



elementenergy

Ultra Low Emission Vans study

Final Report

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Element Energy Limited

elementenergy

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Department for Transport

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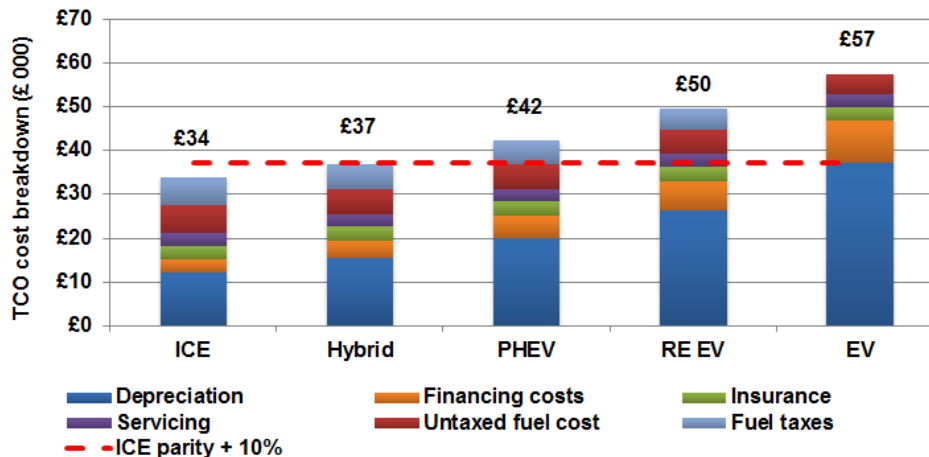
Please note: *the projections in this report pre-date the Government's announcement of the Plug In Van Grant – details at <http://www.dft.gov.uk/topics/sustainable/olev/plug-in-van-grant/>*

- This report contains the outputs of a study commissioned by the Department of Transport and carried out by Element Energy on the total costs of ownership of low and ultra-low emission vans under 3.5t gross weight.
- Throughout this study, the term ultra-low emission van (ULEV) is used to mean any plug-in van, whether pure electric or hybrid configuration, or hydrogen-fuelled vehicles. We have also modelled future costs of conventional diesel vans and a pure (non-plug-in) hybrid vehicle.
- We used a component-based cost model to estimate the current and future costs of conventional and novel powertrains based on peer-reviewed data, for example on batteries and fuel cell costs trends and the costs of vehicle mass reduction. Interviews with van manufacturers and operators were used to define assumptions on other key inputs, such as the driving range of electric vans.
- Total costs of ownership were calculated for the full range of powertrains and van sizes in 2011, 2020 and 2030, taking account of depreciation and financing costs, fuel costs, servicing and insurance.
- These ownership costs were combined with data on operators' willingness to pay for low emission powertrains to predict the future consumer demand for ULEVs.
- Our results highlight the strong potential for ultra low emission vehicles in the light commercial vehicle market in the medium term, as rising fuel costs and falling battery and fuel cell costs cause ownership costs to converge. They also highlight the short term cost challenge for ULEVs, where high battery costs (particularly in larger vans) are likely to restrict widespread deployment beyond fleet trials and early adopters without strong policy support.

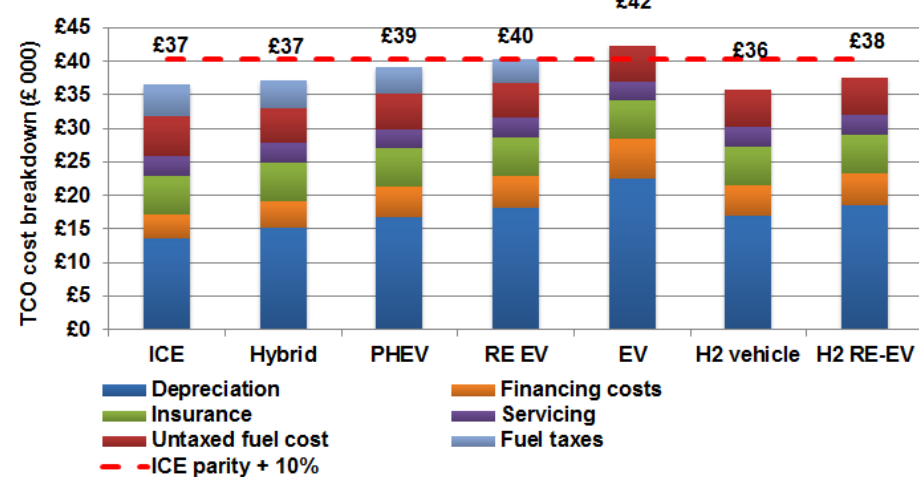
Executive Summary – TCO Results

- Our economic analysis shows that the current total costs of ownership (TCO) of ULEVs are higher than a conventional diesel van over four years, since the running cost savings do not offset the additional purchase price. The current TCO premium is above 50% for a pure EV in larger vans, though this is sensitive to assumptions on fuel price inflation and servicing costs.
- By 2030, falling battery and fuel cell costs and rising fuel costs for diesel vans causes a convergence in ownership costs. All powertrains except the pure EV are within 10% of the ownership costs of a diesel van, which our interviews with van operators suggest is the maximum premium they are willing to pay to deploy ultra-low emissions vans across their fleets.
- This convergence of costs by 2030 will provide fleet managers with a wide variety of cost-effective and low emission powertrains, but will require careful matching of vehicles to duty cycles to provide the lowest operating costs.
- Pure electric vehicles remain the most expensive powertrains under our baseline assumptions in larger vans, though small electric vans are competitive with plug-in hybrids. Our modelling suggests that even in the most favourable cases, a pure EV must have a range below 300km in order to compete on ownership costs with other powertrains.
- Our modelling also predicts that hydrogen vans could reach TCO parity against diesel vans by 2030 (assuming untaxed hydrogen), though this requires aggressive reductions in fuel cell costs towards £50/kW.

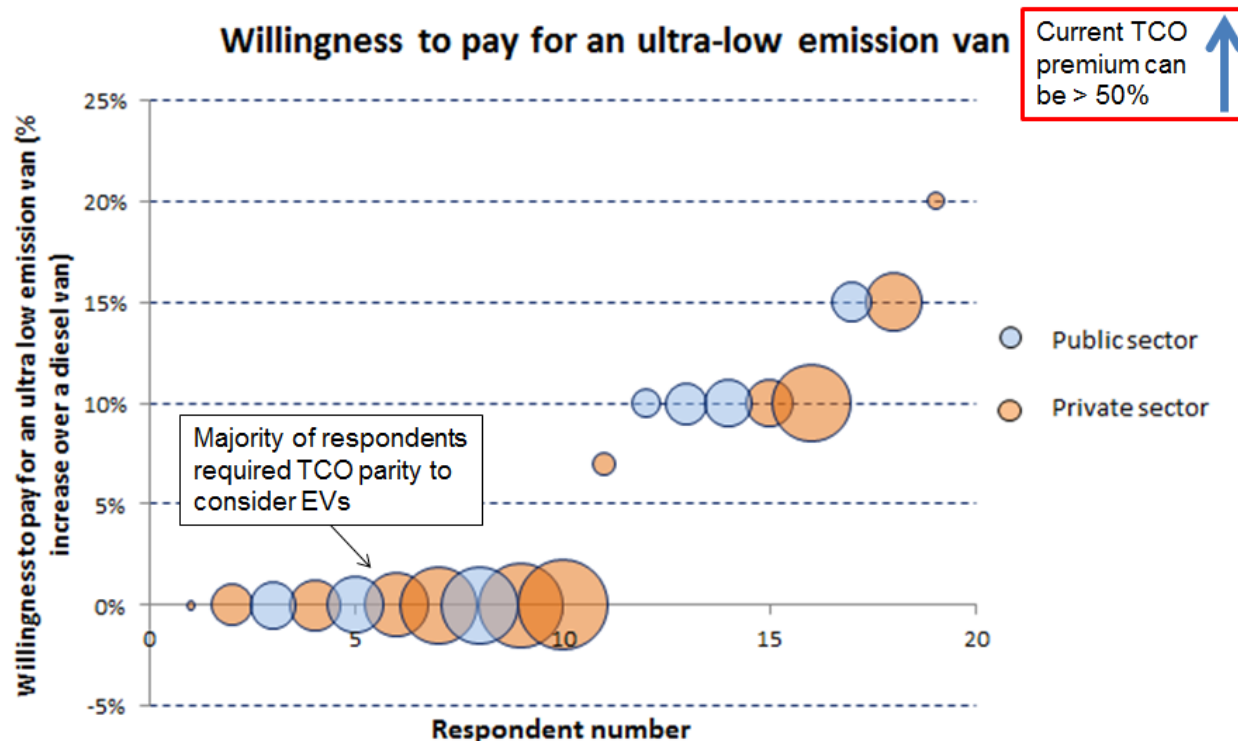
Four Year Total Cost of Ownership
- 2011 - Panel van - 2.6-2.8t



Four Year Total Cost of Ownership
- 2030 - Panel van - 2.6-2.8t



- Interviews were carried out with twenty public and private sector fleet managers. The interviews covered current procurement priorities, duty cycles (e.g. daily driving distance) as well as the feasibility of accommodating ULEVs into van fleets, given constraints on driving range or the need to install recharging/refuelling infrastructure.
- The stakeholder interviews were also used to quantify fleet managers' willingness to pay for a ULEV, all other things being equal. In other words, to what extent are operators willing to buy or lease a ULEV with higher ownership costs than a diesel van due to benefits such as green branding or compliance with company-wide emission reduction goals?
- Our results showed that 50% of respondents required ULEVs to offer TCO parity with a diesel van before they would deploy them across their fleets (i.e. beyond small-scale trials). The remaining half was willing to pay a small premium of 10-15%, suggesting that substantial cost reductions are required before ULEVs will offer a compelling alternative to diesel vans beyond a limited number of early adopters.

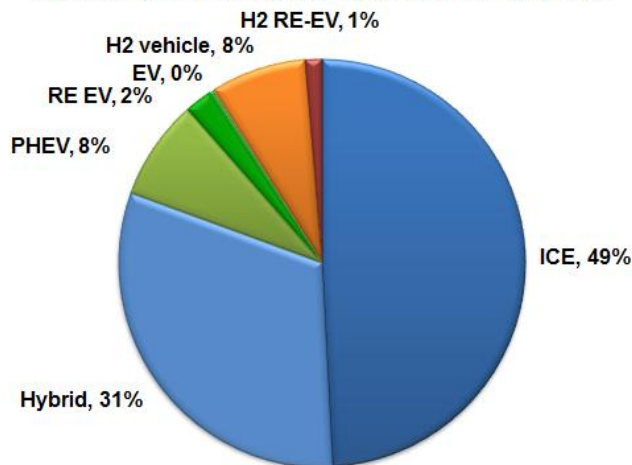


Source: Element Energy Analysis

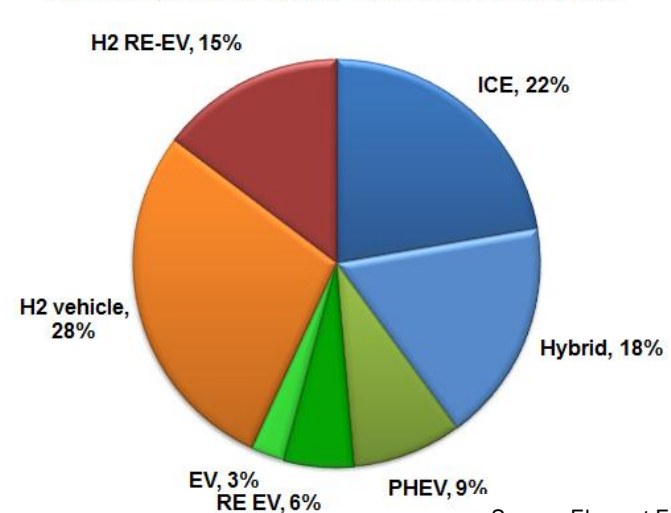
Executive Summary – Uptake of ULEVs

- The TCO results above were used to predict the consumer demand and hence market shares for each powertrain. We have not accounted for infrastructure costs or supply side constraints such as the availability of fuel or vehicles. Instead, this provides an illustration of the *underlying consumer demand* if the cost reductions predicted in this study are met.
- The charts below show the market shares for new panel vans in 2020 (left) and 2030 (right).
- Our analysis suggests that the ICE and pure hybrids will continue to dominate sales of new vans in 2020, with a combined market share of 80%. Plug-in and hydrogen powertrains take a 10% market share each, though supply constraints for hydrogen infrastructure and vehicles may limit deployment in that year.
- The pure electric panel van is expected have negligible market share, since we expect ownership costs to be considerably higher than other powertrains under our baseline assumptions in 2020. This does not take into account incentives such as the current exemption from congestion charging EV, which is valued at up to c. £10k over 4 years.
- By 2030, hydrogen vehicles dominate the new van market as they offer competitive ownership costs relative to diesel vans. However, hydrogen fuel duty or higher fuel cell costs could reduce the market share from 43% to 15% (see main report).
- Finally, it should be noted that the market shares shown below are not required to meet the 2020 EU fleet emissions target for vans of 147g/km. Our analysis suggests that improvements in diesel and non-plug-in vans will be sufficient to meet the target without widespread deployment of ULEVs. However, sufficient cost reduction in powertrain costs may create a demand ‘pull’ from fleet managers towards 2020 to encourage the introduction of new ULEV models.

Market shares in 2020 - Panel van - 2.6-2.8t

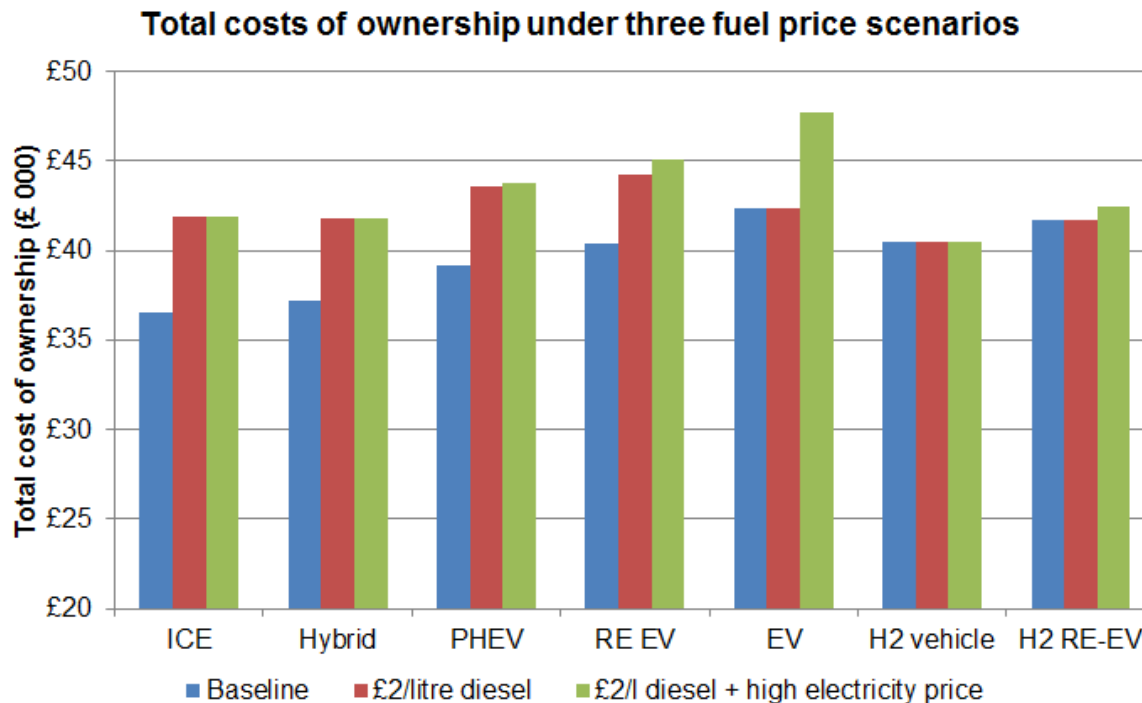


Market shares in 2030 - Panel van - 2.6-2.8t



Executive Summary – Impact of fuel prices

- The baseline fuel price assumptions are based on Government projections from the Interdepartmental Analysts Group, which predicts that pre-VAT diesel prices will rise to £1.34 per litre in real terms by 2030 (from £1.18 in 2011). The figure below shows the impact of a more substantial increase to £2/litre diesel by 2030, in 2011 prices.
- This price increase is sufficient to equalise the ownership costs of the standard panel van for all powertrains by 2030. The pure EV and hydrogen vans have the lowest TCOs of the ultra-low emission powertrains, since they do not use diesel fuel for any part of their drive cycle.
- The results also show the impact of a doubling of electricity prices relative to the baseline projections (to 36p/kWh, again in 2011 prices). This significantly increases the costs of the pure electric van, which becomes the most expensive powertrain in the standard panel van segment.



Executive Summary – Conclusions (1)

- Our economic analysis suggests that the high ownership cost premium for ultra-low emission vans will fall substantially between 2010 and 2030. The TCO premium for plug-in electric powertrains falls from c.50% in 2010 to less than 20% by 2020. By 2030, almost all powertrains are with 10% of the ownership costs of the ICE van.
- Based on our cost assumptions, hydrogen vans are likely to offer a very strong economic case towards 2030 (with untaxed hydrogen), as well as similar performance and range to an ICE van. As long as fuel cell costs can reach the projected 2030 cost of c. £50/kW, sales of these vans are likely to be constrained by supply-side factors such as the availability of vehicles and refuelling infrastructure, since the underlying consumer demand is strong.
- In contrast, the pure electric powertrain in larger vans remains the most expensive in 2030 due to the size of battery required, and hence sales may be limited by consumer demand (and competition from other powertrains), even if vehicles and infrastructure are widely available.
- Our modelling also shows that incremental improvements to diesel vans are broadly sufficient to meet the EU's fleet emission's target in 2020, though it should be noted that fleet emissions for the UK van market are likely to be 15-20g/km higher than level for the EU-27, reflecting the expected continuing dominance of large vans in this country.
- This suggests that EU fleet legislation alone is unlikely to provide a strong driver for the deployment of ULEVs between now and 2020, and a combination of demand from fleet managers and local/national incentives will be required to support the widespread rollout of these vehicles. This is consistent with previous studies on the impact of the EU fleet target for passenger cars, which suggests that the 95g/km target in 2020 can be met without the need for plug-in or hydrogen vehicles.

Executive Summary – Conclusions (2)

- The economics of ULEVs in 2020 suggest that favourable policies will be required to at least this date in order to push the vehicles beyond their current small market share.
- Opening the Plug-in Car Grant scheme to vans would significantly improve the economics of ULEVs in the short term. However, care must be taken to ensure that such support is sustainable, especially when ownership costs are likely to remain at least 20% higher than a diesel van in 2-3 years. Further care is needed to provide the correct level of support for a range of business models, for example for both outright purchase and battery lease models.
- Central and Local governments should investigate the use of other, non-financial measures to support the uptake of ULEVs. These include making allowances for battery mass (and hence lost payload) in vehicles at the 3.5t threshold for the purposes of vehicle and driver licensing. Other measures could include exclusive access to certain loading bays in cities, extended delivery hours, use of bus lanes etc. that would give operators benefits increase the operational efficiency of (and hence profitability) of ULEVs.
- Van manufacturers should assess the business case for introducing plug-in hybrid powertrains (not currently available in the van market) , since these offer the most attractive economics of all ULEV powertrains before 2020 while still delivering strong CO₂ savings and local air quality benefits . Our results suggest that smaller vans should be prioritised, as their economics are likely to be more favourable than larger vans, which would require large batteries to provide a substantial electric range.
- Finally, there is currently a high degree of uncertainty over several costs of ULEVs, particularly depreciation and servicing costs. Until long term data exist from fleet trials, lease companies and operators may be unwilling to include potential servicing and maintenance savings from ULEVs in servicing calculations or use pessimistic assumptions on depreciation to reduce their risk. Guaranteed 'buyback' schemes or fixed price service contracts from manufacturers and dealers may offer a relatively low cost route to de-risking investments in ULEVs until long term costs are known.

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Introduction (1)

Over the last ten years, light commercial vehicles have been one of the fastest growing sectors in the road transport system. The number of vans increased by 40% to three million since 1998 and they are now responsible for 13.4% of all vehicle kilometres travelled on UK roads [CFIT:2010]. As governments and industry work to reduce the environmental impacts of road transport, it is clear that policies and new technologies must be directed at commercial vehicles as well as the passenger car market.

The introduction of EU-wide fleet emissions targets (in 2009 for passenger cars and 2011 for vans) is likely to lead to significant CO₂ improvements in new vehicles during this decade. While incremental improvements, for example improved internal combustion engines, aerodynamics and vehicle mass reduction are expected to deliver the majority of the required savings, manufacturers are also developing ultra-low emission vehicles (ULEVs). These vehicles offer substantial CO₂ savings compared with a conventional vehicle (often over 50%), and can have zero tailpipe emissions for some or all of their drive cycles. Current ultra-low emission powertrains include plug-in hybrids as well as range-extended and pure electric vehicles, while hydrogen-fuelled vehicles are expected to be introduced this decade.

The choice of ultra-low emission vehicles in the van market is currently small. Several companies, for example Allied Electric and Smith Electric Vehicles, supply pure electric vans based on converted diesel vehicles from other manufacturers. More recently, mainstream manufacturers such as Renault and Mercedes are offering factory-built electric vans. Other ULEV powertrains, such as plug-in hybrids, are currently in development and expected to be introduced by 2015.

As the choice of vehicle powertrains increases, van fleet managers will have to consider a larger number of factors when selecting the optimum vehicle for their operations. In addition to assessing total costs of ownership, managers will have to consider issues such as vehicle range and payload, the intended drive cycle, the availability of infrastructure and whether they place a value on ULEV features such as very quiet operation or low tailpipe CO₂ emissions.

Policymakers too must choose if and how to support these vehicles, which this report shows currently have higher ownership costs than an equivalent diesel van. Policy mechanisms must balance the need for sufficient support against the risk of oversubsidy for some vehicles or locations, and avoid perverse incentives such as encouraging the use of multiple small vans over fewer large vans, which may increase overall emissions.

This report was commissioned by the Department for Transport in the summer of 2011. The study focuses on how the costs and performance of ultra-low emission vans is likely to evolve between now and 2030, and how the ownership costs will change relative to conventional diesel vans. Specifically, this report sets out:

- Costs and performance projections of conventional and ultra low emission vans between 2010 and 2030, based on a component-level cost model.
- Projections of total costs of ownership in a range of powertrains and van segments from 2010 to 2030.
- A quantitative assessment of market demand for ULEVs, based on ownership costs relative to a conventional van.
- Analysis of the impact of changes in key inputs such as fuel prices, ownership periods or duty cycles.

Element Energy also carried out stakeholder interviews with van fleet managers and leasing companies to understand current procurement priorities in the van sector, and whether operators were willing to pay a premium for a ultra-low emission vehicle over a diesel van. The resulting consumer preference data have been used to calculate the market shares for a range of van powertrains in 2020 and 2030, taking into account cost and performance improvements by those dates.

The work is intended to provide an evidence base for the Department for Transport on the economics and future potential for ultra-low emission vehicles for use in its policymaking in this sector. The outputs should also provide useful insights for manufacturers developing new powertrains and operators planning vehicle procurement in the short and medium term.

Throughout the study, key inputs and results have been reviewed by an Advisory Group, organised by the Low Carbon Vehicle Partnership and consisting of van manufacturers and operators, ensuring that outputs in this final report are based on the latest and most robust data on future developments in the van sector. The authors wish to thank the Advisory Group for its valuable contribution over the last few months. We also wish to thank Neil McIntee and Kevin Gregory at VansA2Z, who provided many of the contacts for the stakeholder interviews and reviewed interim project outputs.




Structure of this report




The report is structured in the following way:

- In the remainder of the introduction, we describe the segmentation we have adopted for the van market throughout the report, which covers a range of van sizes from small car-derived vans up to large 3.5t vans.
- Section 2 shows the methodology used to assess the ownership costs for current and future vans, and sets out how these costs vary in different vehicle sizes for conventional diesel vans.
- Section 3 describes the methodology employed for predicting the costs and performance of conventional and ultra-low emission vans over the next twenty years.
- Sections 4 and 5 set out the baseline results, both for the purchase price of new vans and their total ownership costs over four years.
- Section 6 contains projections for the market shares of a range of ULEV powertrains, based on the TCO data above and the results of our stakeholder interviews on van procurement priorities.
- Section 7 contains a sensitivity analysis of key inputs, for example on battery or fuel cell prices and fuel costs, while Section 8 contains conclusions and recommendations.

Market segmentation (1)

Throughout this report, the van market has been segmented into six van types, based on a combination of body type and gross weight. Descriptions and illustrative payload and mass data are below.

Segment	Small car-derived	Small van	Standard panel van
			
Description	Based on small passenger hatchbacks	Includes larger car-derived vans and small panel vans	'Standard' panel van, short/medium wheelbase, low roof
Payload volume (m ³)	1	3	6
Payload mass (kg)	500	750	900
Gross weight (t)	1.6	2.1	2.6 (+ up to 3.4t)
Examples	Corsavan, Fiesta van,	Citroen Berlingo, Ford Transit Connect	Ford Transit, Vauxhall Vivaro

Segment	Large panel van	Pick-up truck	Tipper/drop-side/Luton/box van
			
Description	Larger than standard panel van, though can be LWB, high roof variants of same models	4WD pick-up trucks. Double cab variants are best-selling models	Either specialist conversions or factory-fitted. Often with dual rear axle
Payload volume (m ³)	13	N/A	15-20 (Luton/box van)
Payload mass (kg)	1,300	1,000	1,000–1,300
Gross weight (t)	3.5	3.0	3.5
Examples	LWB Sprinter, Iveco Daily, VW Crafter	Toyota Hilux, Mitsubishi L200	Ford Transit, Vauxhall Movano

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Throughout this study, we calculate the total costs of ownership of vans over the first four years of ownership, using the following methodology:

Depreciation – this is calculated from the base price of the vehicle minus the expected residual value after 4 years. A residual value of 30% of the retail price after 4 years is used throughout the analysis based on discussions with industry stakeholders. The same residual value is used for all powertrains, though it is acknowledged that long-term residuals for ULEVs could be lower or higher than for conventional vans. We do not take into account purchase price discounts offered to buyers, since these are highly dependent on fleet size and individual contracts.

Financing cost – this is the interest payable over the 4 year ownership period. The interest is calculated based on the average of the purchase price and residual value, at a rate of 7% per year. This is consistent with the approach used by the British Vehicle Rental and Leasing Association when comparing ownership costs of conventional and low carbon vehicles. Source: [BVRLA:2011]. Explicitly including the cost of financing in this way avoids the need for a discount rate when calculating the other components of the TCO such as fuel and servicing costs. In other words, the BVRLA methodology uses **undiscounted four year values** along with a financing cost, rather than using a discount rate for all future costs and ignoring interest on the capital cost of a van.

Fuel costs – the retail diesel price in 2011 is assumed to be £1.42/l. It is assumed that vans are used entirely for business mileage and hence all VAT on fuel is reclaimable. This lowers the fuel price to £1.18/l. Throughout the report we distinguish between the price of the fuel itself and the fuel duty. This allows comparison with other fuels (such as hydrogen) that are currently untaxed but may be subject to fuel duty in the future.

Servicing and insurance costs

Servicing, maintenance and repair (SMR) – SMR costs over four years were sourced from the BVRLA Data survey (www.bvrladatasurvey.co.uk), which records SMR for all new cars and commercial vehicles and is benchmarked against the industry-standard MCM Maintbook database. Average values for each van segment were used based on the SMR costs of the best selling models. It has been assumed that maintenance costs are identical between powertrains for a given van size. This conservative assumption reflects the current lack of data on ULEV servicing and maintenance costs, where the anticipated lower maintenance cost requirements (for example due to fewer moving parts in a pure electric powertrain) may be balanced by higher parts costs for low volume powertrains.

Insurance – insurance costs were based on the average of the 10 lowest cost quotations from quotezone.co.uk for the best selling model in each van segment. Insurance costs are highly variable due to difference in mileage, region, excess, driver age and no-claims bonuses etc. We have assumed that insurance costs are identical across all powertrains within a given segment, so these have no effect on the *relative* ownership costs of an ultra-low emission and a conventional van.

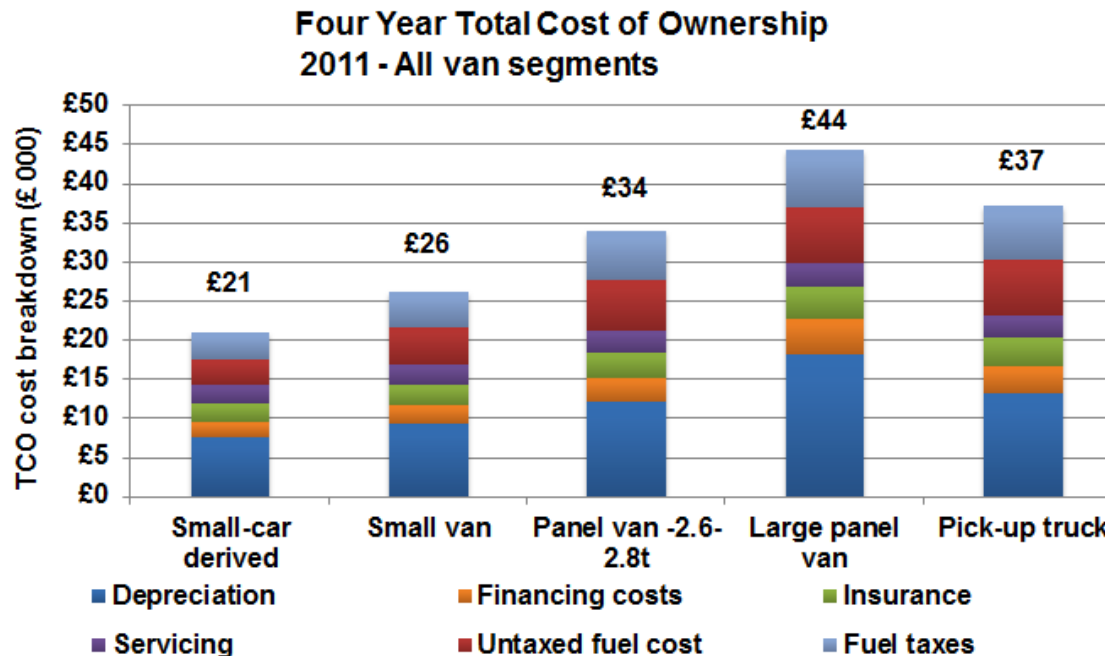
It should be noted that insurance costs for ultra-low emission vans may be higher than those for conventional vehicles, since the replacement cost of the van is currently double or triple the cost of the diesel equivalent. However, since many large fleets are effectively self-insured (which means commercial vehicle lease companies do not hold data on van insurance costs (especially for currently low volume electric vans)), we have not modelled powertrain-specific insurance costs.

Other ownership costs – these include congestion charging, Vehicle Excise Duty etc. We have omitted these from the analysis to highlight the underlying economics of different van powertrains, and how whether differential rates of duties and charges could narrow the gap in ownership costs between conventional and low carbon vans.

On the following slide, we show the ownership costs in each van segment for a conventional diesel van in 2011, using the assumptions above. The following section describes the methodology for calculating capital and ownership costs for current and future ultra-low emission vans.

Total costs of ownership in 2011

- The 4 year total costs of ownership for diesel vans in each segment in 2011 are shown below. TCOs range from £21k for a small car-derived van to £44k for a large panel van.
- For all vans, depreciation and financing costs contribute to c.45% to the TCO. Total fuel costs account for a further 33%, with insurance and SMR accounting for the remaining c. 20%.
- Ownership costs do not scale linearly the carrying capacity of a van in volume terms. For example, the ownership costs of a large panel van are 70% higher than for a small van, but the load volume is four times higher (13m³ versus 3.5m³).
- The TCO scales more linearly with payload, as the payload of a large panel van is 70% higher than for a small van (1,300kg versus 750kg).



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Overview of methodology

- In this section, we present the methodology for calculating the future purchase prices and ownership costs for conventional and ultra-low emission vans.
- The methodology is based on that used for our recent study on the ownership costs for passenger cars for the Low Carbon Vehicle Partnership [ELE:2011]. The following steps were employed:
 - An ‘average’ diesel van was derived for each of the segments defined above based on the attributes of current best-selling vans.
 - Estimates of improvement rates in internal combustion engine technology, aerodynamics, weight reduction and their associated costs were applied to derive the properties of future diesel vans.
 - Cost and performance attributes for ULEVs were derived based on the additional powertrain costs over conventional vans.
 - These future van costs were then added to projected running costs to calculate the total costs of ownership in a given year.
- Since many components of ULEVs, such as batteries and fuels, are similar to those employed in passenger cars, we have used the same peer-reviewed estimates for future costs employed in the LowCVP study. These figures were reviewed by the LowCVP Advisory Group.
- For van-specific attributes, such as the potential for weight reduction, we have sourced data from the literature and have validated these with stakeholders within the van industry.

Description of current vans

- For each segment shown above, the costs and specifications of an ‘average’ van in 2011 were derived using SMMT data on the top 5 best-selling models.
- Cost and performance data were sourced from the van comparison service at www.vansa2z.com
- The table below shows the base price and selected performance attributes for each segment. Specifications are not shown for chassis-cab conversions since these depend on the body fitted. However, the underlying powertrain is always based on the large panel van variant of the same model and so engine power and gross weights are similar.

Vehicle segment	Small-car derived	Small panel van	Standard panel van	Large panel van	Pick-up
Base Price	£10,800	£13,200	£17,100	£25,700	£18,900
Maximum Power (kW)	53	65	64	86	116
Maximum Torque (Nm)	150	220	240	300	360
GVW (kg)	1,620	2,090	2,660	3,500	3,020
Kerb Weight (kg)	1,130	1,350	1,750	2,180	1,930
Fuel consumption (l/100km)	4.1	5.7	7.7	8.7	8.5
CO₂ (g/km)	107.5	149.8	204.0	230.2	223.6
% of new van sales in 2010 – from SMMT	2%	30%	34%	21%	9%

- The sales-weighted average CO₂ emissions of the vehicles above is calculated to be 192g/km, within 2% of the 2010 figure of 196g/km from the JATO database. This suggests that the ‘average’ vans used above are a strong proxy for the van market as a whole.

To predict the characteristics of future low carbon vans, we begin with the expected improvements in the conventional internal combustion engine (ICE) vehicle. This allows improvements in the ICE and improvements outside the powertrain, such as aerodynamic improvements and vehicle 'light-weighting', to be quantified and applied across all vehicle types.

Two improvement approaches are considered:

1. The first approach is based on improvement measures considered technically feasible, and may require additional legislation to encourage strong evolutionary improvements to continue beyond 2020 when the existing 147g/km fleet average is expected to be met.
2. A second approach conforms to DfT's Transport Analysis Guidance where only currently announced policies/legislation are considered.

The first approach is used throughout the results in this presentation. The rate of improvement after 2020 in the absence of further legislation is subject to considerable uncertainty, as it depends on progress delivered by 2020 and macroeconomic factors such as fuel prices, which determine whether further improvements are cost-effective for van users.

For the second approach, we propose to maintain the van performance levels at 2020 levels in the absence of further legislation. In other words, no further weight reduction or ICE efficiency improvements occur beyond 2020 in this scenario. We have not modelled the feedback of legislation on other component costs (e.g. batteries), for example if a stricter EU emissions target leads to an increase in battery / fuel cell demand and influences their costs.

Fuel consumption for future ICE vans is calculated by applying the improvement factors on the following slides to the fuel consumption of current vans. Current consumption is based on published NEDC values for the best-selling vans in each segment, with a scaling factor applied to reflect the higher fuel consumption observed in real-world conditions. This scaling factor was taken to be 30%, based on interim results from the Low Carbon Vehicle Procurement Programme, which compared real world and NEDC fuel consumption and CO₂ emissions for low carbon vehicles and a 'control fleet' of diesel vans.

* The LCVPP control fleet of 18 short and long wheel base diesel vans had average real world emissions of 347g/km, compared with NEDC emissions of 266g/km, a difference of 30% [LCVPP:2011]

We assume modest mass reductions in vans (2010– elementenergy 2030) following discussions with manufacturers

Vehicle size and mass assumptions

Vehicle mass and size have a significant influence on the fuel consumption of a van. In passenger cars, it is expected that manufacturers will pursue an aggressive light-weighting strategy in future vehicles, which reduces the energy (and hence fuel) required to move a vehicle through a drive cycle and also allows powertrain components to be downsized with additional fuel saving benefits.

While mass reduction in vans also improves fuel consumption, it is likely that OEMs would use reductions in van kerb weights to increase maximum payload for a given gross weight. In such a case, powertrain downsizing would not be possible since vehicle performance at gross weight must be maintained. Note that this type of downsizing (a reduction in engine power for a given van as kerbweight is reduced) is different from engine downsizing aimed at maintaining engine performance while reducing the cylinder displacement. The latter is widely expected to be important strategy for reducing fuel consumption by decreasing friction and pumping losses.

We have made the following assumptions on the size and mass of future vans.

- It is assumed that the size (frontal area and length) of the different van classes will not change through time. This is consistent with vans being designed for a given payload mass or volume and not undergoing the gradual size increase seen in passenger cars in recent decades.
- We have assumed that a 10% reduction in vehicle mass delivers fuel savings 2.7–3.6% [SAE:2006] [SAE:2007] [RIC:2008]. This is lower than the highest value found in the literature of 8.2% for a 10% mass reduction [SAE:2007], which includes secondary efficiency improvements through engine down-sizing.
- The annual rate of mass reduction is assumed to be 1% per year, based on discussions with van OEMs. This is considerably lower than the maximum technical mass reduction, for example the 38% reduction demonstrated (for a 2020 car) in the Lotus weight reduction study [LOT:2010], though this reflects the more limited ability to reduce mass from a van without compromising its payload.
- Some OEMs felt that even a 1% reduction was optimistic, since vehicle masses have tended to increase over time, due to additional safety or emissions control equipment. We have assumed that the use of lightweight materials in the van chassis and body panels is able to offset these mass increases in the future.

ICE vehicle evolution (1)

Vehicle improvements

To calculate future vehicle energy demands the existing losses over a drive cycle and how these are likely to change are needed. The key areas of improvement in the existing drivetrain are:

- Aerodynamics
 - Rolling resistance
 - Driveline transmission
 - Engine efficiency
- We have based the assumptions below on AEA’s 2009 report on emissions targets for vans. The contribution of each factor to the post-engine losses were sourced from MIT [MIT2008] These were reviewed by van OEMs, whose comments are shown.

	Annual improvement	Relative losses post engine	Fuel efficiency improvement in 2020	Fuel efficiency improvement in 2030	Comment
Aerodynamics	0.5%	30%	1.5%	3.1%	Aerodynamics are unlikely to have an effect on urban delivery vehicles but considerably more than a 1.5% improvement by 2020 for extra-urban drive cycles [OEM:2011]
Rolling	0.8%	25%	2.0%	4.2%	Although a reduction in rolling resistance is possible care must be taken between the trade off with other tyre attributes such as tyre lifetime [MICH:2011]
Driveline transmission	1.2%	26%	3.3%	6.9%	OEMs quoted as high as 4% CO ₂ savings from current dual clutch systems [OEM:2011]

Vehicle improvements

Efficiency improvements can also be made by reducing idling losses through stop-start systems and reducing braking losses through regenerative braking. We have assumed a combined efficiency improvement of 10% over the NEDC, based on industry feedback on the LowCVP project.

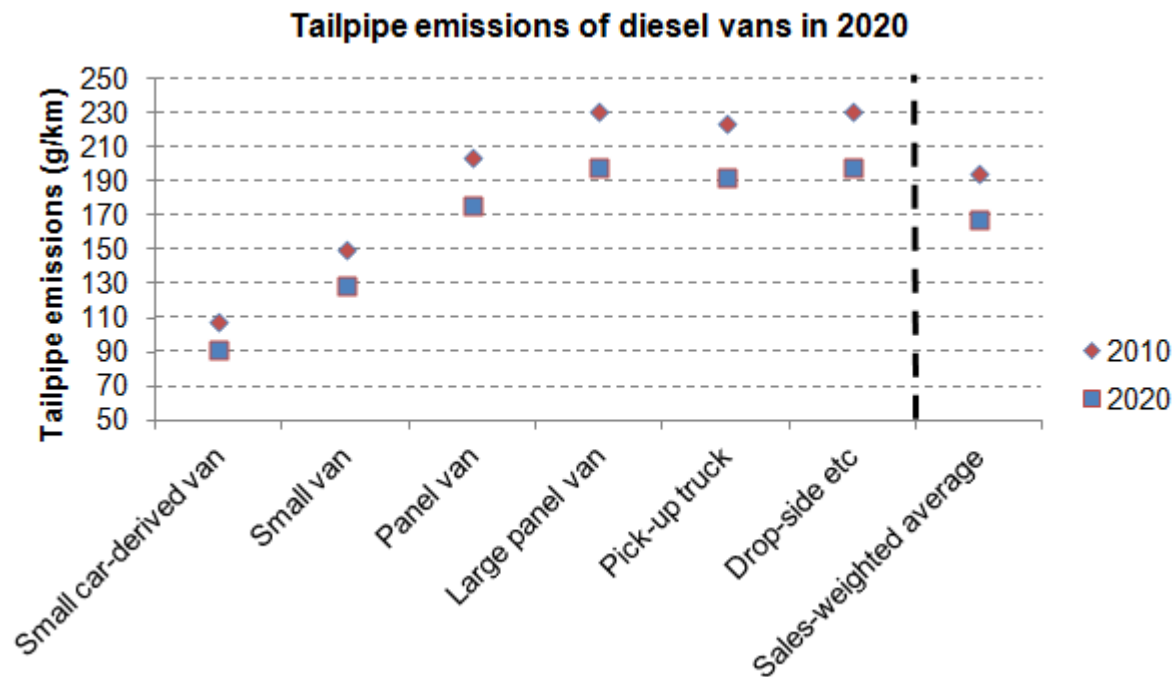
ICE engine efficiency

Annual improvements in ICE efficiencies are set at 0.5% over the incumbent, with an initial overall (thermodynamic) efficiency of 28% in 2011. Both stop-start and ICE efficiency improvements are included in the future ICE vehicles.

Future ICE vans are assumed to be diesel powered, since diesel vans represent the overwhelming majority of the new van market (and existing fleet). An efficiency improvement of 0.5% per year for diesel engines reflects the fact that the current efficiency is higher than for petrol engines and there is probably less scope for improvement than in the latter (where we have previously assumed a 1% improvement rate for the passenger car market).

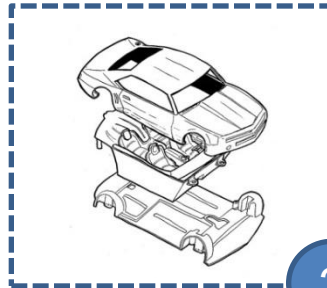
Predicted emissions of diesel vans in 2020 are consistent with EU van fleet target of 147g/km

- The figure below shows the predicted tailpipe emissions of diesel vans in 2020 in each segment, with a weighted average based on the current segment market shares in the UK from SMMT.
- The weighted average emissions in 2020 are 167g/km, which appears to be 20g/km higher than the mandatory EU-27 target of 147g/km.
- However, UK van fleet emissions have historically tracked 15-16g/km higher than in the EU-27 as a whole, reflecting the high proportion of large vans in the UK market. Since our incremental improvement methodology used current UK fleet emissions as a starting point, the predicted tailpipe emissions from our analysis are in fact within 5g/km of the expected value, assuming the UK market bias towards larger vans is maintained.
- If these ICE van improvement factors were to be applied to the current EU27 fleet emissions value, which was 180g/km in 2010 [ICCT:2011], our analysis suggests that the 2020 target is feasible using existing ICE technology, perhaps with a minor role for non-plug in hybrids. In other words, achievement of the target is not dependent on the widespread rollout of ULEVs.

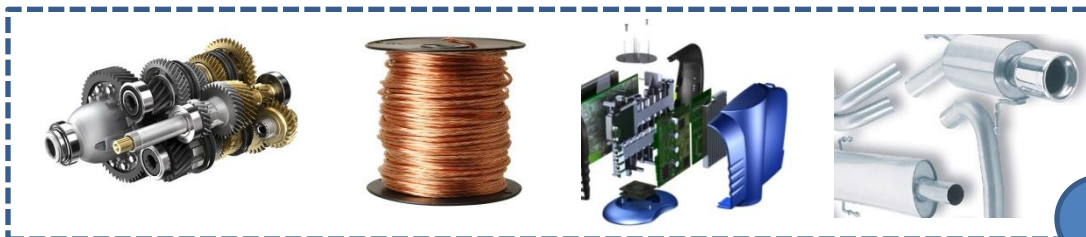
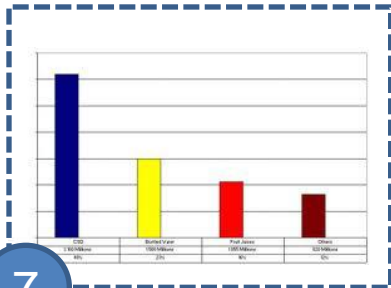


Capital cost assumptions

The capital costs of future vans are calculated by adding the relevant powertrain component to a standard van 'glider', which includes the chassis and body and other common components (e.g. interior trim, steering and braking systems, safety equipment). The cost model is based on seven main vehicle components.



1. Margins
2. Chassis and body
3. Primary and secondary power plant
4. Hydrogen tank (where relevant)
5. Electric motor (incl. controller and inverter)
6. Additional components (e.g. wiring)
7. Chassis and body light weighting



Capital cost assumptions – chassis costs

Chassis cost and margins

The cost of the vehicle chassis is assumed to remain constant through time with the additional costs from vehicle light-weighting calculated separately.

The chassis cost is calculated by removing the margins and cost of the ICE powertrain from the selling price of current vans. Industry feedback suggested that discounts of 10-20% on list prices were widely available even for purchases of single vans. To account for this, we applied a 15% discount on list prices when calculating chassis costs.

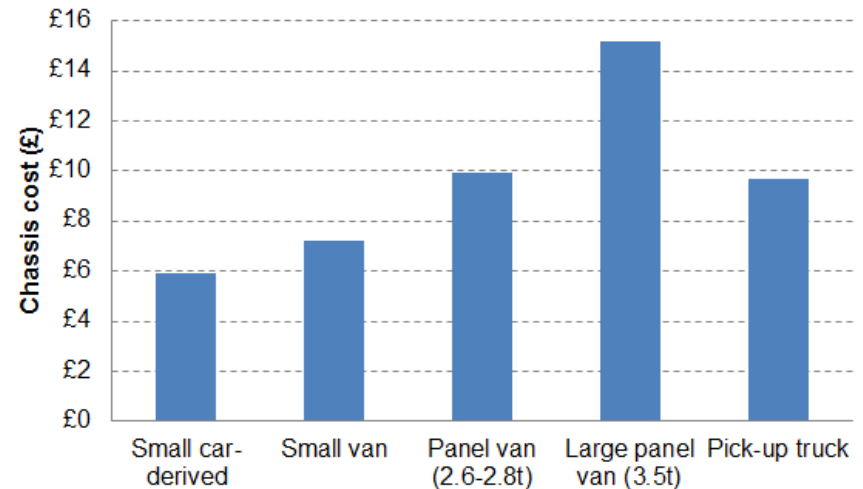
Industry margins and production costs for van chassis are not published, and we have used publicly available data on standard automotive industry margins (see Appendix). If margins are higher than we have assumed, this would lower the implied chassis costs for all van types. However, since this chassis cost is assumed to be the same for all powertrains, this does not affect the relative costs of conventional and low emission vans.

Electric motors

Electric motor types can be separated into two types, wheel motors and centrally mounted transmission-connected systems. For simplification costs stated are for a central motor connected to transmission rather than for individual wheel motors (which require additional electronics). The motor costs include the controller and the motor inverter.

Sources: [EPRI:2001];[EPRI:2002];[CONC:2007];[MIT:2008];[LOT:2010]

Rolling chassis costs



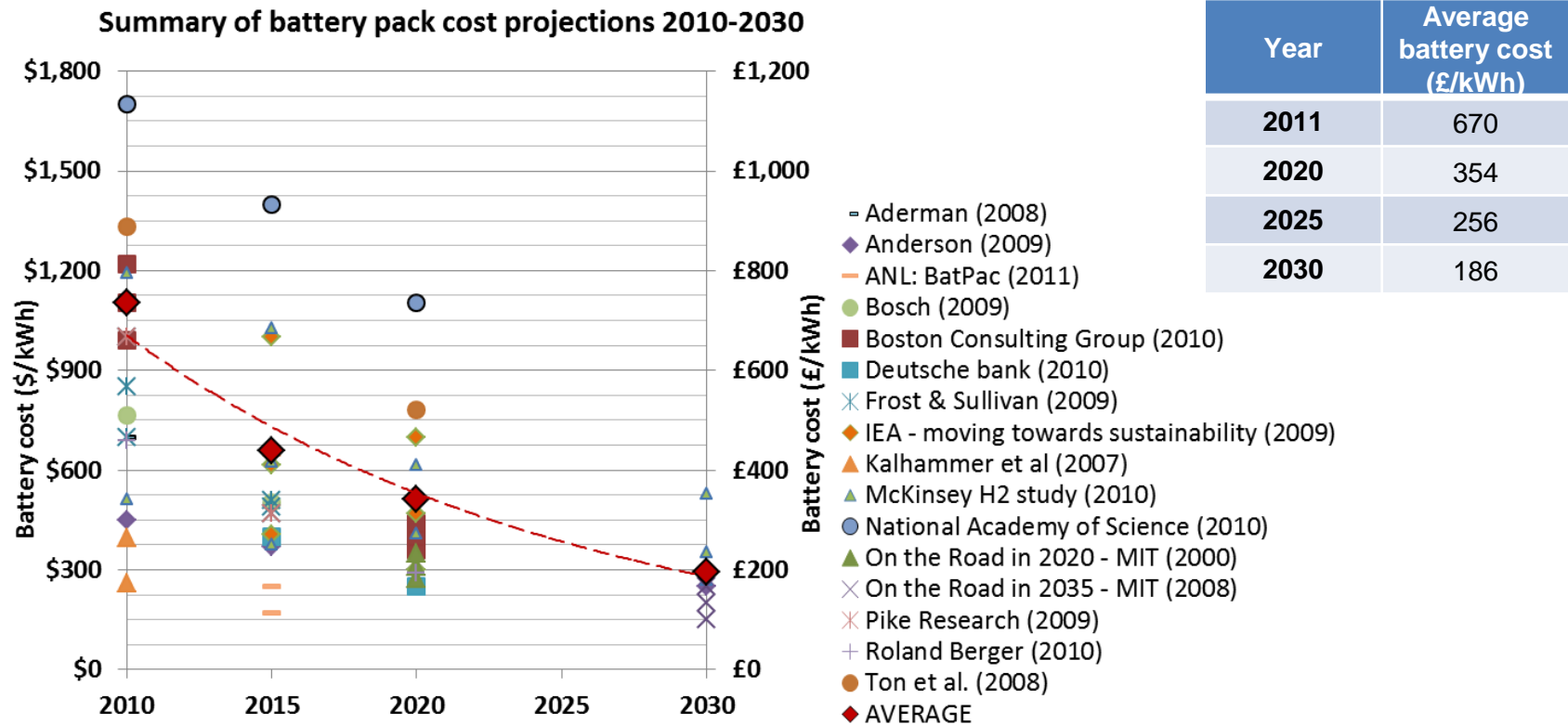
Year	Electric motor (£/kW)
2011	33
2020	21
2025	21
2030	21

Capital cost assumptions – batteries

Battery Packs

Battery packs consist of the control system, cell packaging and cells. The majority of the pack costs come from the cell cost (50-70%) but this varies significantly depending on the power and energy requirement of the battery pack. The costs used here represent costs for an average battery pack (in £/kWh) as delivered to the OEM. This includes a fully assembled pack, but does not include the costs of the battery tray to mount the pack in the vehicle.

The battery cost projections for this study have been drawn from 18 different sources and averaged to generate a time-dependent cost curve.



Note A 45kWh battery (providing a 160km range in a standard panel van) decrease in cost from £30,000 in 2011 to £16,000 in 2020, a reduction of 47%.

Capital cost assumptions – fuel cells

Fuel Cells

Automotive fuel cells currently have very high costs due to low production volumes. This cost is expected to be reduced by an order of magnitude with large-scale series production. This cost-volume relationship is as important as time-dependent cost reductions, such as improvements in new product generations.

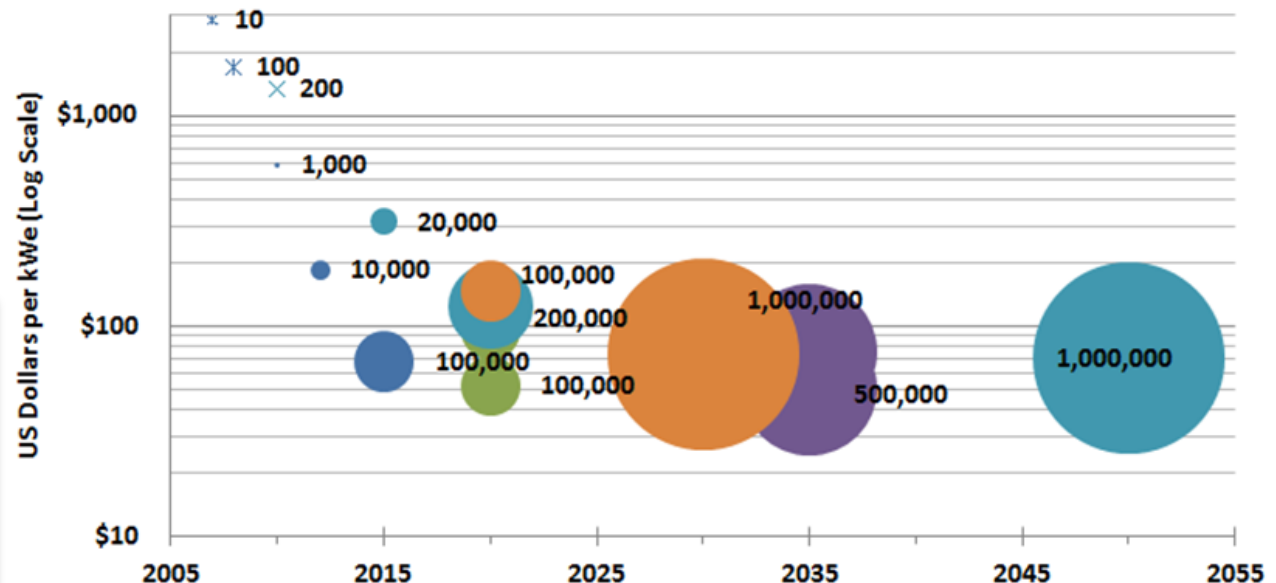
A review of published data on expected and current fuel cell costs is shown below in a bubble chart on a logarithmic scale showing volume and time effects on fuel cell costs. Costs for most studies are expressed in terms of volumes per vehicle manufacturer per year, which assumes that a limited number (c.5) major OEMs are the 'first movers' until 2020, with other OEMs following in the 2020s.

Year	Fuel cell cost (£/kW)	Volume
2011	811	~10
2020	75	~100,000
2025	64	~500,000
2030	53	>>500,000

Note

A 64kW H₂ fuel cell (suitable for a standard panel van) decreases in cost from £52,000 in 2011 to £4,800 in 2020, a reduction of over 90%.

Fuel cell system cost projections over time and volume



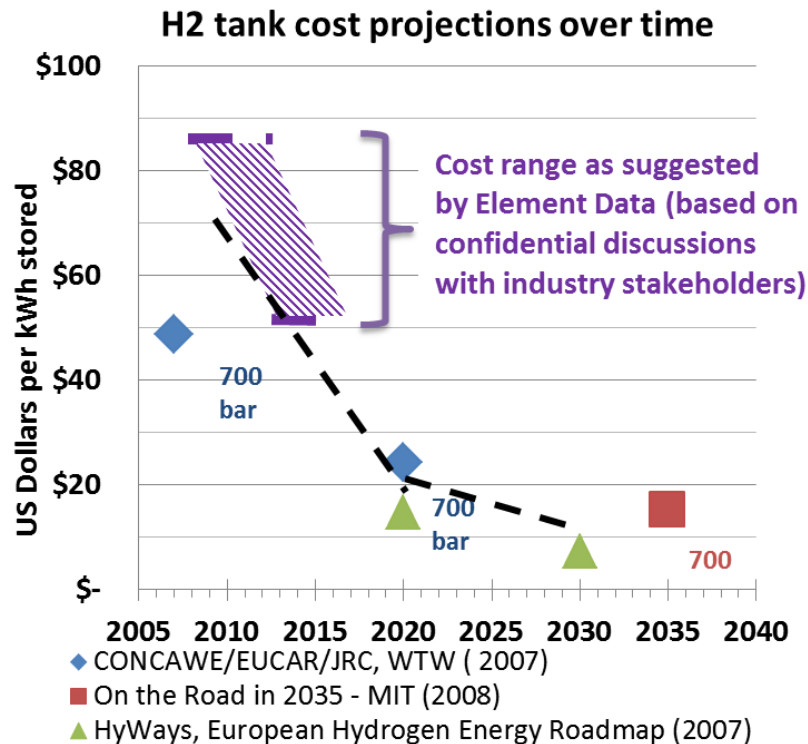
- ✖ Byung Ki Ahn, Hyundai-Kia Motor presentation during "IPHE Infrastructure Workshop", 25-26 February 2010, Sacramento, CA
- CONCAWE/EUCAR/JRC, Well-to-Wheels analysis of future automotive fuels and powertrains in the European context (2007)
- On the Road in 2020 - MIT (2000)
- On the Road in 2035 - MIT (2008)
- ✖ McKinsey H2 study (2010)
- HyWays, European Hydrogen Energy Roadmap (2007)

Capital cost assumptions – hydrogen storage

Hydrogen Tank

Hydrogen tank costs are also expected to decrease substantially over time. Hydrogen tank costs are less well documented, and existing academic studies have underestimated costs relative to OEM data seen in Element Energy’s recent work in this sector.

The values to the right represent a best estimate for long term tank costs. Due to the paucity of data, it has not been possible to explicitly model the relationship between sales volumes and costs.



Year	H ₂ tank cost (£/kWh)	H ₂ tank cost for a standard panel van (£)
2011	47	£10,000
2020	17	£3,600
2030	8	£1,500

Current and future electric ranges of ULEVs

- At current battery costs, OEM decisions on an electric van’s range have a significant influence on the purchase price. For a large panel van, the cost of providing an extra 50km of range is approximately £10,000 (for an additional 15kWh of battery capacity).
- Since battery costs are predicted to fall in future, OEMs can use this saving to reduce the vehicle selling price or increase the range for a given price. The optimal trade-off will depend on future battery costs, the cost of the competing diesel van, and the range required by customers.
- For hybrid powertrains (such as the plug-in hybrid and the range-extended EV), we have assumed that OEMs ‘spend’ all future battery cost reductions on reducing the vehicle price and hence keep the range constant. These values are assumed to be 30km for the PHEV and 60km for the RE-EV.
- The RE-EV range of 60km is lower than that of two prototype Vauxhall Vivaro vans, developed separately by Vauxhall and Protean. These vehicles have claimed electric ranges of 100km. However, we have assumed that production versions will offer lower ranges in order to offer vehicles closer to the costs of conventional vans. This is supported by the cost modelling results, which show that the additional battery cost of increasing the electric range is not offset by lower fuel bills at current battery costs.
- The ranges of pure electric vans is assumed to increase moderately between 2011 and 2030 as OEMs balance increasing functionality against the need to offer competitive ownership costs. The table below highlights the EV range assumptions for each van segment. The model takes into account reductions in energy consumption per km (due to mass reduction, aerodynamic improvements etc.) when calculating the battery size required to provide these driving ranges.

Year	Small-car derived	Small panel van	Standard panel van	Large panel van	Pick-up
2010	100km	100km*	160km	160km	160km
2020	160km	200km	230km	230km	230km
2030	160km	240km	300km	300km	300km

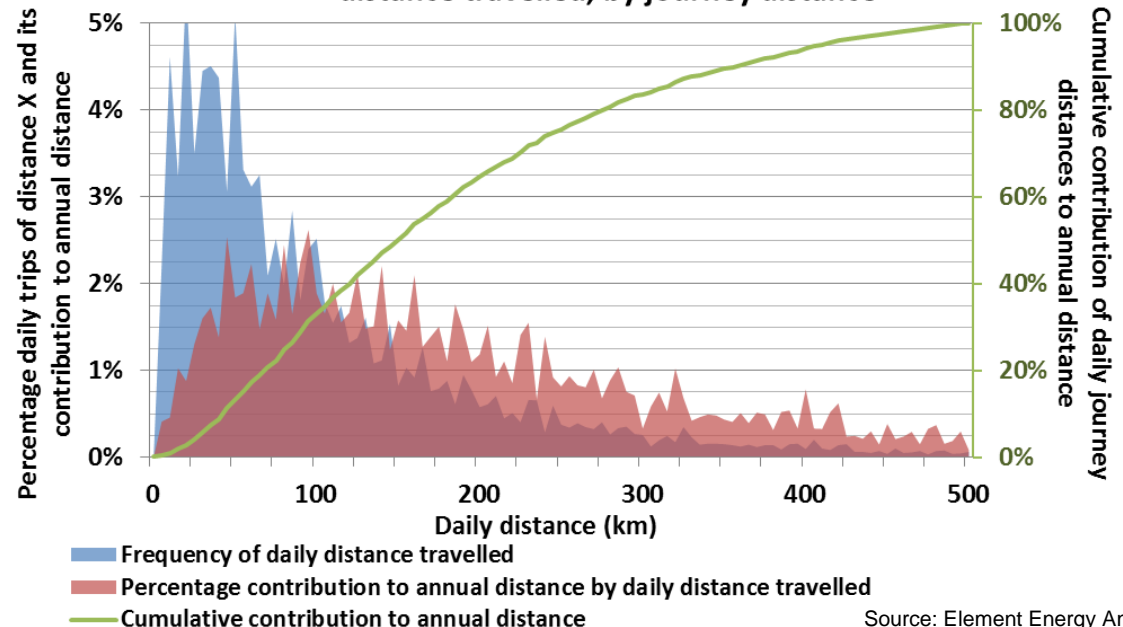
- The impacts on van ownership costs of increasing these ranges further is explored later in the report.

* This values was based on the stated ranges of the Allied Electric conversions. This is consistent with the stated range of the electric Transit Connect (80-130km), but lower than the recently announced KangooZE range, which is 170km.

Calculating fuel consumption for hybrid powertrains

- Since this study aims to highlight the real-world operating costs of vans, we have developed a methodology for calculating the fuel and electricity consumption for hybrid powertrains.
- The approach is similar to that used in our report on ownership costs of passenger cars for the LowCVP [ELE:2011] but has been adapted to take into account van-specific duty cycles.
- We have used travel diary data from the DfT's Survey of Company Owned Vans to calculate the proportion of a van's annual driving distance covered in trips of varying lengths. Using this distribution, we calculated the total mileage covered in 'electric mode' and using liquid fuels for PHEVs and RE-EVs.
- In the figure below, a RE-EV with a 60km range could cover 20% of an 'average' van's annual driving distance in EV mode, assuming it was only recharged once at the end of the day.
- This methodology is more conservative than the NEDC methodology for hybrid drivetrains, which assumes that plug-in vehicles can be recharged every 25km, which is unlikely to reflect current van drive cycles.

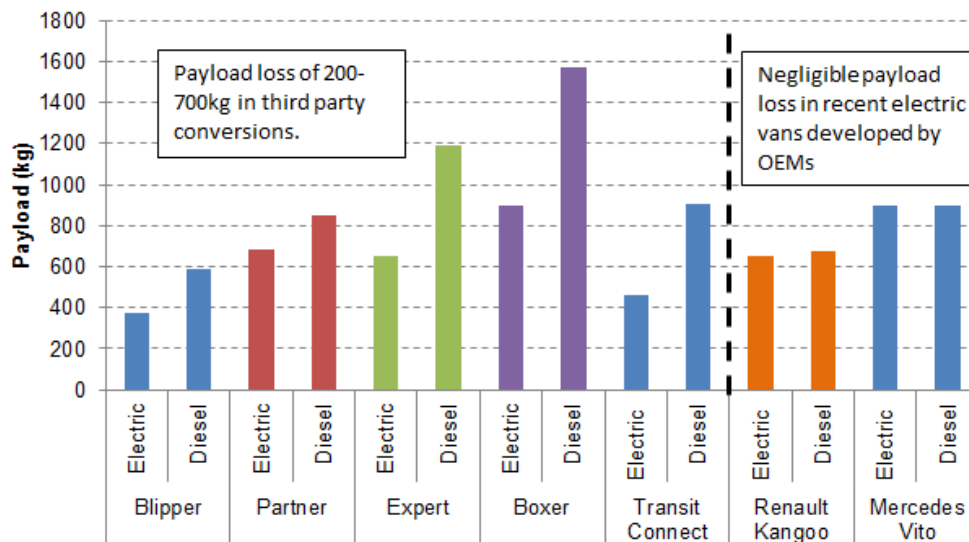
Histogram of distance frequency and its contribution to annual distance travelled, by journey distance



Payload loss in ULEVs

- Payload loss in ULEVs was raised as a significant concern during our fleet manager interviews, who highlighted the operational difficulties caused by lost payload for a given van size.
- The figure below compares payloads in electric and diesel versions of currently available vans. The five left-most vehicles are third party conversions (by Allied Electric and Azure Dynamics), while the Kangoo and Vito have been developed directly by Renault and Mercedes respectively.
- The converted vans have a reduced payload of between 200 and 700kg in the electric versions, with the biggest reduction in the 3.5t Peugeot Boxer conversion.
- In contrast, both the OEM vehicles have negligible payload loss (5-10%), as the gross weights have been increased to compensate for the mass of the batteries.
- This suggests that payload loss in EVs can be mitigated by uprating suspension/brakes etc. in smaller vans. However, using this approach for large 3.5t vans would require operators to comply with more stringent licensing requirements (e.g. O-licence, increased driver training, use of tachographs), which would deter many fleet managers from purchasing these vehicles.
- This suggests that amending licensing requirements to allow the 3.5t licensing threshold to rise in line with the battery mass (up to the vehicle's Design Weight) could remove a major barrier to purchase for large electric vans.

Comparison of payloads in electric and diesel vans



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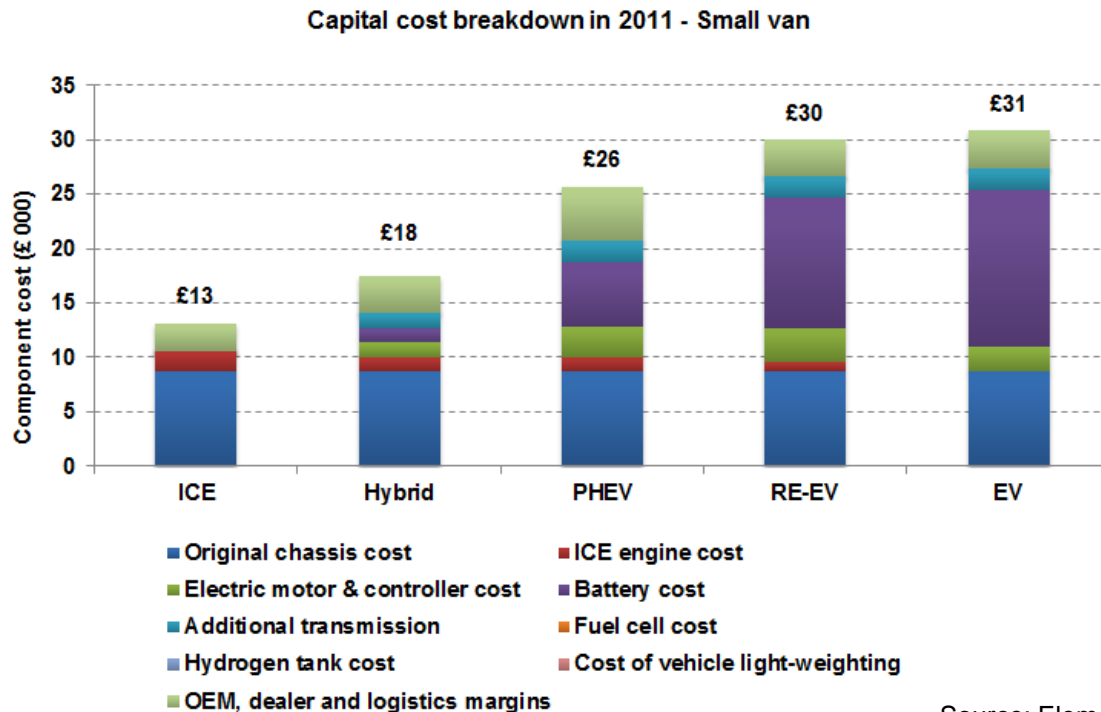
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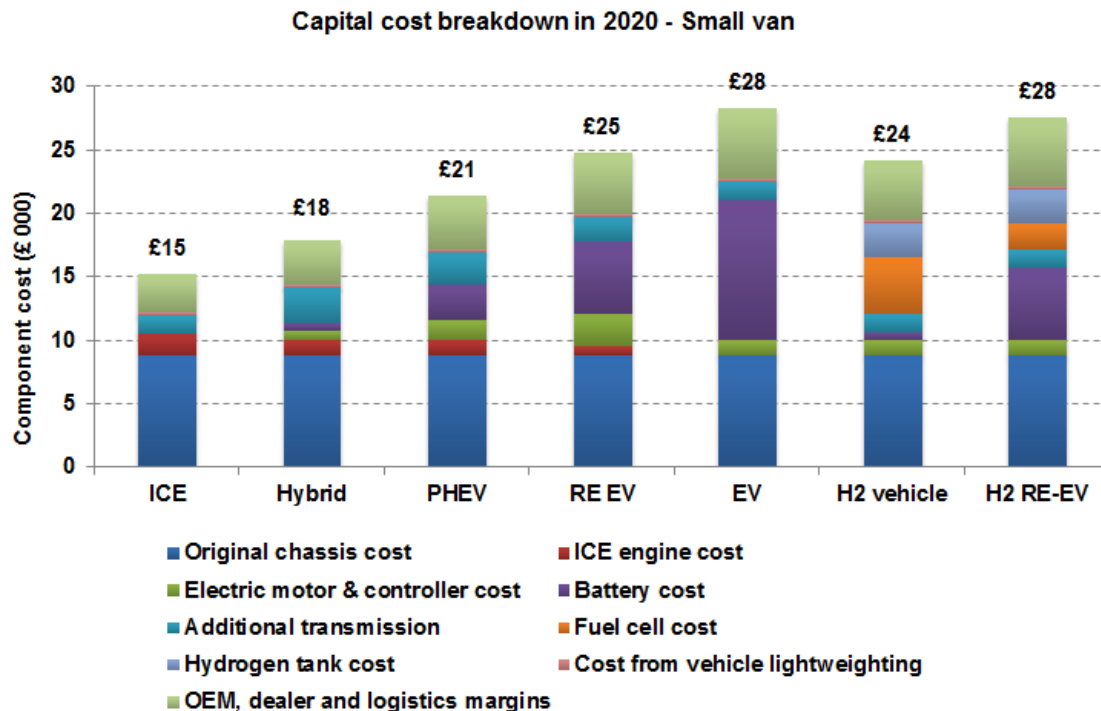
Capital costs in 2011 – Small van

- The figure below shows the capital costs in 2011 for a small van. Vehicle costs throughout this report include standard margins but exclude VAT. The costs shown are consistent with current list prices for these vans, before discounts are taken into account, which may vary significantly between customers, order sizes, OEMs etc.
- Note that only the ICE and pure electric vehicles are currently on the market in the small van segment. Costs of the three hybridised powertrains are therefore projections based on the cost of battery and powertrain components described above.
- The calculated cost of the pure EV at £31k is considerably lower than the selling price of the electric Transit Connect (at £40k). However that vehicle is a slightly larger van than the ‘average’ small van and has a larger battery pack than required by our model (28kWh versus 21kWh).
- In comparison, the slightly smaller Renault Kangoo ZE has a battery size of 22kWh, closely in line with our modelling, though Renault’s battery leasing model means that its capital costs cannot be compared directly to the electric Transit Connect.



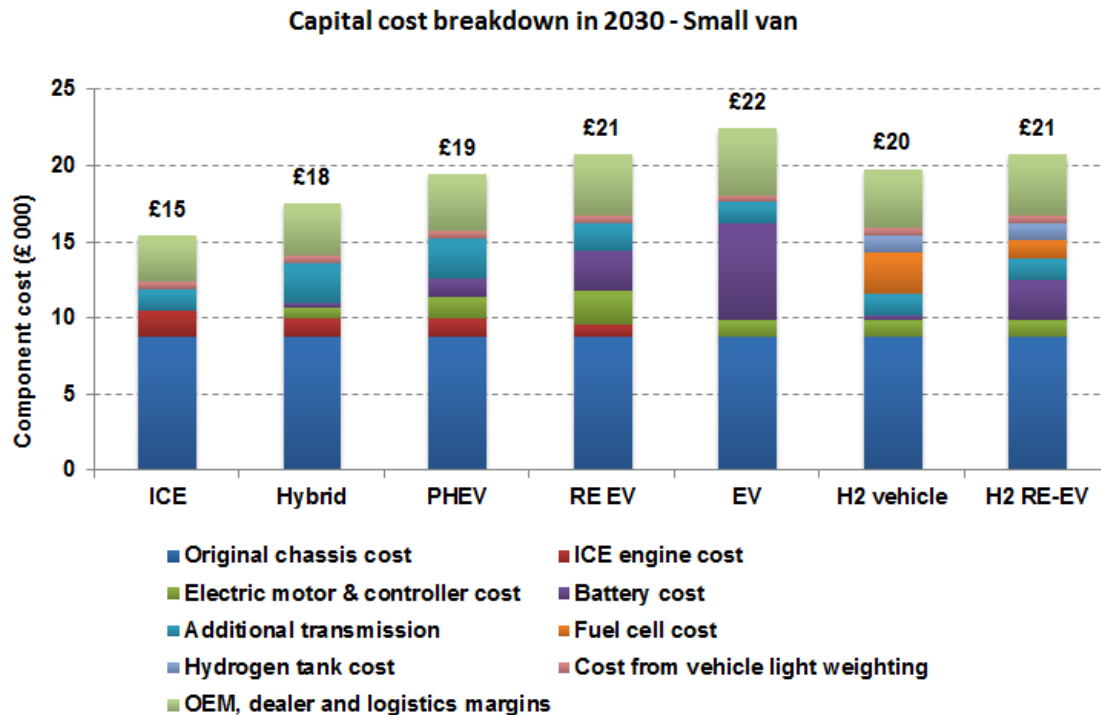
Capital costs in 2020 – Small van

- By 2020 the capital cost premium of ULEVs over conventional models remains high. PHEVs have a premium of £6k, while a pure EV is projected to cost £13k more than an equivalent ICE vehicle.
- The cost of the conventional ICE van rises by £2k by 2020, reflecting the additional costs of stop-start systems and transmission improvements (e.g. dual clutch gearboxes).
- The EV cost reduction is c. 10% relative to the 2011 value. This is because falls in battery costs are balanced by increased vehicle range (increased from 100 to 160km) and a return to industry standard margins, which are higher than those added to the 2011 ULEVs.
- Hydrogen vehicles are projected to have similar costs to a internal combustion RE-EV, though it should be noted that this is dependent substantial fuel cell cost reductions through increased production volume, in the order of 100,000-500,000 fuel cell vehicles (including passenger cars) per year in the global market (i.e. up to 100,000 vehicles for c.5 OEMS).



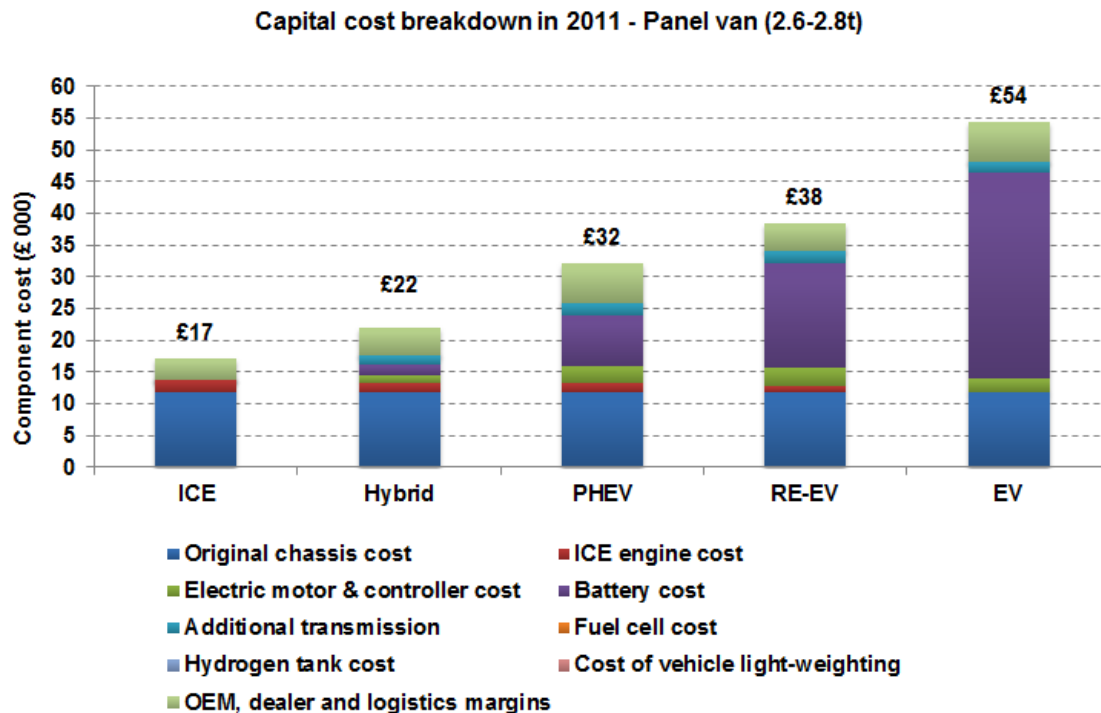
Capital costs in 2030 – Small van

- Significant further cost reductions are seen between 2020 and 2030, with RE-EV and pure EV capital costs falling by £4-6k in real terms. The capital costs of these two vehicle types are within £1k by 2030, as falls in battery costs mean that the larger battery in the EV is a similar cost to the more complex hybrid powertrain in the RE-EV.
- The costs of the pure fuel cell and H₂ RE-EV also converge in 2030, in this case because the costs of hybridisation are similar to those of the larger fuel cell in the pure fuel cell van.
- The ICE vehicle is still the lowest capital cost small van, with non-plug-in hybrids at a £3k capital cost premium in 2030 and PHEVs at £4k. The cost premium for non-plug-in hybrids in 2030 is assumed to be similar to the 2020 premium, reflecting the limit cost reductions in power electronics and gearboxes, which make up the majority of the system cost. We have not considered other hybridisation systems such as flywheels, which may offer lower longer term costs than electric hybrids and are currently undergoing testing in the passenger car market.



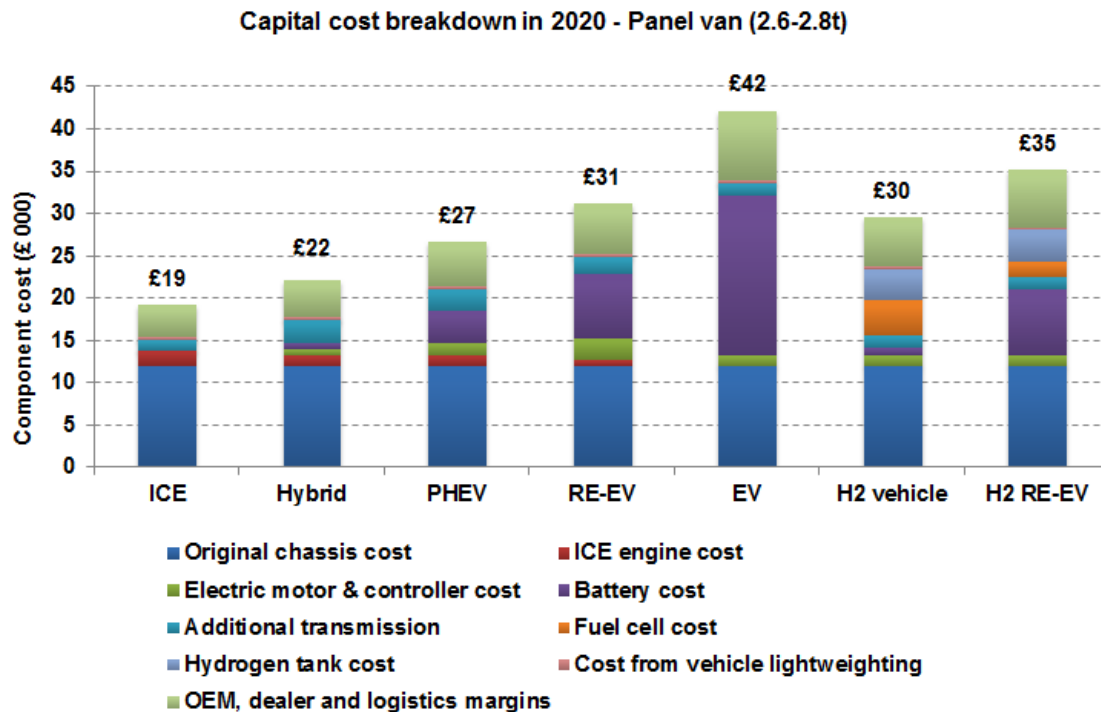
Capital costs in 2011 – Panel van (2.6-2.8t)

- The costs for the standard panel show a similar pattern to the small van, with capital costs increasing with an increasing degree of hybridisation.
- The cost of the battery itself is the primary driver of this increased cost; the cost of the battery alone in the pure EV is £32,000, double the battery cost in the RE-EV.
- The selling price of the EV presented below is consistent with the cost of the 2011 Smith Edison van, based on the Ford Transit. The medium roof, medium wheelbase version has a selling price of £54k.



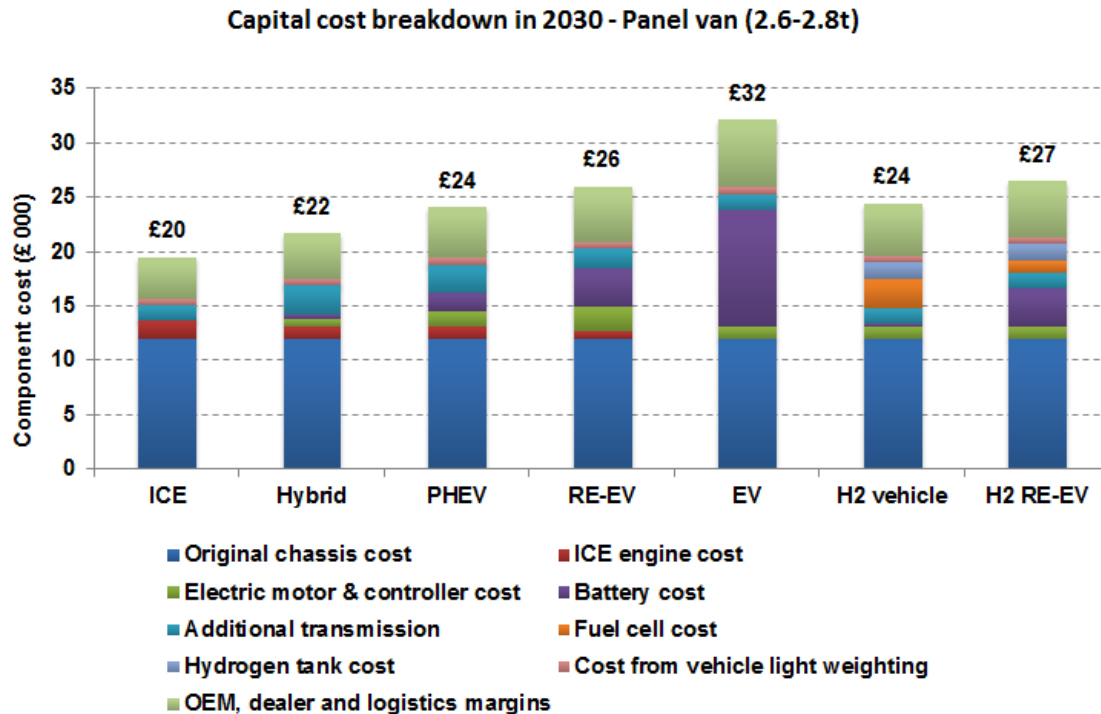
Capital costs in 2020 – Panel van (2.6-2.8t)

- The 2020 capital cost projections show a similar pattern for ‘standard’ panel vans as was seen for small vans (above). In both cases, ULEVs have a significant capital cost premium over either an ICE or non-plug-in hybrid powertrain.
- Note that the costs for the pure EV are significantly higher than the RE-EV. This is due to the very large battery in the pure EV, which is c.50kWh to provide a range of 200km compared with 20kWh in the RE-EV.



Capital costs in 2030 – Panel van (2.6-2.8t)

- As in the small vans, panel vans show further cost reductions between 2020 and 2030, with the costs of the pure EV falling by £10k to £32k.
- With the exception of the pure EV, the capital costs of panel vans with each of the other powertrains are within c.30% of the traditional (ICE van) cost.
- By 2030 capital costs for hydrogen powertrains are similar to ICE-powered RE-EVs and PHEVs and considerably cheaper than the pure EV. However, some of the EV's capital cost premium is offset by the lower cost of electricity versus hydrogen per unit distance travelled, as shown in the total costs of ownership section below.



Summary – ULEV capital costs fall significantly by 2030 but a premium relative to conventional vans remains

- Current capital costs for ultra-low emission vans are substantially higher than for conventional diesel vehicles. For plug-in vehicles battery costs comprise the majority of the price premium.
- In the current market, the price premiums for ULEVs are likely to be higher than shown here, due to substantial discounts (at least 10-20%) on the list price available on diesel vans. Discussions with manufacturers suggest that these discounts are not currently available on ULEVs as margins are already lower on these vehicles.
- However, our analysis suggests that the current very high selling prices of ultra-low emission vans will fall significantly by 2020 and 2030.
- The majority of this decrease is driven by projected reductions in battery and fuel cell costs. For example, the cost of a pure electric standard panel van is projected to fall from £54k in 2011 to £42k in 2020 and £32k in 2030.
- The internal combustion engine vehicle remains the lowest cost powertrain in 2030, though its cost rises by £2-3k by this date (in real terms) due to the costs of technology improvements, such as stop/start technology, dual clutch gearboxes, light-weighting and more stringent exhaust after-treatment.
- Hydrogen vehicles appear to be competitive with ICE-based hybrids (the PHEV and RE-EV) from 2020, assuming that worldwide sales of automotive fuel cells are sufficient to drive costs down to £75/kW (in today's prices).
- The results above emphasise the need to account for total costs of ownership rather than purchase prices when choosing between future powertrains, as all except the non-plug-in hybrid have more than 25% higher purchase prices than the ICE van.
- While this may require a significant shift in purchasing priorities for private car buyers, our interviews with commercial fleet managers show that these decision-makers already conduct a more rigorous analysis of whole life costs. The results of our analysis of total costs of ownership are presented in the following section.

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In this section, we calculate the total costs of ownership for future van powertrains using the capital costs developed above.

We have used the following assumptions on future running costs (all figures are real 2011 prices):

Finance

Finance costs are calculated by applying an annual 7% interest rate to the average of the purchase price and residual value after 4 years (which is assumed to be 30% over all van segments and powertrains).

Fuel prices

Future fuel costs were sourced from the Interdepartmental Analysts Group projections published by the UK Government. Hydrogen prices are sourced from McKinsey's *Power-trains for Europe* study (2010). All fuel prices exclude VAT as it assumed that businesses reclaim VAT on all mileage. The hydrogen price is assumed to be untaxed throughout the modelling, and the effect of adding fuel duty to hydrogen is explored in the sensitivity analysis.

Year	Electricity (£/kWh)	Diesel (£/l)	Hydrogen (£/kg)
2011	£0.12	£1.19	£13.71
2020	£0.15	£1.29	£5.69
2030	£0.18	£1.34	£4.31

Insurance

Insurance costs in 2011 were sourced from the Quotezone price comparison site as described in Section 2. We have assumed a 3% per year rise in insurance costs (in real terms), the same increase used in our LowCVP report on passenger cars. It should be noted that this is significantly lower than the recent rate of increase (of 30-50% per year according to the AA), but an increase of that magnitude is unlikely to be sustained over 10-20 years, since it would lead to insurance costs of over £10,000 per year (in real terms) by 2020.

Annual insurance costs for each van segment are shown below. We do not account for differences in different powertrains, given the current paucity of data on insurance costs for current ULEVs, instead assuming that premiums are similar for all vehicles within the same segment.

Annual insurance costs (£/year)

Year	Small car-derived van	Small van	Panel van	Large panel van	Pick-up truck
2011	£600	£650	£800	£1,000	£900
2020	£806	£874	£1,075	£1,344	£1,210
2030	£1,084	£1,174	£1,445	£1,806	£1,626

Servicing, maintenance and repair costs

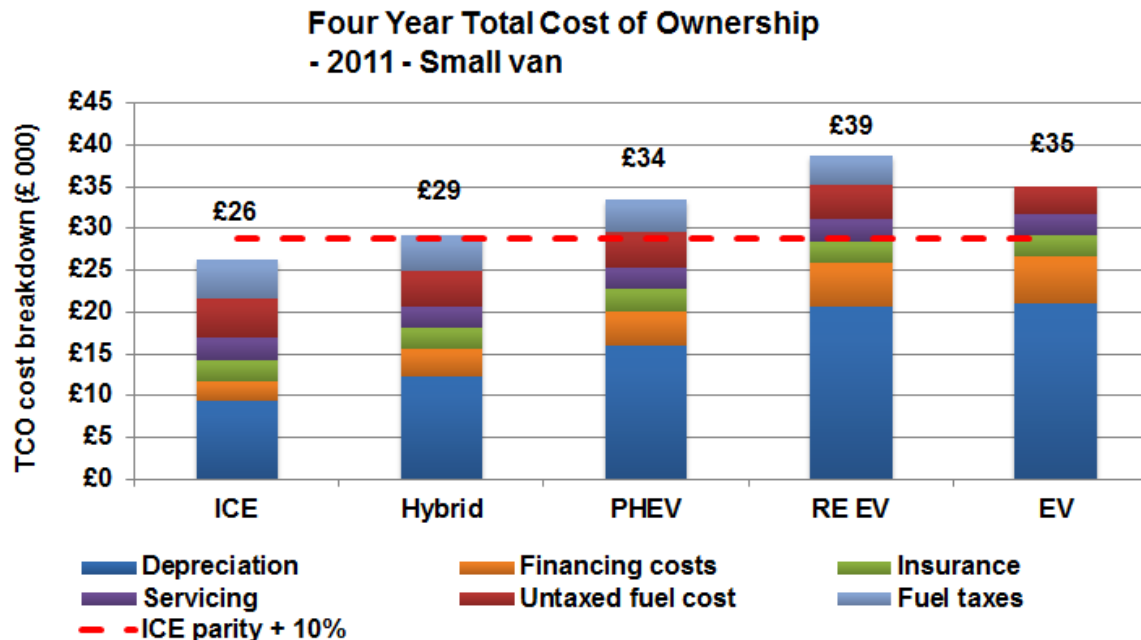
SMR costs are assumed to stay the same in real terms throughout the model period, and vary by van segment but not powertrain, again due to the current paucity of data on long term SMR costs for ULEVs.

Annual SMR costs (£/year)

	Small car-derived van	Small van	Panel van	Large panel van	Pick-up truck
All years	£550	£650	£720	£770	£720

4 year TCO in 2011 – Small van

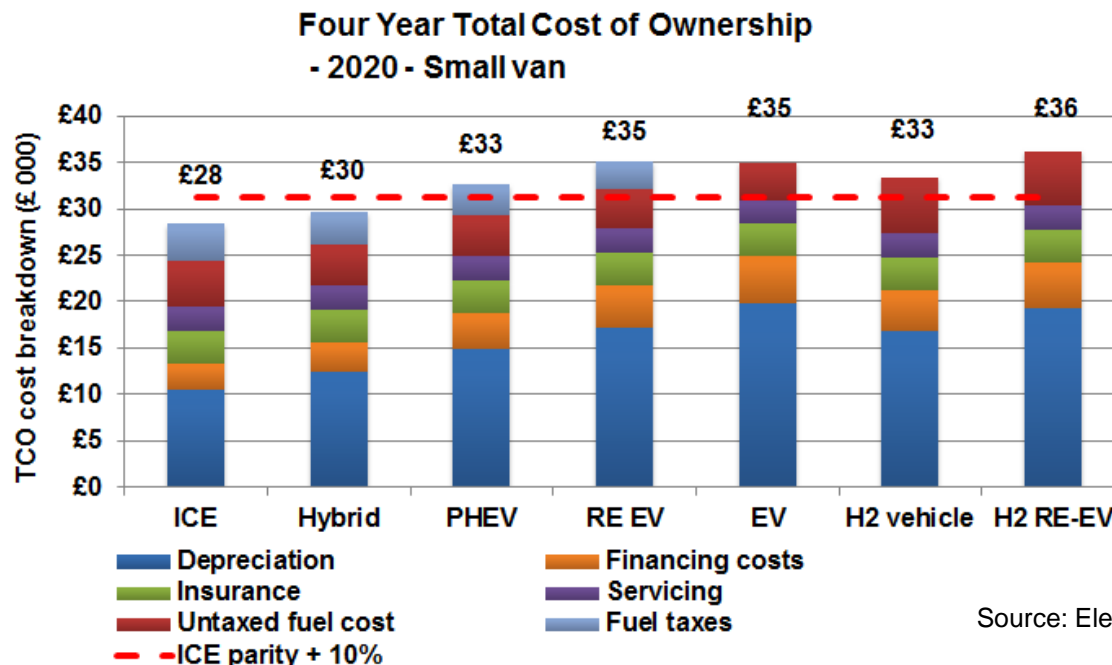
- Current total costs of ownership for small vans are significantly higher than for the standard diesel van. A non-plug-in hybrid has a TCO premium within 10% of the ICE, while the pure EV costs 35% more than an ICE van over 4 years.
- The pure EV is predicted to have lower ownership costs than the RE-EV, due to its ability to use low cost electricity for all trips (rather than only a proportion for the RE-EV). It is also assumed that the EV uses a higher proportion of its battery capacity than the RE-EV does, meaning that its battery is only 20% larger even though the electric range is 100km versus 60km. This is consistent with existing models in the passenger car market, where the battery utilisation in the Chevrolet Volt is c. 65% but is 80-90% in the Nissan Leaf.
- The TCO below does not include savings from Congestion Charge exemption, which applies to the pure EV. This is worth c. £10k over 4 years (£10/day at 250 days per year), meaning that a small electric van has similar ownership costs to a diesel van when operating in the Congestion Charge zone.



Parameter	Value
Annual distance	27,000km
EV range	100km
Fuel price (£/l)	£1.19
Elec price (p/kWh)	12p
Hydrogen price (£/kg)	£13.71

4 year TCO in 2020 – Small van

- Total costs of ownership for ULEVs show significant reductions between 2011 and 2020, driven primarily by falling capital costs for these vehicles. The pure EV costs are similar in both 2010 and 2020, since the assumed increase in vehicle range from 100km to 160km and increases in electricity prices offset the reduction in battery prices.
- Though fuel prices are projected to rise by 10% in the next 10 years (in real terms), fuel costs for the internal combustion engine van decrease by 5% during this time (again in real terms), showing that fuel efficiency improvements outweigh the fuel price rise.
- Only the non-plug-in hybrid van falls within 10% of the TCO of the ICE vehicle, shown by the dotted line in the figure below. This represents the premium that 50% of the fleet managers interviewed as part of this study were willing to pay for a low or ultra-low emissions van (the other 50% were unwilling to pay any premium).
- This suggests that without additional policy support (or higher than expected fuel price rises), ULEVs are unlikely to be taken up by the mass market in 2020. Note that the cost of the PHEV with a 30km electric range is within 15% of the ownership costs of the ICE vehicle, which may be attractive to a subset of buyers with particularly suitable drive cycles or with a higher willingness to pay for a 'green' vehicle.

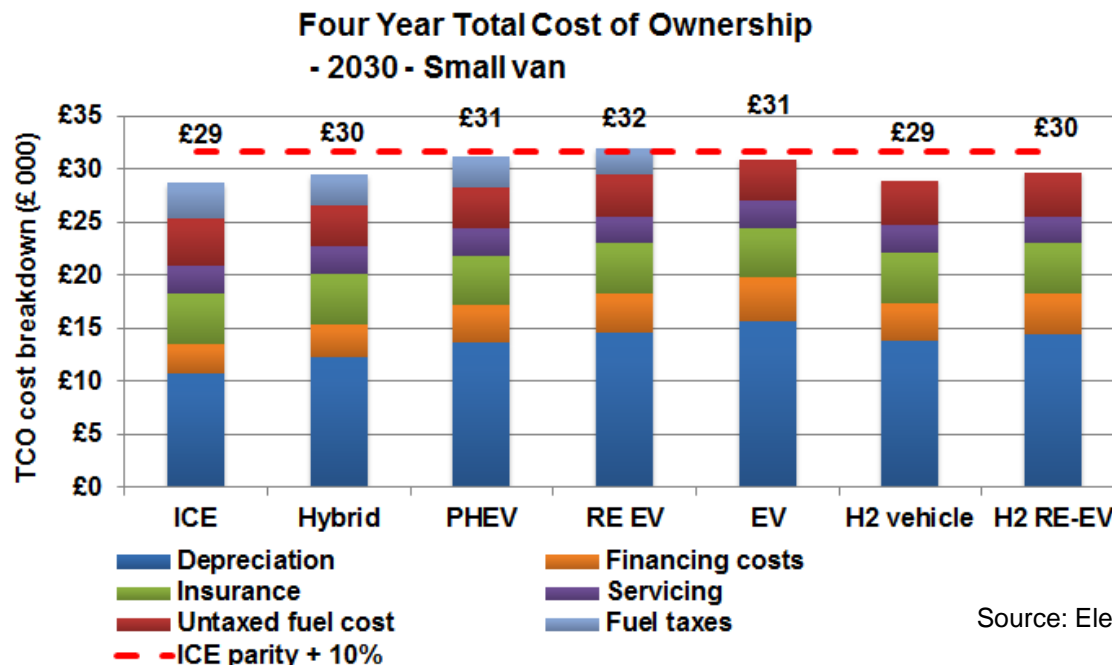


Parameter	Value
Annual distance	27,000km
EV range	160km
Fuel price (£/l)	£1.29
Elec price (p/kWh)	15p
Hydrogen price (£/kg)	£5.69

Source: Element Energy analysis

4 year TCO in 2030 – Small van

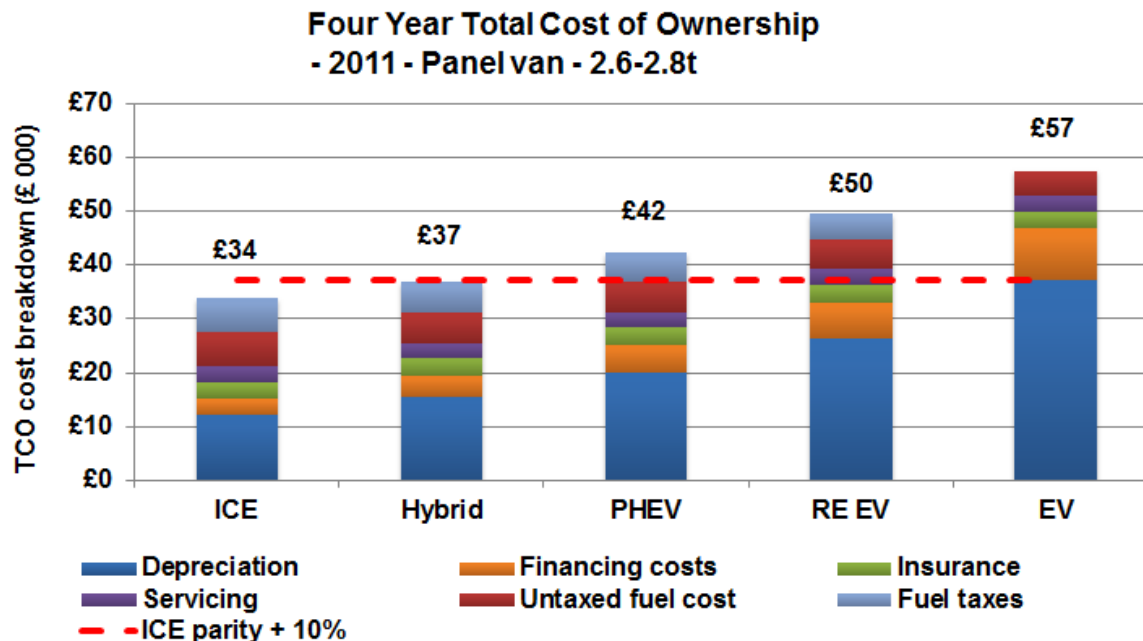
- By 2030, further capital cost reductions for ULEVs result in TCOs for all powertrains within 10% of the ICE van.
- PHEVs, RE-EVs and pure EVs have similar TCOs. This is primarily due to the additional fuel bill savings of the pure EV (as it uses no liquid fuels) offsetting the slightly higher capital costs.
- Note that the range of the pure EV in 2030 is assumed to be 200km, considerably lower than other vehicles. Increasing the range by 50% to 300km raises the TCO by £1,800. This is explored further in the sensitivity analysis.
- Both hydrogen powertrains are competitive with the TCO of a conventional van, based on an untaxed hydrogen price of £4.30/kg.
- Since the capital costs for fuel cell vehicles and delivered H₂ prices assume widespread uptake of hydrogen vehicles in the UK and internationally, it is possible that future governments would levy a tax on hydrogen fuel, which would raise the TCO to the level of the petrol/diesel RE-EV or pure EV (see sensitivity analysis).



Parameter	Value
Annual distance	27,000km
EV range	200km
Fuel price (£/l)	£1.34
Elec price (p/kWh)	18p
Hydrogen price (£/kg)	£4.31

4 year TCO in 2011 – 2.6t-2.8t panel van

- The current price premium for ultra-low emission vans is significantly higher in the standard panel van compared to smaller vans.
- The TCO premium for the pure EV is 65% relative to the diesel van, with the cost of the 45kWh battery responsible for the majority of this additional costs.
- PHEVs and RE-EVs are predicted to have lower ownership costs than the pure EV, since the savings on the smaller batteries outweigh the increased fuel costs for trips using the internal combustion engine.
- Note that for larger vans, the savings from exemption of the London Congestion Charge are not sufficient to bridge the TCO gap between the pure EV and the diesel van.

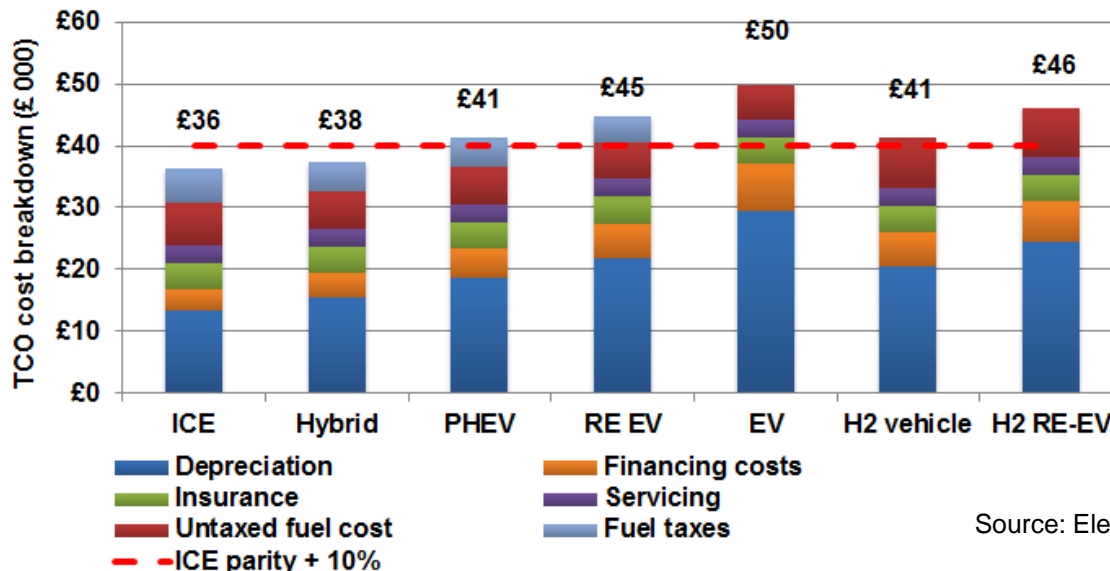


Parameter	Value
Annual distance	27,000km
EV range	160km
Fuel price (£/l)	£1.19
Elec price (p/kWh)	12p
Hydrogen price (£/kg)	£13.71

4 year TCO in 2020 – 2.6t-2.8t panel van

- The results for the 2.6-2.8t panel van show a similar pattern to the small van above, although more powertrains are within 10% of the TCO of the conventional ICE van.
- Of the ultra-low emission powertrains, both the PHEV and pure fuel cell van have TCO premiums within 10% of the ICE van. The fuel cell TCO is based on an untaxed hydrogen price of £5.70/kg in 2020.
- The TCO premium for the pure EV falls to 38%, compared with 65% in 2011, though it remains the most expensive powertrain in 2020.
- This suggests that the cost challenge will remain significant to 2020 for larger vans. In contrast, the TCO premium for the small electric van is c.25% by 2020, albeit with a lower electric range of 160km rather than 200km.
- The predicted high costs of the plug-in vans in 2020 presents a challenge for policymakers aiming to support these vehicles (as well as manufacturers attempting to sell them to fleet operators). This is because any support granted in 2012, for example capital grants, is likely to be required to 2020 unless technology costs fall much more rapidly than assumed in our analysis. In other words, short term support is unlikely to produce a self-sustaining market while ULEV costs remain at this level.

**Four Year Total Cost of Ownership
- 2020 - Panel van - 2.6-2.8t**

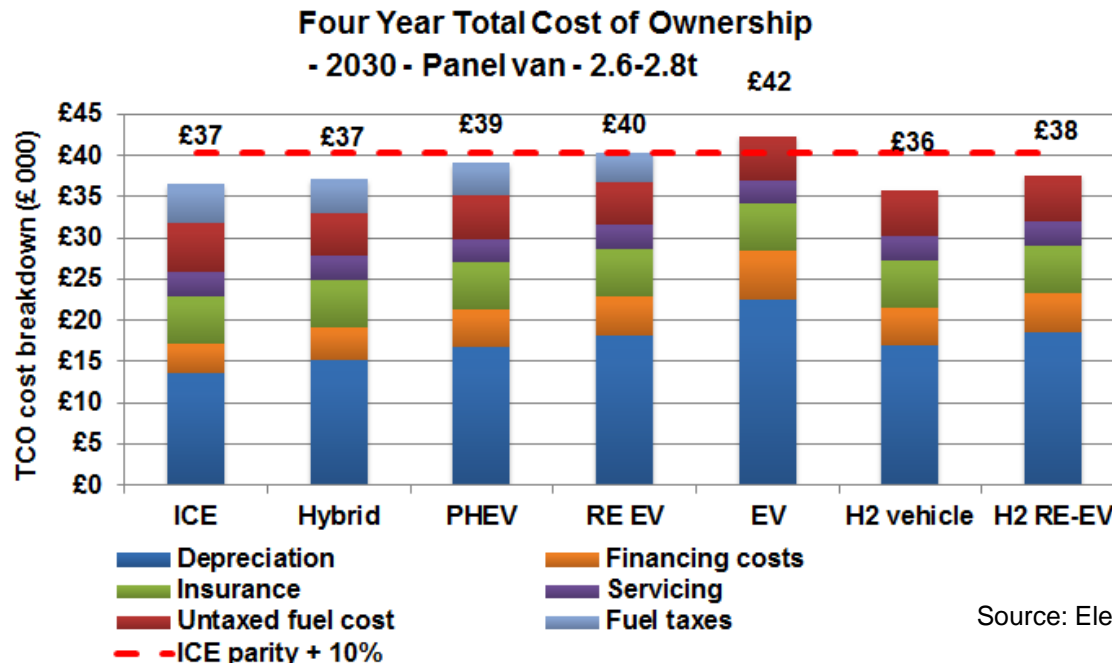


Parameter	Value
Annual distance	27,000km
EV range	200km
Fuel price (£/l)	£1.29
Elec price (p/kWh)	15p
Hydrogen price (£/kg)	£5.69

Source: Element Energy analysis

4 year TCO in 2030 – 2.6t-2.8t panel van

- By 2030 nearly all powertrains are within 10% of the ownership cost of the ICE van, suggesting that fleet operators will have a wide range cost-effective low emissions vans by this date.
- The premium for the pure EV is slightly higher, at 13%. This is due to the higher range assumption in the standard panel van (250km in 2030 compared with 200km in the small van).
- Note that the even in 2030, fuel costs (+ fuel taxes) comprise 30% of the total ownership costs, or over 50% of the running costs excluding depreciation and finance costs. This is due to the relatively low capital costs, high fuel consumption and high annual driving distance of commercial vehicles compared with passenger cars.
- In 2030 the pure fuel cell vehicle has a marginally lower TCO than the ICE vehicle if hydrogen fuel is untaxed. Note also that the H₂ RE-EV has higher ownership costs than the non-hybridised fuel cell van. This is because the additional cost of the hybrid powertrain (£3,000) outweighs the £1,000 in fuel bill savings over 4 years.

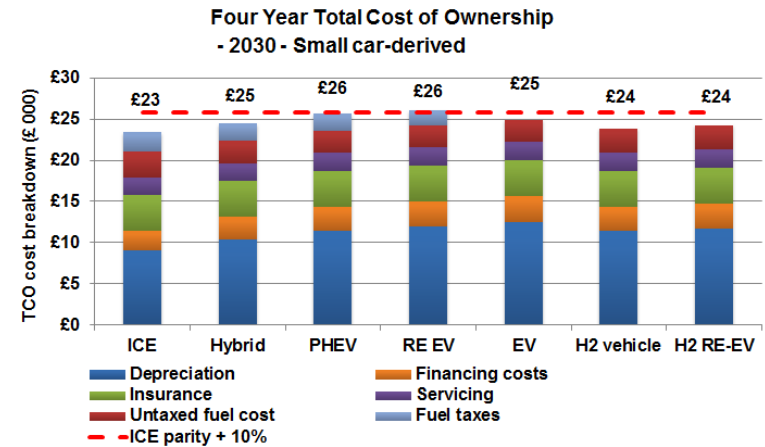


Parameter	Value
Annual distance	27,000km
EV range	250km
Fuel price (£/l)	£1.34
Elec price (p/kWh)	18p
Hydrogen price (£/kg)	£4.31

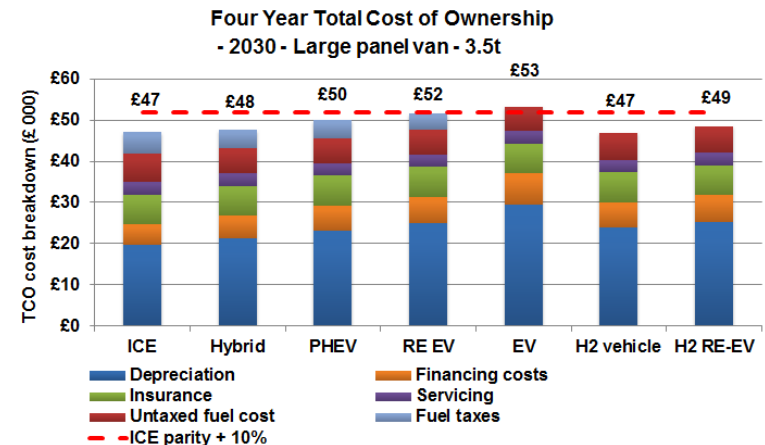
Source: Element Energy analysis

Future TCOs show similar patterns in other van segments

- Other segments such as small car-derived and large panel vans exhibit similar trends in total costs of ownership as those shown above.
- For small car-derived vans, all powertrains are within 10% of the TCO of the conventional van. The pure EV with a 200km range has similar costs as the hybridised powertrains.
- If the EV range is lowered to 160km (similar to the current NEDC range of the larger Renault Kangoo ZE), the TCO falls to £24k.



- The large panel van results highlight the cost of providing a 250km range in a large electric vehicle, as the TCO values are £1-3k higher than the PHEV and RE-EV and £6k higher than the ICE.
- Like the standard panel van, the pure fuel cell vehicle achieves TCO parity with a conventional diesel van if hydrogen fuel remains untaxed.



Source: Element Energy analysis

Wide variation in current ownership costs for ULEVs present challenges for devising support mechanisms

- The results above highlight the significant premium in ownership costs for ULEVs relative to diesel vans, based on 'generic' vans for a range of size classes.
- However, it should be noted that there is significant variation in purchase prices and ownership costs within a given size class due to the pricing strategies employed by different manufacturers.
- For example, the list price of the electric Ford Transit Connect is £40,000, where as the similarly sized Renault Kangoo MaxiZE is £17,990 plus the cost of battery rental. Over a 4 year, 15,000 mile per year rental contract, the battery cost for the Kangoo ZE is £4,200, resulting in a total purchase and rental cost of c. £22,000. It should be noted at the battery costs assumed in this report, the value of the battery in the KangooZE is £12k+, suggesting that Renault is making limited margins on the combined vehicle and battery package or assuming that the battery will retain the majority of its value/performance after the first four year rental period, allowing subsequent rentals or resale.
- For the electric Transit Connect, the TCO premium over 4 years is over £10,000 under our modelling assumptions, while the Renault Kangoo ZE has similar costs to the diesel equivalent.
- This example highlights the challenge for DfT in supporting ULEVs under such a variety of pricing strategies and van sizes. However, it is possible that this variation could be handled using an existing mechanism in the Plug-in Car Grant, where the grant awarded is the lower value of 25% of the purchase price or £5,000. This avoids excessive support to low cost vehicles.

Introduction

Ownership costs of current vans

Performance and cost projections 2011-2030

Results – capital costs for vans 2011-2030

Results – total costs of ownership

Uptake projections of Ultra Low Emission Vans

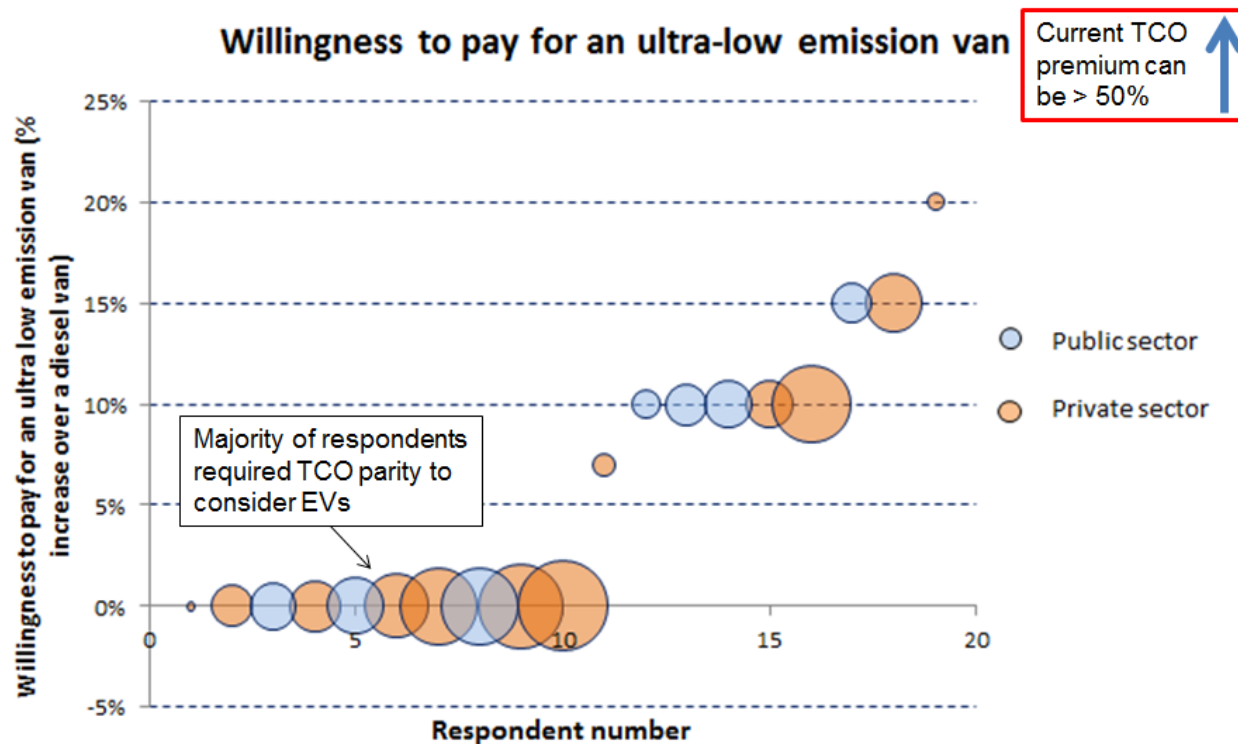
Sensitivity analysis

Conclusions

- The previous sections have shown the likely ownership costs of low and ultra-low emission vans in 2020 and 2030. While ownership costs have a strong influence on consumer demand for a given van type, the actual sales of ULEVs will depend on a number of other factors:
 - The willingness of fleet managers / van owners to pay a premium for ULEVs.
 - The availability of models from OEMs and the specifications of these vehicles, for example whether range is sufficient for the expected duty cycle or whether the issue of lost payload in EVs has been overcome through lightweight batteries or changes to vehicle regulations.
 - The availability and costs of supporting infrastructure such as charging points or hydrogen fuel.
 - Policy support – this could affect the economics of ULEVs directly, for example through the use of banded Vehicle Excise Duty, or the introduction of congestion charging in other UK cities (in addition to London) with ULEV exemptions.
 - EU fleet emissions regulation – a stricter emissions target beyond 2020 will affect the number of ultra-low emission models offered and OEM pricing strategies (such as cross-subsidising ULEVs to reduce fleet average CO₂ emissions). It is also likely to influence the price and specification of conventional vehicles, for example the rate of improvement in ICE technology, vehicle mass reduction etc.
- A detailed exploration of these issues is outside the scope of this study. However, in this section we use a simple price-based uptake model to estimate sales of each van powertrain across the full range of van segments.
- The uptake model is based on the willingness to pay data collected through interviews with twenty fleet managers and lease companies (see graph on following slide).
- These data are used to estimate the likely market share of a particular powertrain, given its total costs of ownership relative to a conventional diesel van.

50% of respondents were willing to pay a small premium for a ULEV over the total cost of ownership

- Interviews with fleet managers and lease companies showed that approximately half of respondents were willing to pay a 10% premium for an ultra-low emissions vehicle, provided that it has similar functionality to a conventional van (i.e. can carry similar payloads on similar routes).
- The other half of respondents were not willing to pay any premium. For this group, a ULEV must reach TCO parity with a diesel van to be considered attractive enough to purchase.
- From these results, it is possible to derive the 'elasticity of demand', which shows the change in demand for a 1% change in price.
- This figure is -6.6 for a price increase between 0 and 10%, and -16 between 10% and 20%, with an average of -11.



Source: Element Energy Analysis

A simple 'Logit' model allows calculation of market shares for competing powertrains based on their relative TCOs

- Though the elasticity of demand gives a useful indication of how demand for a single powertrain type changes as a function of price or ownership costs, it cannot predict the market shares of several competing powertrains with different prices.
- To do this, we use a simple 'Logit' model which can calculate market shares of competing models given their 'utility'. The term 'utility' can account for financial attributes of a vehicle (i.e. its ownership costs) and non-financial attributes (such as its range or payload). Since we have not quantified the 'value' of these non-financial attributes we take 'utility' to be equal to the 4 year costs of ownership calculated in the previous section.
- For a Logit model based only on ownership costs, we require only a single 'coefficient' to derive the consumer behaviour. This can be calculated from the elasticity of demand according to the following formula:

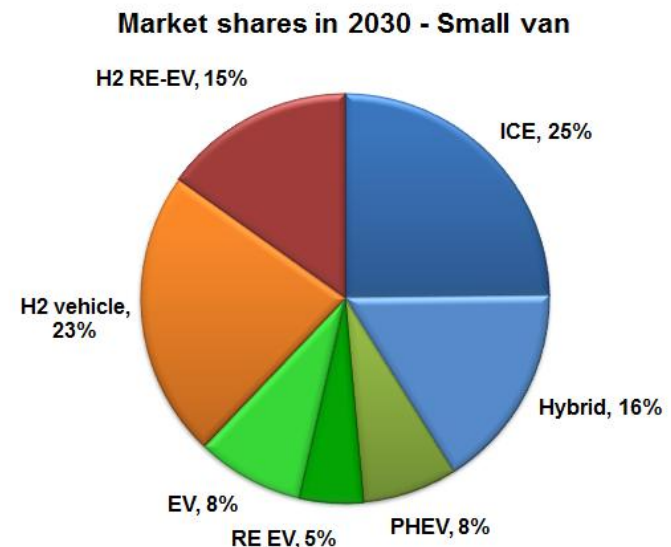
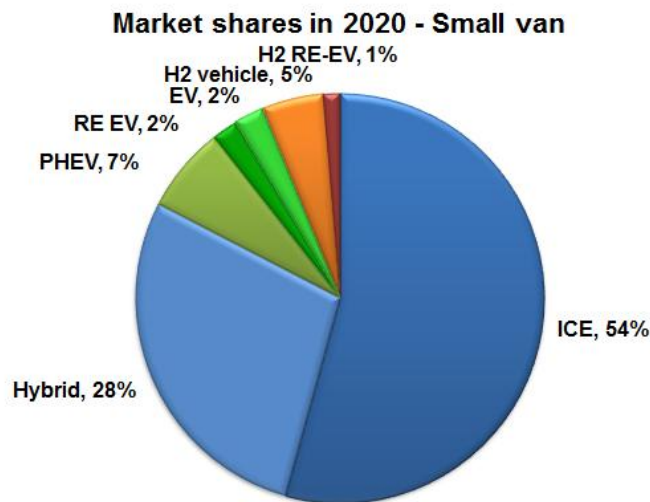
$$b_i = \frac{\beta_i}{P_i(1 - p_i)}$$

where b is the price coefficient, β is the elasticity of demand, P is the average ownership cost of a van and p is the average market share of a given van model. A full derivation of the formula is given in [GREENE:2004]

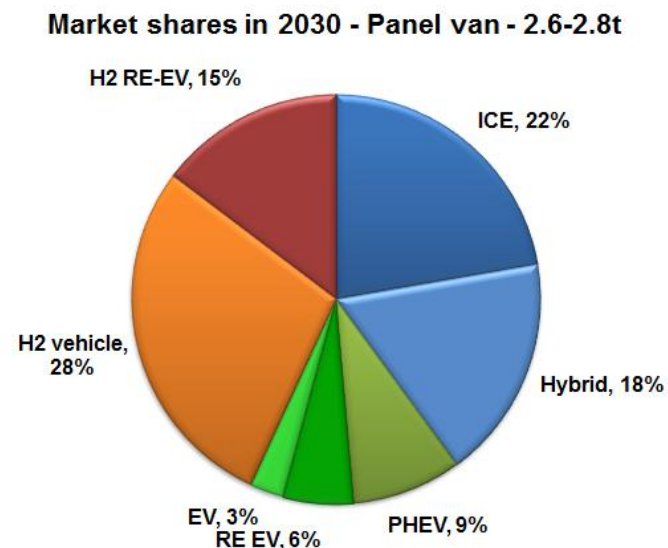
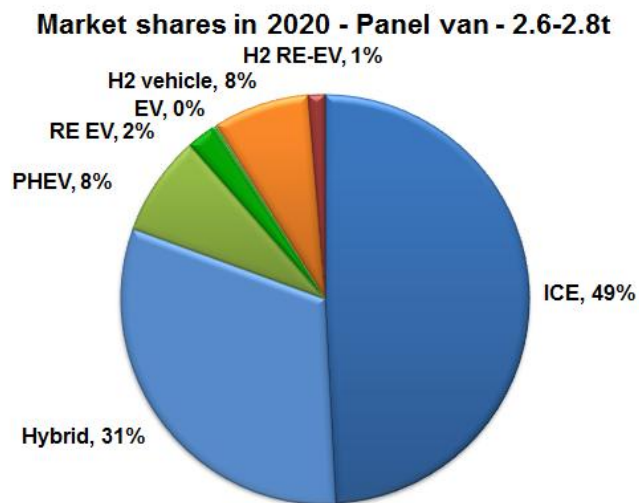
- The average market share of a given van model is simply 100 divided by the number of models available for sale in a given van segment. For example, if there are 10 van models on sale in a given segment the average market share is 10%.
- The price coefficients calculated for each van segment can be found in the Appendix.

Uptake projections – Small van

- The figures below show the projected market shares in 2020 and 2030 for the small van based on the methodology described above. Note that these are based solely on consumers' response to the total cost of ownership, and results do not account for differences in payload, infrastructure availability, driving range or the availability of models from OEMs.
- Our cost analysis suggests that the ICE and hybrid powertrains will remain dominant in 2020, with 82% of the market. PHEVs and RE-EVs have a 9% combined market share, with pure EVs capturing 2% of the market.
- Note that there is already consumer demand for the H₂ van in 2020, based on the vehicle and fuel cost assumptions described in the previous sections, though this demand may exceed the supply of hydrogen powered vans in that year.
- By 2030, the hydrogen powertrains have similar market shares to the ICE powertrains, assuming that H₂ remains untaxed to this date (which may be unlikely given this level of uptake).
- Electric powertrains (the EV, PHEV and RE-EV) reach a combined market share of 20% by 2030.



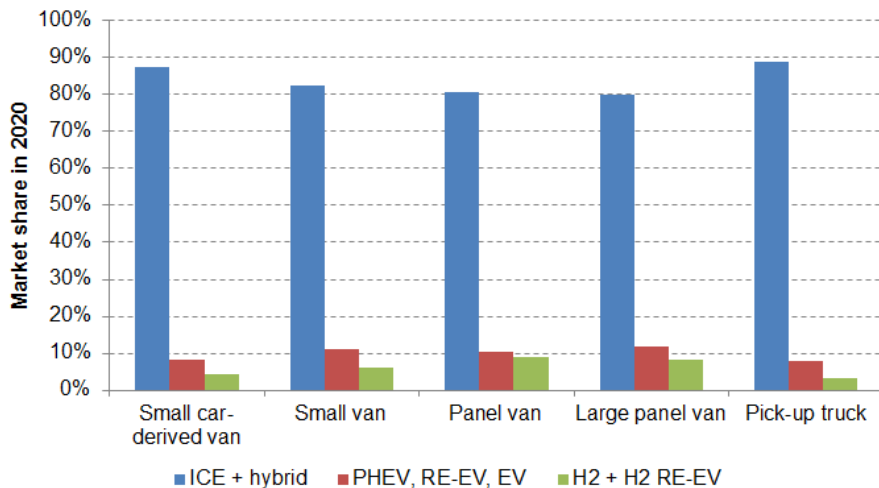
- Results for the standard panel van show a similar trend to the small van, with the exception of the pure EV, which is projected to have near zero market share in 2020. This reflects the high ownership costs even in 2020, which is significantly higher than the 10% premium that fleet managers are willing to pay, according to our interviews.
- In reality, some consumers are likely to purchase pure EVs despite the high costs, for example for branding reasons or due to policy incentives such as grants or congestion charging exemption.
- By 2030, consumer demand for H₂ powertrains is expected to exceed that for ICE and hybrid vehicles, again assuming that H₂ is untaxed and infrastructure is widely available. The sensitivity of the results to fuel prices is shown in the following section.
- Plug-in powertrains take an 18% market share in 2030 (33% including the H₂ RE-EV), but demand for the pure EV remains low at 3%. This is purely due to the high ownership costs in that year, rather than concerns over range, payload etc. which are not accounted for here.



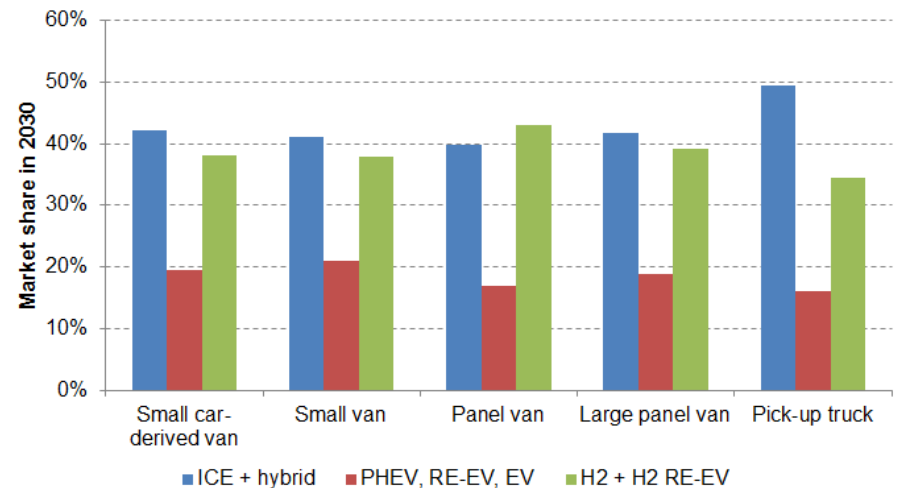
Uptake projections – all powertrains

- The figures below show the market shares of ICE, plug-in and hydrogen powertrains in 2020 for a range of van segments.
- The pattern is broadly similar in all segments. ICE (and non-plug-in hybrids) continue to dominate in 2020, with demand for plug-in vehicles exceeding that for hydrogen vehicles in that year.
- A reversal is seen between 2020 and 2030, where the continued falls in fuel cell costs (to near £50/kW) allow these vehicles to offer near parity on total costs of ownership against ICE vans.
- Demand for plug-in vans is predicted to be 15-20% of the market in 2030, with the majority in PHEVs and RE-EVs rather than pure electric vans.

Comparison of market shares across all van segments in 2020



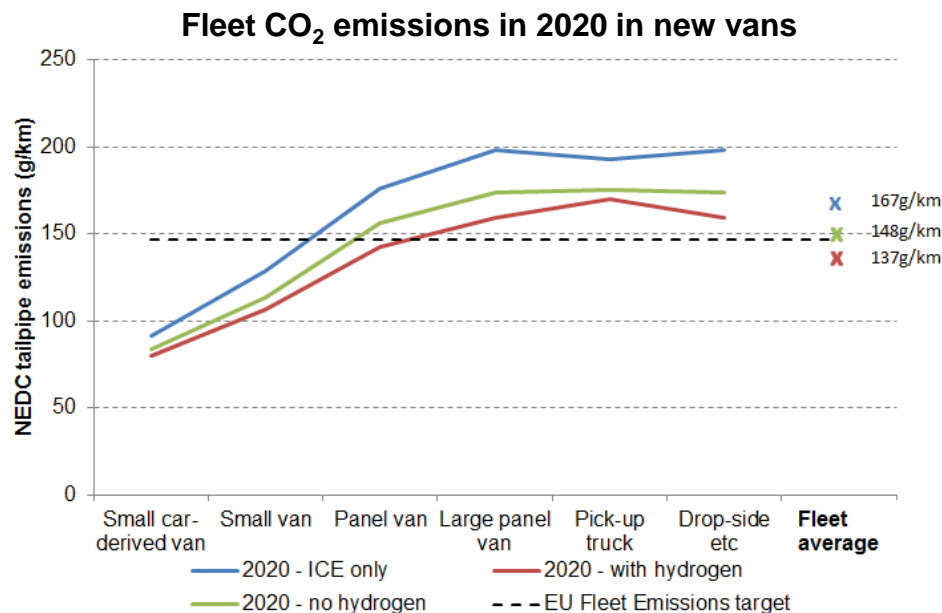
Comparison of market shares across all van segments in 2030



Source: Element Energy analysis

Our market share projections are consistent with the EU fleet CO₂ emissions target in 2020

- The figure below shows the average tailpipe emissions for new vans in each van segment, based on the relative market shares of each powertrain (as shown on the previous slide). The series show average emissions in 2020 for the 'baseline', where all powertrains are available, and a scenario where hydrogen commercial vehicles are not available in 2020. A third series shows the CO₂ emissions for the conventional diesel van in each segment in the same year.
- The overall fleet average emissions are also shown, based on the relative market shares of each van segment in 2010 (using data from SMMT), allowing direct comparison with the 147g/km EU fleet emissions target in 2020.
- Our baseline results shown on the previous slide deliver fleet average emissions for new vans of 137g/km if hydrogen vehicles take a 10% market share by 2020. If H₂ van availability is very limited in that year (due to OEMs focusing on the much larger passenger car market during the early roll-out), fleet emissions rise to 148g/km, very close to the EU target of 147g/km.
- Our results also suggest that incremental improvements in diesel vans will not bring UK fleet average emissions to the EU target, as the average emissions of UK diesel vans in 2020 are predicted to be 167g/km. However, there has been a historical difference of 15g/km between the UK and EU-27 fleet averages - in 2010, fleet average emissions were 195g/km for the UK and 180g/km for the EU27 [ICCT:2011]. In other words, 15g/km of the apparent 20g/km 'gap' can be explained by the historically higher emissions of the UK fleet (due to a higher proportion of large vans). This suggests that the EU target of 147g/km is feasible without widespread deployment of ULEVs by 2020.



Summary – uptake of ultra-low emission vans

Overall demand for Ultra Low Emission Vans

- The uptake results presented above highlight the significant potential for ultra-low emission vans to offer competitive ownership costs over the next 10-20 years.
- Falling technology prices (and modest rises in the price of ICE vans) lead to hydrogen vehicles offering similar ownership costs and hence reaching similar levels of annual sales, assuming that there are sufficient models available and that refuelling infrastructure is widely available by 2030, and that there is no duty levied on hydrogen fuel.
- The results also show that the market share of plug-in vehicles is likely to grow significantly during the coming decade, reaching c. 10% by 2020. While this is a relatively small proportion of the market, it should be noted that non-plug-in hybrids in the passenger car market required over 10 years to reach a market share of new sales of less than 5%.
- The market demand for pure EVs is expected to remain relatively low from 2011-2030 unless there is a fundamental shift in the ownership costs of these vehicles. This could be brought about by quicker than expected battery cost reductions (for example through disruptive new chemistries), supportive policies such as grants or tax breaks, or by increases in the cost of the incumbent (for example through rising oil prices).
- Our modelling also shows that incremental improvements to diesel vans are broadly sufficient to meet the EU's fleet emission's target in 2020, though it should be noted that fleet emissions for the UK van market are likely to be 15-20g/km higher than level for the EU-27, reflecting the high sales of large vans in this country [ELE:2011].

Hydrogen

- The results for hydrogen vans suggest that the market will be limited by supply-side factors rather than consumer demand. In other words, if the costs projected in this report can be achieved (i.e. fuel cell costs of £75/kW in 2020 and £50/kW in 2030) and cost-effective hydrogen can be made widely available, the underlying consumer demand for such a vehicle is very strong.
- Since our uptake modelling has not accounted for supply side limitations (or changes in the tax regime for hydrogen fuel) the sales projections above should be considered an upper bound which serves to highlight the consumer appetite for such vehicles.
- The strong demand for H₂ vans is also consistent with our interviews with fleet managers, many of whom highlighted hydrogen as a promising option that would provide substantial CO₂ savings without requiring compromises in payload or in operational practices.

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Sensitivity analysis

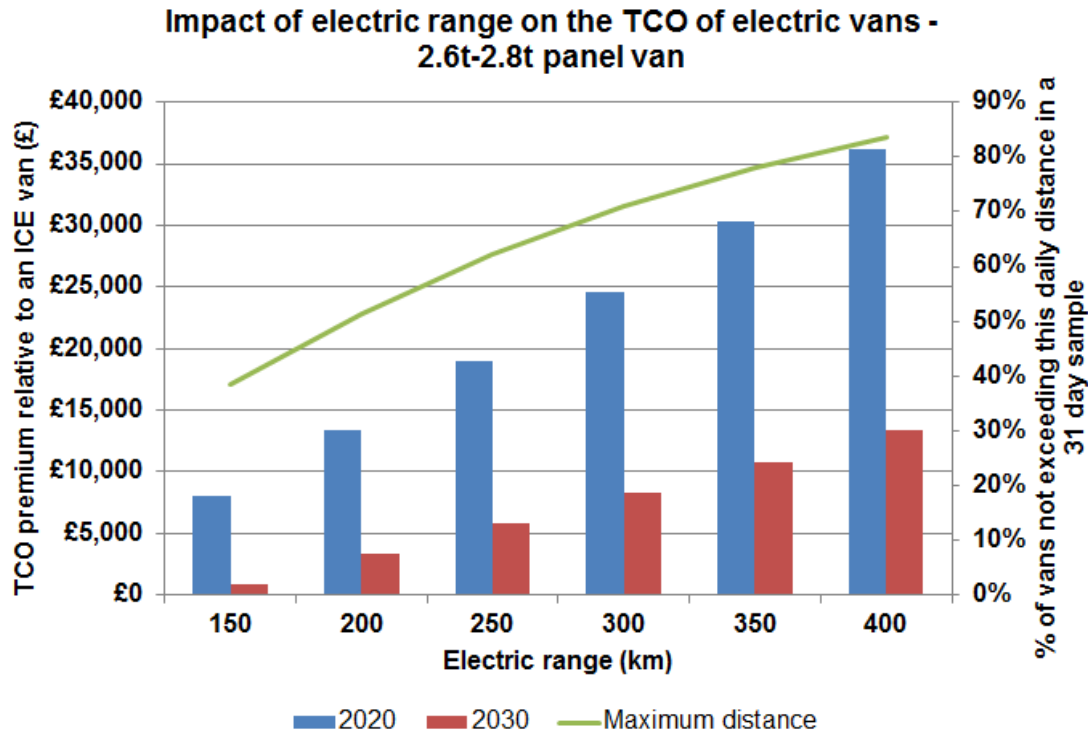
Conclusions

Sensitivity analysis

- On the following slides, we have shown the sensitivity of the baseline results to changes in a six key inputs:
 - Electric range of pure EVs
 - Battery costs
 - Hydrogen taxation and fuel cell costs
 - Diesel and electricity prices
 - Van ownership periods
 - Annual driving distances
- The implications of each sensitivity for policymakers and fleet managers are also discussed.
- For each test we have shown the effect on the same van segment, the 2.6-2.8t panel van in 2030. Though the absolute ownership costs differ in smaller or larger segments, the same broad patterns occur across the all segments. For example, the effect of hydrogen taxation on the relative ownership costs of hydrogen versus ICE vans is similar on small-car derived vans and large panel vans.

The impact of electric range on the TCO premium and potential market for pure EVs

- The results above show that the TCO values for pure electric vans fall within 10% of the costs of conventional vans by 2030 provided that van manufacturers prioritise cost reduction over increasing range.
- The figure below shows the TCO premium (relative to an ICE vehicle) as a function of vehicle range for a 2.6t-2.8t panel van. In 2020, an increase from 200km in the baseline to 300km raises the TCO premium from £13,000 to £24,000. In 2030, the premium rises from £3,000 to £8,000, due to lower battery costs in that year.
- A higher range increase to 400km would raise the TCO premium to £35,000 in 2020 and £13,000 in 2030.
- The figure also shows the proportion of vans not exceeding a given range in a 31 day period, based on Trafficmaster telematics data provided by DfT. This shows that increasing the vehicle range from 200km to 300km increases the technically addressable market (i.e. those vans that could operate with such a range constraint) from 50% to over 70%.

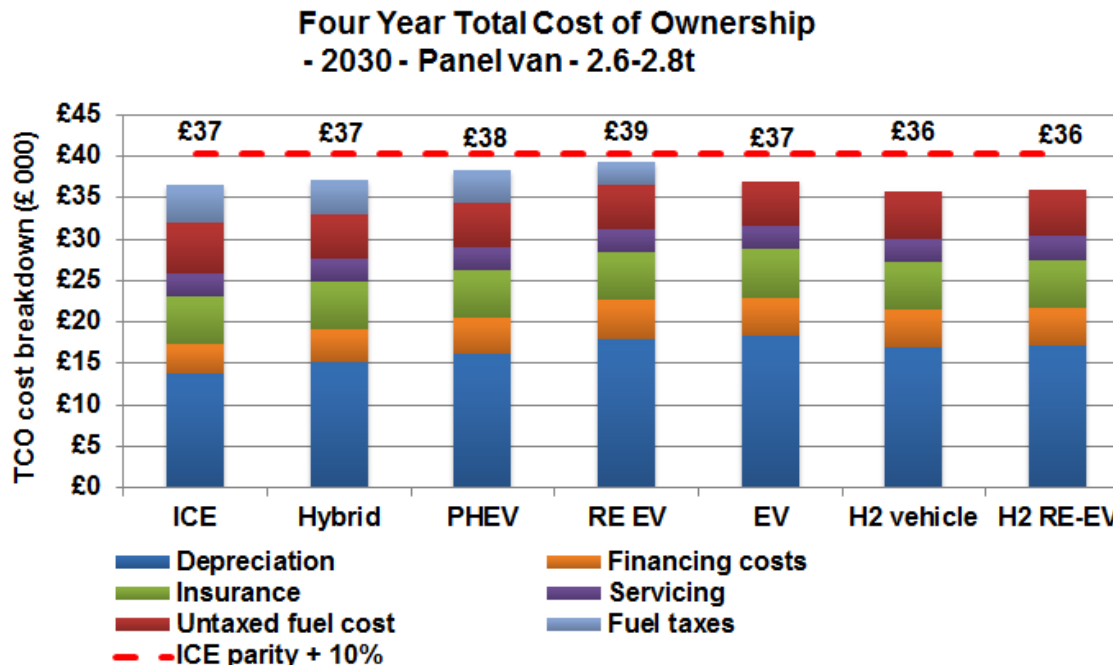


Our analysis suggests that OEMs should prioritise **elementenergy** cost reduction over increasing vehicle range

- The analysis above shows that even in 2030, the ranges of pure electric vans must be limited to between 200 and 300km in order to approach a TCO of within 10% of a conventional diesel van.
- This means that OEMs have a choice of maximising sales in a specific part of the market (i.e. urban vehicles with predictable driving distances) by offering a low cost but short range van, or broadening the addressable market by increasing the range offered by their vehicles.
- Our interviews with fleet managers suggest a clear 'step' in their willingness to pay for low emission vans, where vans have extremely limited appeal once the TCO premium relative to the diesel incumbent exceeds 10%.
- Increasing the range beyond 200-300km (for example to 400km+) raises the TCO significantly above a 10% premium. This suggests that while the proportion of duty cycles that can be met with an EV is increased by a 400km+ vehicle, the cost of such a van will strongly limit its appeal.
- In other words, our analysis suggests that OEMs should prioritise cost reduction over range improvements beyond 200-300km, even in 2030 when battery costs are lower.
- This also suggests that offering multiple battery pack sizes in a given van model, to allow consumers to make their own trade-offs between cost reduction and extended range, would allow a given vehicle to have broader appeal while meeting the demanding price points of commercial fleet managers.

A reduction in battery costs to £100/kWh by 2030 would allow plug-in vehicles to achieve cost parity with the conventional vans

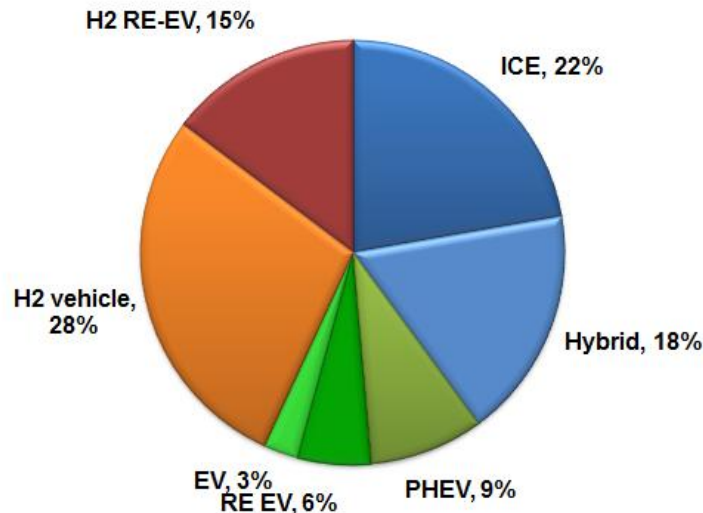
- In the model baseline, battery costs are assumed to fall from £670/kWh in 2011 to £186/kWh in 2030. At these costs, pure EVs still have a TCO premium of 10% over conventional vans in the larger segments.
- The figure below shows the effect of a long term battery cost of £100/kWh. This is equivalent to the \$150/kWh goal for ‘long-term commercialisation’ published by the US Advanced Battery Consortium [USABC:2011]. Note that this is a target rather than a projection of what is achievable using current chemistries, but still provides a useful scenario for battery cost reductions.
- A £100/kWh battery cost leads to identical ownership costs for the diesel van and the pure EV. The PHEV and RE-EV are £1k and £2k more costly over 4 years, since the additional powertrain costs outweigh the savings from smaller battery.
- Note that although the pure EV reaches parity against the diesel ICE, its driving range is still limited to 250km. This suggests that pure EVs are likely to remain limited range vehicles even with substantial falls in battery costs.



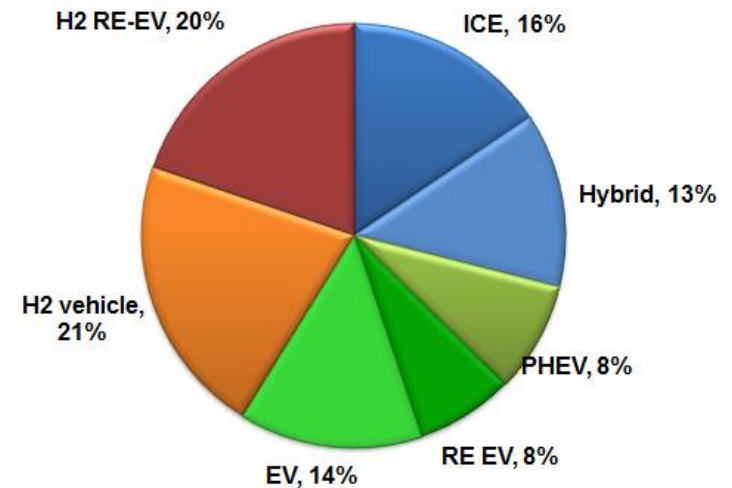
The market share for plug-in vehicles could reach 30% of new sales in 2030 with £100/kWh battery costs

- The figures below compare the predicted market shares of each powertrain for a standard panel van under the baseline and low cost battery scenarios.
- The market share for the pure EV increases from 3% to 14% under £100/kWh battery costs. The market share for plug-in vehicles (the EV, RE-EV and PHEV) reaches 30% in 2030, with a further 20% market share for the hydrogen-fuelled RE-EV (assuming zero taxation of hydrogen).
- These market shares are based on the ownership costs of the vehicles themselves, and do not take account of infrastructure costs or the availability of refuelling/recharging infrastructure. These factors are likely to constrain uptake of ULEVs and hence these figures should be regarded as an upper bound showing the underlying consumer demand.

Market shares in 2030 - Panel van - 2.6-2.8t - Baseline



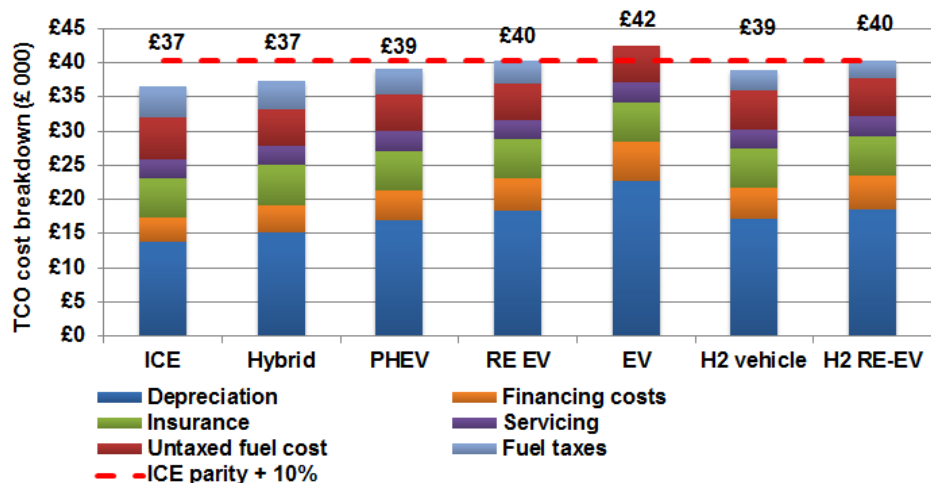
Market shares in 2030 - Panel van - 2.6-2.8t - £100/kWh battery costs



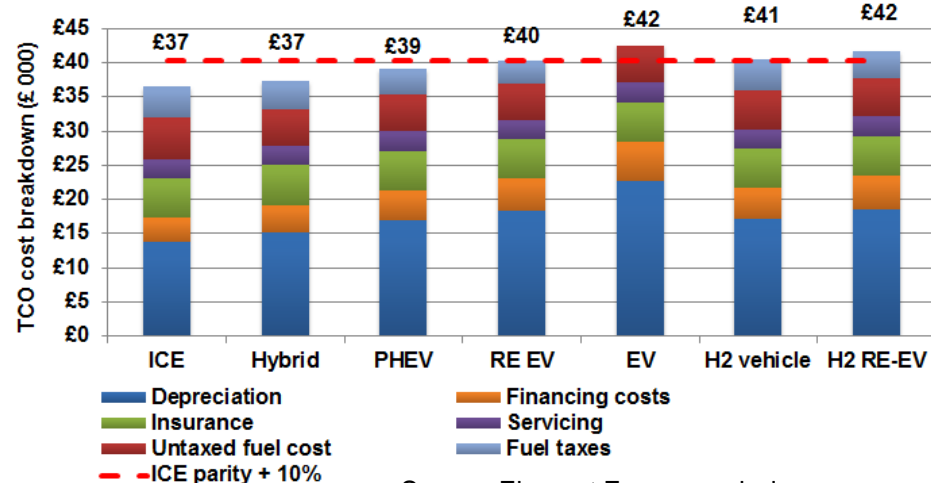
Taxing H₂ fuel has a strong influence on the TCO of elementenergy hydrogen vans

- The TCO and uptake results for hydrogen vans above are based on untaxed H₂ fuel, costing c.£4.30/kg in 2030. Under this assumption, hydrogen vans achieve cost parity with a diesel ICE van in 2030, and have lower ownership costs than most plug-in powertrains.
- However, fuel cell vehicles see widespread uptake in the marketplace, it is possible that Government would tax the fuel to preserve the revenue currently provided by diesel fuel duty.
- We have modelled two scenarios for H₂ taxation in 2030, one at 50% of the pre-tax price and one at 80%. The latter scenario results in the same Treasury revenue per vehicle as the conventional ICE panel van in 2030. The duty payable is £2.15/kg and £3.45/kg respectively.
- Hydrogen taxation has a significant effect on the TCO of hydrogen vans. A 50% tax adds £3k to the TCO of a non-hybridised H₂ van over 4 years, while an 80% tax adds £5k.
- In other words, fuel duty on hydrogen raises the TCO of hydrogen vans from parity with the ICE to similar levels as the PHEV and RE-EV, and close to the pure electric van. This highlights the need to account for potential changes in taxation when assessing long term ownership costs of new powertrains.

Four Year Total Cost of Ownership
- 2030 - Panel van - 2.6-2.8t - 50% hydrogen tax



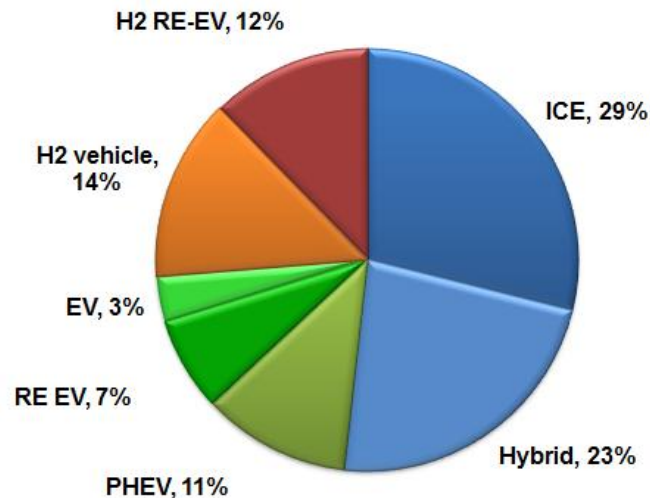
Four Year Total Cost of Ownership
- 2030 - Panel van - 2.6-2.8t - 80% hydrogen tax



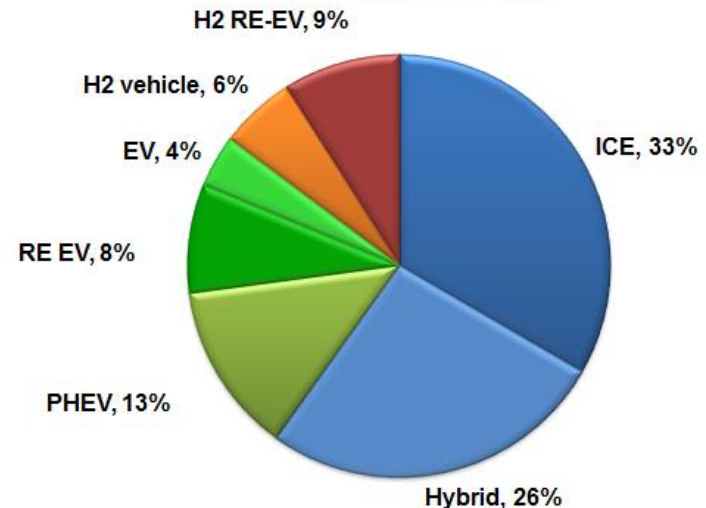
High fuel cell costs reduce the market share of hydrogen vans from 43% to 15%

- Our baseline results assume substantial fuel cell cost reductions from £800/kW in 2011 to £50/kW in 2030, a reduction of over 90%. At these price points, our analysis suggests very high operator demand for hydrogen vans.
- We show below the impact on hydrogen van market shares if this cost reduction is not achieved, and instead fuel cell costs are £100/kW or £150/kW in 2030 (i.e. double or triple the costs in the baseline).
- These fuel cell costs add £2.5k and £5k respectively to a non-hybridised fuel cell panel van (i.e. similar increases to the hydrogen fuel tax scenario on the previous slide). The predicted market share in 2030 for both H₂ vans falls from 43% in the baseline to 26% at £100/kW and 15% at £150/kW.
- High fuel cell costs also favour a hybridisation strategy for fuel cell vans, where a fuel cell RE-EV takes a higher market share than the pure fuel cell van at £150/kW due to its smaller (and hence lower cost) fuel cell.

**Market shares in 2030 - Panel van - 2.6-2.8t -
£100/kW fuel cell costs**

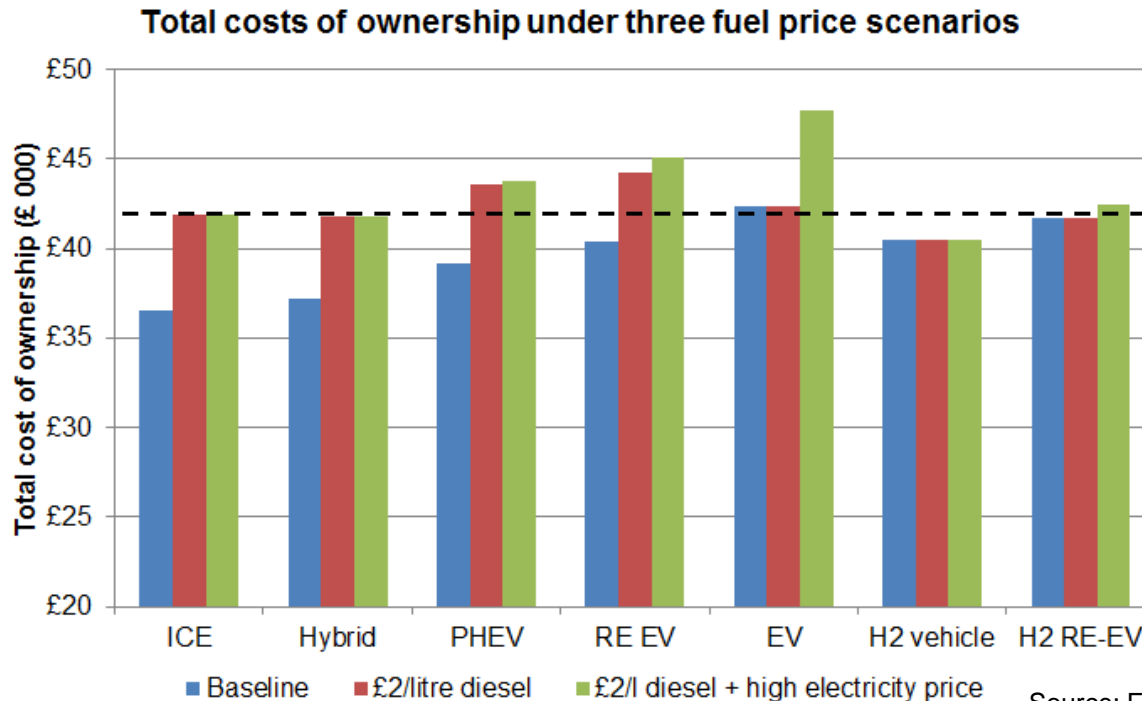


**Market shares in 2030 - Panel van - 2.6-2.8t -
£150/kW fuel cell costs**



A 25% real terms increase in diesel fuel costs is required for ULEVs to provide cost parity in 2030

- The diesel price in the results above is based on DECC's Central scenario, where the retail price increases from £1.40/l in 2011 to £1.60/l in 2030 (in real terms). Assuming 3% annual inflation this would give a *nominal* fuel price of £2.80/l
- We have analysed the impact of a larger real terms price increase to £2/litre (i.e. 25% higher than in the baseline), while keeping the electricity price constant. Hydrogen taxation in this scenario is assumed to be equal to 80% of the pre-tax price. The pre-tax price is the same as in the baseline (i.e. it is not increased in line with the diesel price).
- Since this scenario is highly favourable to the pure EV (since electricity prices stay constant while diesel prices rise), we have shown a third scenario below where the oil price rise is combined with a doubling of the electricity price in 2030 (to 36p/kWh in real terms). This could reflect high fossil fuel prices, or high costs due to grid reinforcement, high renewables penetration, etc.

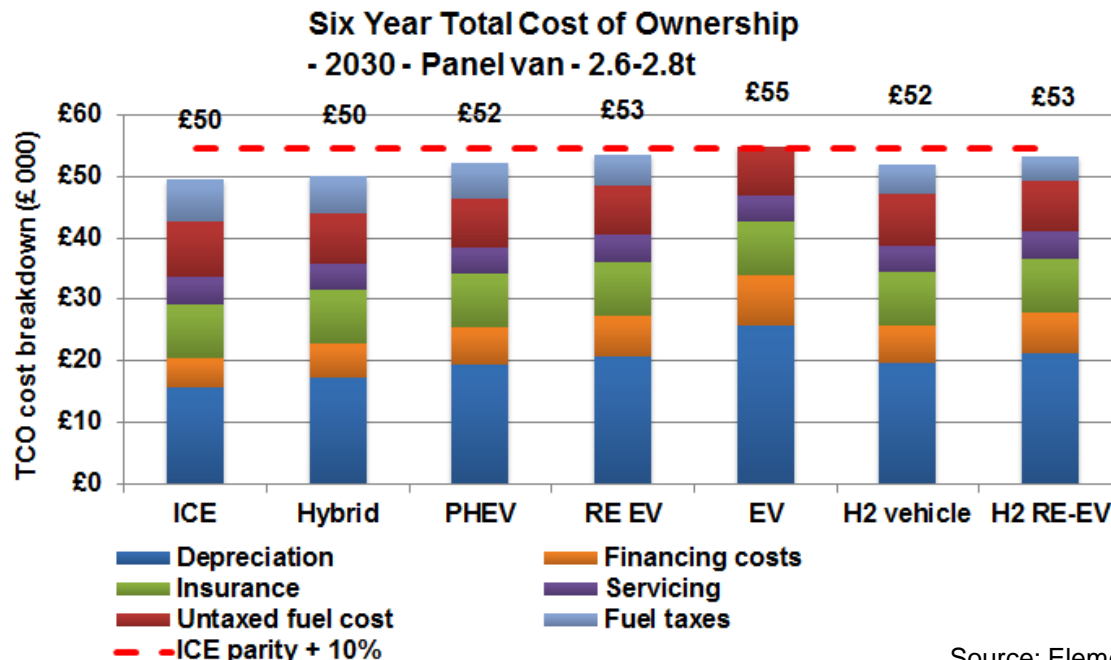


£2/l diesel leads to TCO parity in 2030 with the pure EV and against taxed hydrogen for a standard panel van.

A doubling of the electricity price to £0.36/kWh adds c.£5,000 to the TCO over 4 years.

The benefits of increasing the van ownership period depend strongly on long term servicing costs and residual values for ULEVs

- In the figure below, we have shown the TCO for a panel van in 2030 with a six year ownership period (compared with four years in the results above).
- Since ULEVs are characterised by higher purchase prices but lower running costs, operating vehicles for longer allows more time for the higher capital cost to be recovered through fuel bill savings.
- Anecdotal evidence suggests that expected savings in servicing and maintenance costs between ULEVs and conventional vans could increase as the vans age, for example due to new cambelts or parts failure such as turbos in ICE vans. We have not factored this into the modelling, due to the uncertainty over the equivalent long term costs of ULEVs, for example due to maintenance/replacement of batteries.
- In the scenario below, we have assumed that the residual value for all powertrains after six years is 20%, compared with 30% after 4 years.
- Over the longer ownership period, all powertrains are now within 10% of the TCO of the conventional ICE over six years. On the following slide we discuss typical ownership periods for new vans.

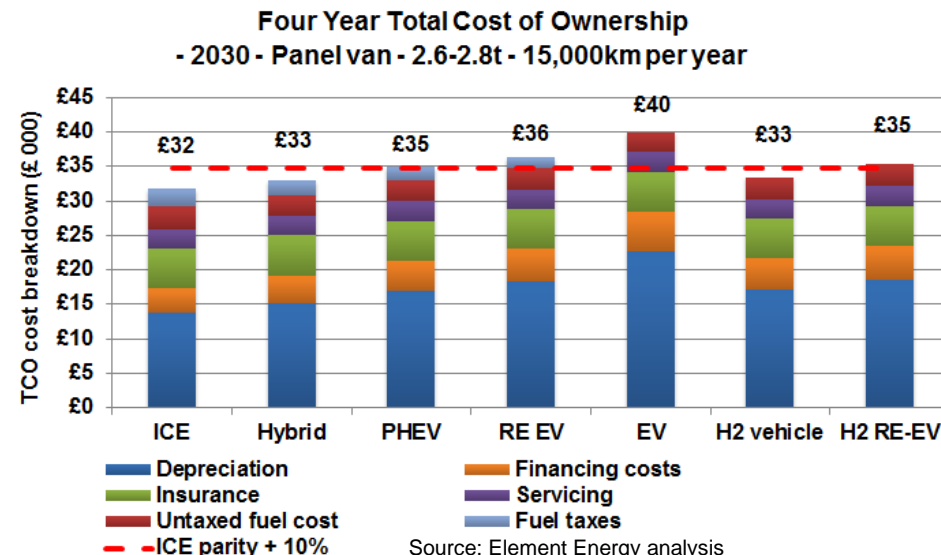
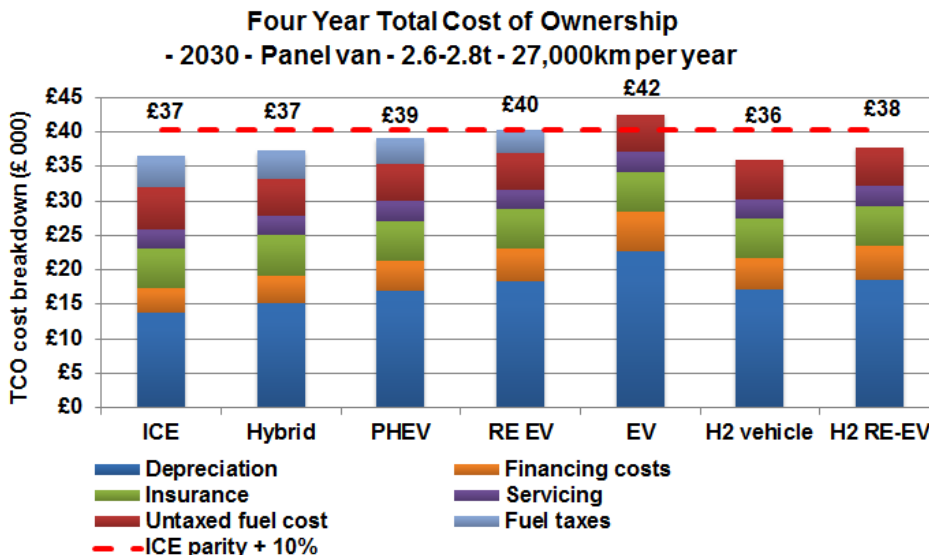


Fleet managers must balance economics and reliability when selecting an optimum ownership period

- Our fleet manager interviews highlighted the fact that first ownership periods for vans have increased over the last 3 years, and many operators are now running new vans for 5-6 years rather than 3-4.
- Reasons for this include short term pressures, such as cashflow or wider economic uncertainty following the recession, but several managers felt that the reliability and build quality of modern vans enables longer ownership periods without compromising operations.
- This trend is likely to benefit ULEVs, so long as their long term reliability and servicing costs are lower than conventional vans, and managers of early ULEV fleets should track these long term costs relative to ICE vans.
- However, there is still considerable uncertainty over long term battery performance and depreciation of ULEVs. In the short term, operators may run ULEVs for a shorter period to guarantee to be able to sell them while they still have a second life, rather than risk running them to near scrap value and finding that no buyers can be found for a six year old electric van.
- Finally, while longer ownership periods could improve the economics of capital intensive ULEVs, they would also slow the adoption of more fuel efficient conventional vehicles throughout the second hand van market. In other words, as fuel efficiency improves over the coming decade (driven by the EU fleet emissions regulations), a relatively short first ownership period would have a stronger effect of reducing emissions from the existing vehicle parc.

Annual driving distance plays a significant role in the economics of ULEVs

- Our interviews with fleet managers highlighted a paradox that the managers most willing and able to accommodate electric vans had relatively low annual driving distances, which lowers the potential fuel savings and lengthens the payback period on the higher capital cost of EVs.
- This is shown below, where the TCO of a panel van in 2030 is calculated for an annual driving distance of 15,000km, compared with 27,000km in the baseline. 15,000km is the average distance covered by 'Public Administration' vehicles in the DfT's Survey of Company Owned Vans.
- The main effect of lowering the annual driving distance is to reduce the ownership costs for all powertrains, since fuel costs are reduced by c.45%. This lowers the ownership costs of the ICE by £5k over 4 years.
- This reduction in TCO is more pronounced in the non plug-in powertrains, where the fuel cost per kilometre is highest. The corresponding electricity bill saving for the reduced driving distance is only £2k.
- This means that the TCO premium for ULEVs widens as the driving distance decreases; the pure EV has a premium of 13% with a driving distance of 27,000km per year and this grows to 25% at 15,000km.
- Note that we have not accounted for a reduction in depreciation or servicing costs under a reduced driving distance, due to uncertainty about the long term values for ULEVs. Accounting for this would offset some of the increase in the TCO premium.



Introduction

Ownership costs of current vans

Performance and cost projections 2011-2030

Results – capital costs for vans 2011-2030

Results – total costs of ownership

Uptake projections of Ultra Low Emission Vans

Sensitivity analysis

Conclusions

The long term outlook for ULEVs is highly positive, **elementenergy** though strong cost challenges will remain until 2020

- Our economic analysis suggests that the high ownership cost premium for ultra-low emission vans will fall substantially between 2010 and 2030.
- The TCO premium for plug-in electric powertrains is predicted to fall from c.50% in 2010 to less than 20% by 2020. By 2030, almost all powertrains are with 10% of the ownership costs of the ICE van.
- Our interviews with fleet managers suggest that around half of organisations would be willing to pay a 10% premium ownership costs for a ULEV, reflecting the benefits of CO₂ and fuel bill savings and 'green branding'.
- By 2030, operators are likely to have a wide range of zero or ultra-low emission powertrains to choose from with competitive economics, suggesting significant long term growth potential for the ULEV market.
- However, in 2020 only the non-plug-in hybrid and the PHEV offer TCOs within 10% of the ICE, potentially limiting the size of the ULEV market unless policy support is provided to close this economic gap.
- Based on our cost assumptions, hydrogen vans are likely to offer a very strong economic case towards 2030 (with untaxed hydrogen), as well as similar performance and range to an ICE van. As long as fuel cell costs can reach the projected 2030 cost of c. £50/kW, sales of these vans are likely to be constrained by supply-side factors such as the availability of vehicles and refuelling infrastructure, since the underlying consumer demand is strong.
- In contrast, the pure electric powertrain in larger vans remains the most expensive in 2030 due to the size of battery required, and hence sales may be limited by consumer demand (and competition from other powertrains), even if vehicles and infrastructure are widely available.
- However, the economics of hydrogen depend on the availability of low cost hydrogen (at c. £4/kg in 2030). If costs were higher, either due to higher production costs or fuel taxes, the ownership costs of H₂ vans are likely to be similar to plug-in powertrains such as PHEVs or RE-EVs.

Short and medium term policy support will be required to support growth in the ULEV market

- The economics of ULEVs in 2020 suggest that favourable policies will be required to at least this date in order to push the vehicles beyond their current small market share.
- For a standard panel van, such support would need to be equivalent to approximately £1k per year over four years for a PHEV and £2k per year for a RE-EV in order to provide TCO parity with the ICE.
- Of the policies currently in place to support low carbon vehicles, only the London Congestion Charge exemption for electric vans provides a similar level of subsidy (currently over £2,000/yr based on £10/day and entering the charging zone five days per week).
- This suggests that vehicles operating within the Congestion Charging Zone would have lower ownership costs than an ICE by 2020 if the exemption were to be retained in that year.
- For vans operating outside this area, other policy mechanisms would be required to bridge the economic gap. These could include capital grants (similar to the OLEV Plug-in Car Grant), or changes to existing mechanisms such as the introduction of banded Vehicle Excise Duty.
- Opening the Plug-in Car Grant scheme to vans would significantly improve the economics of ULEVs in the short term. However, care must be taken to ensure that such support is sustainable, especially when ownership costs are likely to remain at least 20% higher than a diesel van in 2-3 years. Further care is needed to provide the correct level of support for a range of business models, for example the battery lease model launched by Renault for the Kangoo ZE which already offers near cost parity for an electric van in 2012.
- Central and Local governments should investigate the use of other, non-financial measures to support the uptake of ULEVs. These include making allowances for battery mass (and hence lost payload) in vehicles at the 3.5t threshold for the purposes of vehicle and driver licensing. Other measures could include exclusive access to certain loading bays in cities, extended delivery hours, use of bus lanes etc. that would give operators benefits increase the operational efficiency of (and hence profitability) of ULEVs.

Manufacturers should bring new hybrid powertrains to market to provide alternatives to pure EVs for longer range duty cycles

- Our analysis suggests a significant medium term role for hybrid or plug-in vans, which offer superior economics and capabilities to pure EVs between now and 2020.
- There are no plug-in vans for sale on the market, and non-plug-in hybrids are only available through third party conversions of specific van models.
- Van manufacturers should assess the business case for bringing more hybrid powertrains to market. Our results suggest that smaller vans should be prioritised, as their economics are likely to be more favourable than larger vans, which would require large batteries to provide a substantial electric range.
- Small vans, such as the Transit Connect or Renault Kangoo, have similar power and battery requirements to similar powertrains in passenger cars, and could potentially offer a useful cross-over route. This also applies to non-plug-in hybrids, for example where Peugeot's HYbrid4 powertrain could be introduced on small vans following its deployment in the 3008 cross-over vehicle.
- However, while the medium term outlook for these vehicles is highly positive (providing that cost targets can be met), the short term consumer demand is likely to be low without additional policy support. The development costs of these vehicles must also be weighed against likely sales, given that the van market is approximately 10% of the size of the car market in the UK.
- Finally, there is currently a high degree of uncertainty over several costs of ULEVs, particularly depreciation and servicing costs. Until long term data exist from fleet trials, lease companies and operators may be unwilling to include potential servicing and maintenance savings from ULEVs in servicing calculations or use pessimistic assumptions on depreciation to reduce their risk. Guaranteed 'buyback' schemes or fixed price service contracts from manufacturers and dealers may offer a relatively low cost route to de-risking investments in ULEVs until long term costs are known.

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APPENDIX – Definition of vehicle types

- Hybrid** – hybrid configuration consisting of regenerative braking, small battery (2km electric range) and small electric motor. There is no provision for charging this vehicle from the mains. The electric motor is sized to meet power requirements for low speed driving and to supplement the internal combustion engine.
- PHEV** – plug in hybrid where the vehicle can be charged from mains electricity and runs in electric mode until the battery is depleted (or high power is demanded), at which point the ICE takes over. The electric motor power is sized similarly to the hybrid vehicle. The range of the vehicle is between 20–40km.
- RE-EV** – range extended electric vehicle with a range greater than the PHEV. This has a different drivetrain configuration compared to the PHEV. The wheels are driven by one or more electric motors powered by an on board battery that is charged primarily from the mains. There is also an on-board ICE generator that is used during ‘charge sustaining’ operation. The range of this vehicle is set at 60km for the purpose of this study.
- EV** – pure electric vehicle contains a battery and an electric motor only. The vehicle is charged by mains electricity. Examples include the Nissan Leaf and Mitsubishi I-MIEV.
- Hydrogen vehicle** – the pure hydrogen vehicle has a limited degree of hybridisation such that the hydrogen fuel cell is sized to meet the peak load of the vehicle with the battery/capacitor used for load smoothing only. This vehicle has a hydrogen tank that gives the vehicle a range comparable to the ICE vehicle (500km).
- Hydrogen RE-EV** – the hydrogen RE-EV is a fully hybridised hydrogen vehicle. The vehicle can be plugged into the mains for charging and can run for extended periods on the battery alone (60km); once the range limit is reached the fuel cell starts and is designed to run at high load to directly run the vehicle or to recharge the battery. The fuel cell is sized to meet just more than the base load of the vehicle (c.50% of the rated motor power).

GLOSSARY

ICE – Internal combustion engine

NEDC – New European Drive Cycle

OEM – Original Equipment Manufacturer (of light commercial vehicles)

VED – Vehicle Excise Duty

ULEV – Ultra Low Emissions Vehicle

APPENDIX – Capital costs

ICE Engine Costs

Year	ICE cost (£)
2011	28
2020	30
2025	31
2030	33

- The data available in public literature are scarce as ICE is a mature technology and the information is normally commercially sensitive.
- Values used are per £/kW only with no fixed cost element. There is the potential for smaller engines used in RE-EV to be more expensive per kW as they are engineered to work at optimum power bands.

Sources: [EPRI:2001] [EPRI:2002] [CONC:2007]

Margins

- The margins seen by the consumer from vehicle manufacture and distribution can be high. As all of the costs stated in the report are for cost seen by the OEM, the vehicle suppliers' margins have been excluded from our analysis.

Profit margins on total vehicle costs %	Fixed Value	Comment
Vehicle supplier	6.5%	Not used for analysis
OEM	6.5%	
Dealer	11.5%	
Logistic, marketing, etc.	6.3%	

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APPENDIX – Price coefficients

- The table below shows the price coefficients calculated for each van segment, based on the willingness to pay data collected during the fleet manager interviews.
- The number of makes/models was sourced from the VansA2Z Van Comparison tool. For example, the small car-derived van market consists of four models in the UK, the Fiat Punto, Ford Fiesta, Peugeot 207 and Vauxhall Corsa. These values are used in the formula shown on Page 56 to calculate price coefficients.

	Small car-derived van	Small van	Panel van	Large panel van	Pick-up truck
TCO in 2011	£20,879	£26,223	£33,948	£44,198	£37,161
Number of makes/models	4	11	13	8	7
Elasticity	-11	-11	-11	-11	-11
Implied price coefficient	0.00074	0.00048	0.00037	0.00030	0.00036

- The price coefficients above are used to calculate the ‘utility’ of each powertrain, using the following formula:

$$Utility = Price\ coefficient \times 4\ year\ TCO$$

- Utilities for each powertrain in each segment are used to calculate the market shares in a given year using the a simple Multinomial Logit (MNL) model with the following formula:

$$Market\ share_i = \frac{e^{v_i}}{\sum_j e^{v_j}}$$

where v_i is the utility of the powertrain of interest and v_j are the utilities of the other powertrains within that van segment.