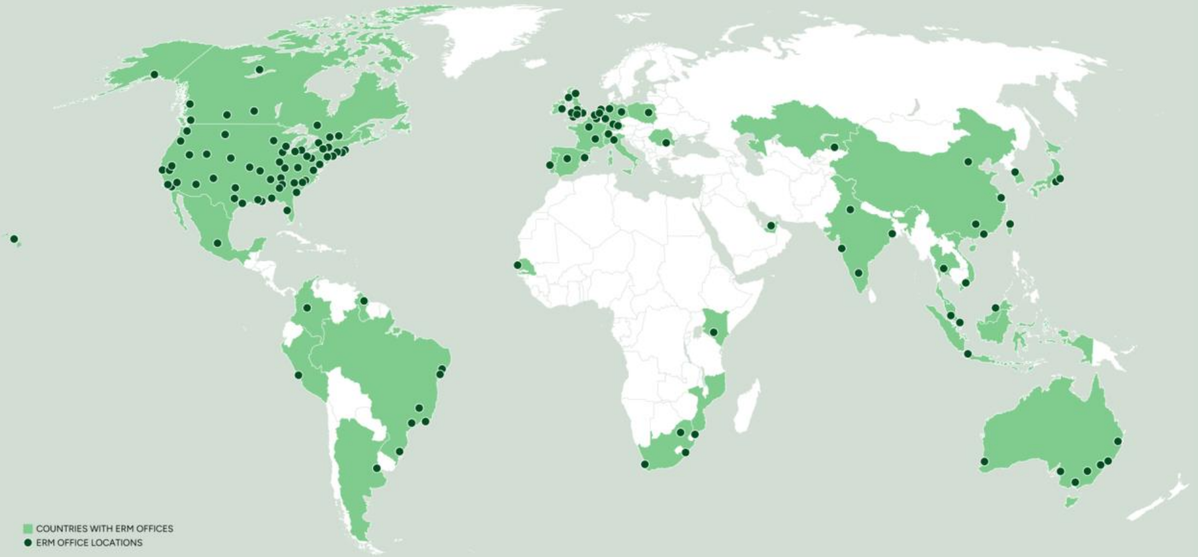
HFS Horizons: Sustainability Services, 2024

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**#1=**
breadth and depth of ESG & sustainability offer
Verdantix, ESG & Sustainability Consulting Green Quadrant, 2024

**#1**
operational transformation capabilities
Verdantix, ESG & Sustainability Consulting Green Quadrant, 2024

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Verdantix, Climate Change Consulting Green Quadrant, 2023

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HFS Horizons: Sustainability Services, 2024

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Verdantix, ESG & Sustainability Consulting Green Quadrant, 2024

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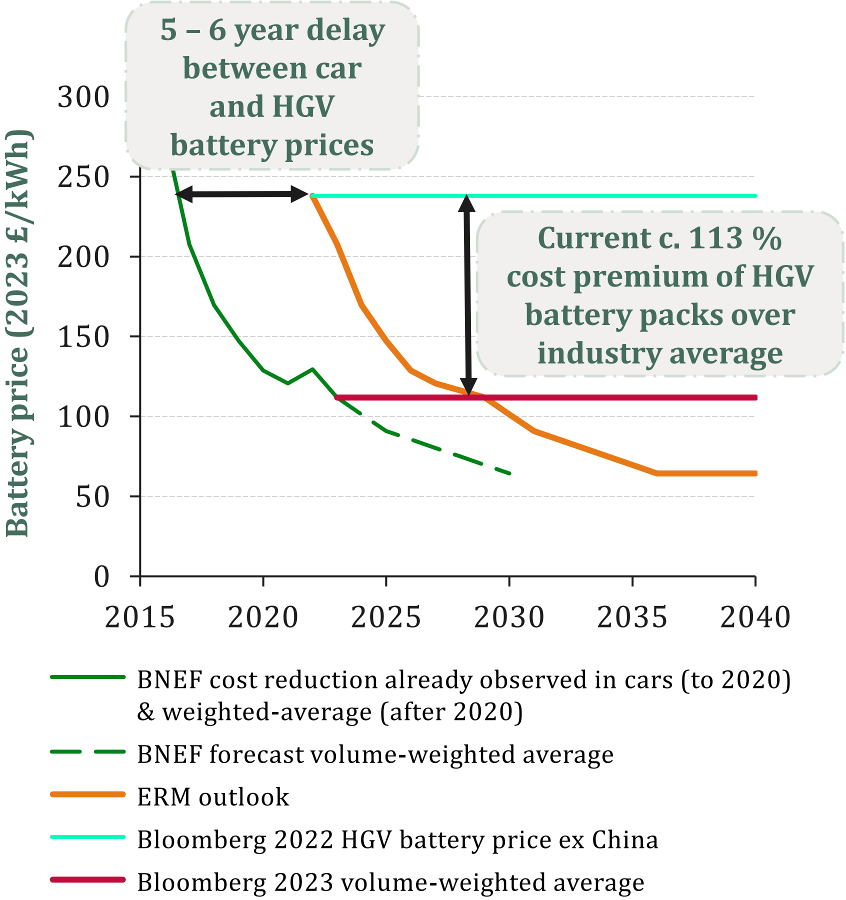
Verdantix, Environmental Services Green Quadrant, 2024

# Agenda

- Component Costs
- Infrastructure Rollout Rate
- Fuel Costs
- Travel Distances & Depreciation
- About ERM
- **Appendix**

# Battery costs

## Proposed Input




## Evidence base

**Bloomberg NEF (BNEF) data shows that HGV battery pack prices are currently around 2.1 times higher than industry-average prices.** This is largely due to HGV manufacturers not yet experiencing the same economies of scale as car manufacturers – 2022 prices for **China** show commercial vehicle battery prices already on-par with the industry average and BNEF are forecasting a rapid drop in HGV battery costs to within 10% of the industry average by 2030.

**Our proposed baseline (orange) is more conservative and composed of two phases:**

- **Initial rapid cost reduction** (2023-2026), this matches the rate already seen in the car market (green line) and is based on
  - Some industry **switchover to lower-cost LFP-cathode** batteries (32% cheaper than NMC cells in 2023) with this move already seen by European OEMs.[1]
  - Investments by HGV manufacturers in onsite production[3,4,5,6] and purchasing alongside car batteries at a group level[4,7], resulting in massive increase in supply and economies of scale for HGV batteries.
  - The current premium of HGV battery prices over car battery prices being due to **scale**, rather than other factors.
- **An asymptotic value** of 64 (2023)£/kWh reached in 2036, 6 years behind the BNEF forecast industry-average battery price for 2030.[8] Conservatively, limited further cost reductions are assumed beyond 2036.

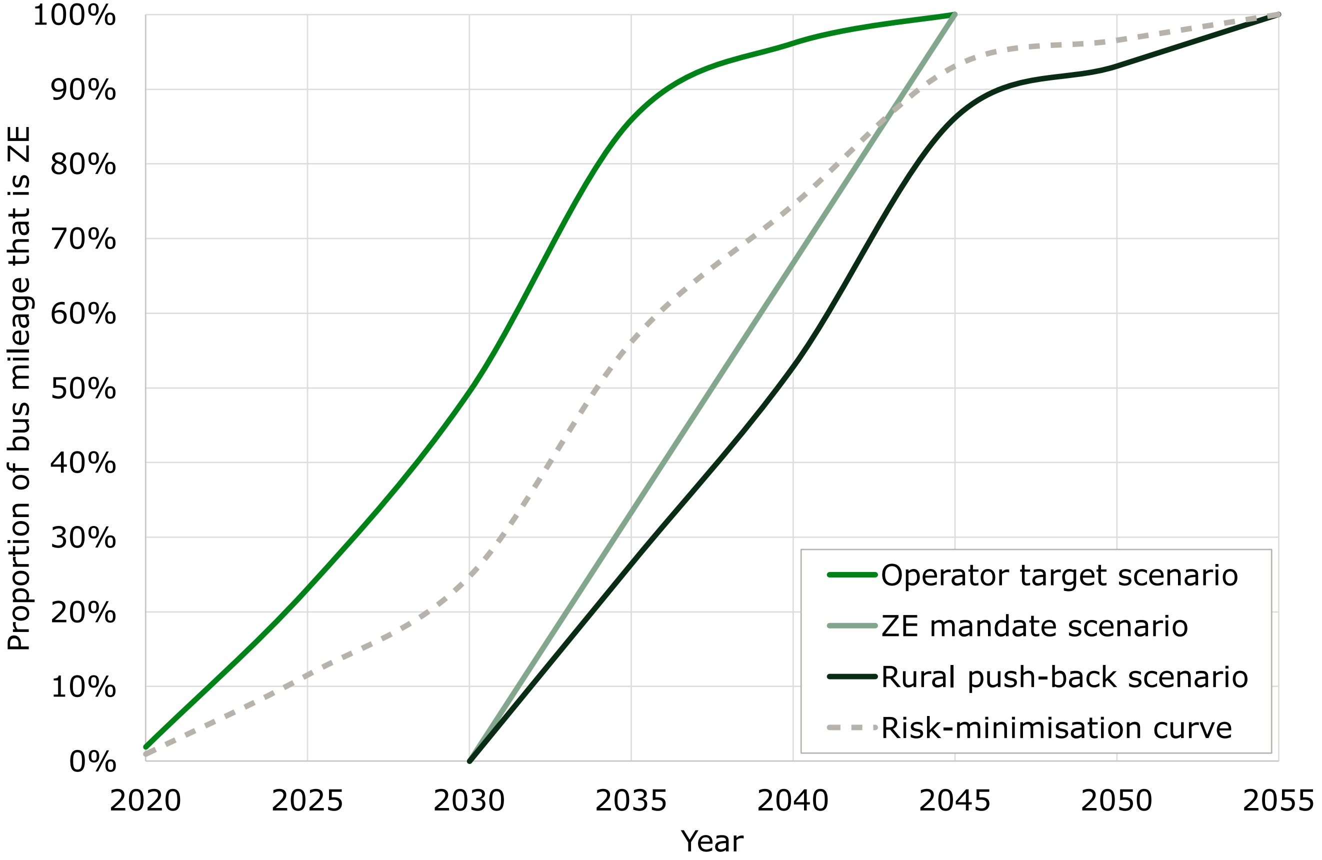
The conclusions of this work are not materially affected by higher raw material prices in 2035. This is mainly because new battery chemistries are highly likely to be available in 2035, mitigating the impact of raw material prices.

LFP = Lithium Iron Phosphate; NMC = Nickel Manganese Cobalt ; 1: Currently, European HGV manufacturers are primarily using NMC and related chemistries, similar to those used in cars – see references 2-5; 2: https://theicct.org/sites/default/files/publications/eu-tractor-trailers-analysis-aug21-2.pdf; 3: https://www.electrive.com/2020/11/17/scania-to-build-their-very-own-battery-plant/ 4: https://www.reuters.com/article/us-volkswagen-electric-scania-northvolt-idUSKCN1SJ12L; 5: https://northvolt.com/; 6: https://www.volvotrucks.com/en-en/news-stories/press-releases/2022/may/volvo-trucks-opens-battery-plant-in-belgium.html; 7: e.g. Scania and MAN are part of VW's commercial vehicle arm TRATON and are sourcing their batteries from Northvolt alongside VW passenger cars; 8: https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/

# Scheduled ZE bus and coach uptake and infrastructure build-out

Infrastructure logically pre-empts operational conversion, but typically by less than a year, so the two measures will be similar.

Overall, operators are expected to manage risks between their own ambitions and expected legislative limitations, with realpolitik likely to push back on Zero Emission mandates for rural mileage.




**Operator target scenario (ambition)**: Current scheduled bus and coach mileage for each operator has been compared to that operator's Zero Emission fleet target for the 5 major groups, CPT's commitment for the smaller groups, and expected legislative requirement for SMEs. Assuming a 15-year commercial life for bus and 5 years for scheduled coach, the steady replacement cycle to attain the target has been calculated.

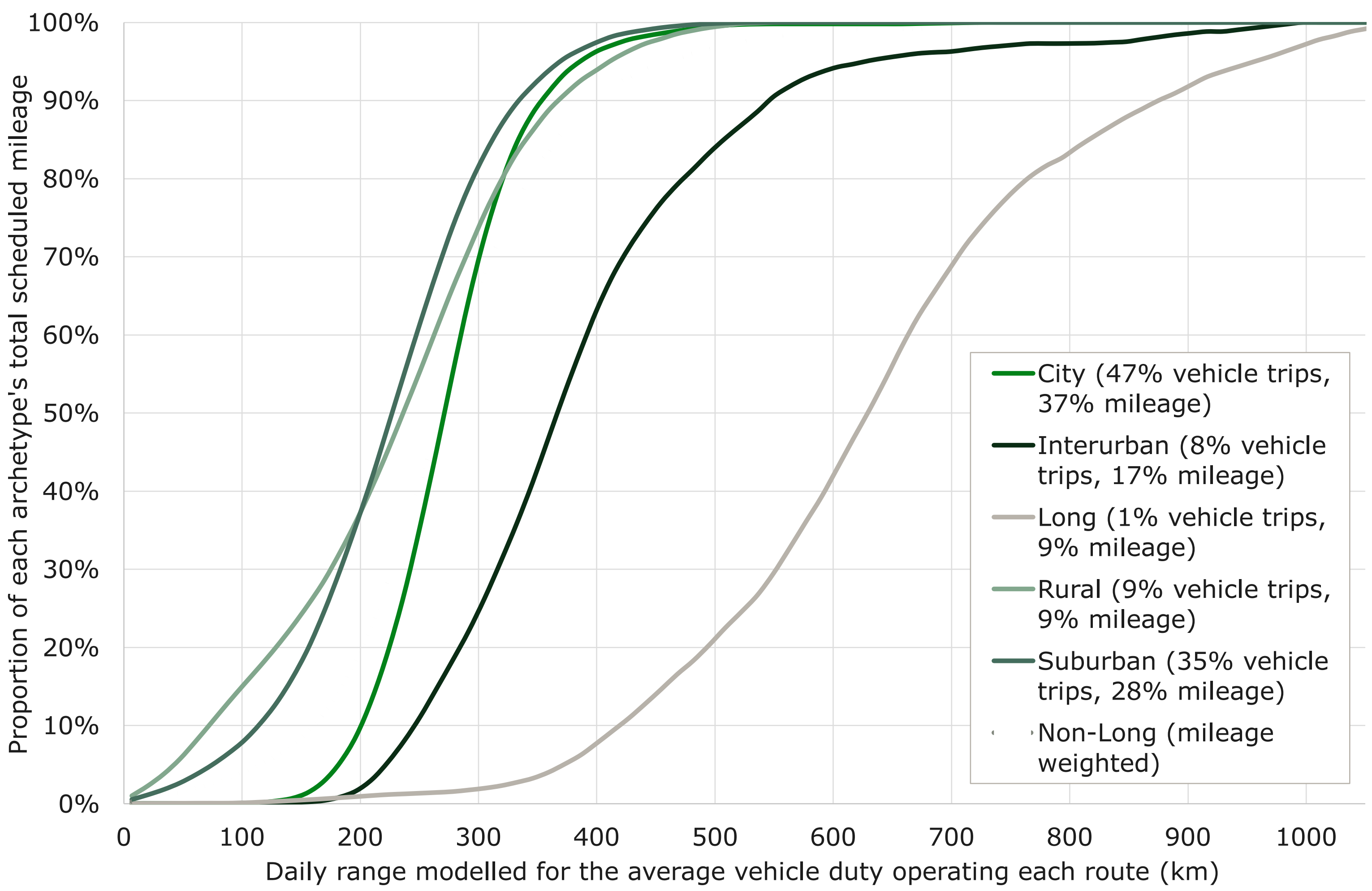
**ZE mandate scenario (legislative)**: Government is assumed to legislate no new non-Zero Emission bus after 2030 and no new non-ZE coach after 2040, with fleet replacements after these dates therefore ZE.

**Rural push-back scenario (realpolitik)**: Bus routes primarily serving rural territory adopt a 2040 coach ZE mandate. Pragmatic as hydrogen emerges as "too expensive", raising the risk of a rural policy backlash.

**Risk-minimisation curve**: Average of upper and lower scenarios, one that operators attempting to manage the sector's broadly equal balance of public and private may adopt in practice. This curve best maps to current reality: At the start of 2024, about 8% of the fleet was ZE.

# Range of scheduled bus & coach by operational archetype, GB

Interurban and long-distance coach duties will remain challenging for single-charge battery electric vehicles




Battery electric buses are typically specified at just under 2kWh of battery capacity per kilometre, to allow sufficient margin for both optimal battery charging and degradation management, and extreme weather conditions, especially cabin heating.

The latest two-axle models thus align to about 250km in practice. This range can be extended by charging during the day, although this strategy typically raises overall capital and operating cost.

Many interurban, and almost all long-distance services will remain out of single-charge range for the foreseeable future. Interurbans raise a particular policy/social equity concern because they provide the backbone of rural service provision.

# Scheduled bus and coach categories and method

## Approach and key assumptions

Results are derived from analysis of all scheduled public bus and coach across Britain, excluding private contracts, tours and non-local bus niches such as airport ground operations.

The straight-line distances between sequences of bus stops are weighted up by a road *indirectness* factor of 17%, with dead mileage between depot and route modelled as an extra 6% of route length (both factors based on more detailed analysis of samples). Note that dead mileage for smaller local bus operations is about three times greater than for larger operators – SMEs may be assumed to require 10% greater range overall.

Modelling assesses each route's total vehicle requirement by hour of day, then distributes vehicle duties to average the mileage of any one vehicle on the route. The ranges calculated are roughly a third lower than the absolute maximum requirement, if one vehicle were to operate the route continually for all hours scheduled. Our approach reflects how most operators manage their fleets across the day but may understate actual requirements in specific local cases.

Classifications (right) are non-standard, but indicative of typical operating styles and territories served. Most service provision in rural areas is interurban. The entire "long" dataset is small, so confidence in those patterns is lower, hence the curve dotted (graph in previous slide).

## Operational archetype classifications

| Archetype | Description | Weekly vehicle trips | Mostly urban or rural | Route length (km) |
|---|---|---|---|---|
| **City** | Core high-frequency urban | >= 600 | Urban | < 40 |
| **Interurban** | To regional centre from outside that centre | >= 100 | Rural | 20-100 |
| | | Any | Urban | 40-100 |
| **Long** | Long-distance - inter-city/region | Any | Any | >= 100 |
| **Rural** | Local rural or small town | Any | Rural | < 20 |
| | | < 100 | Rural | 20-100 |
| **Suburban** | Secondary urban - lower frequency | < 600 | Urban | < 40 |

# Thank you