Battery and fuel cell future cost comparison

March 2023

An insight report provided by the Technology Trends team at the APC

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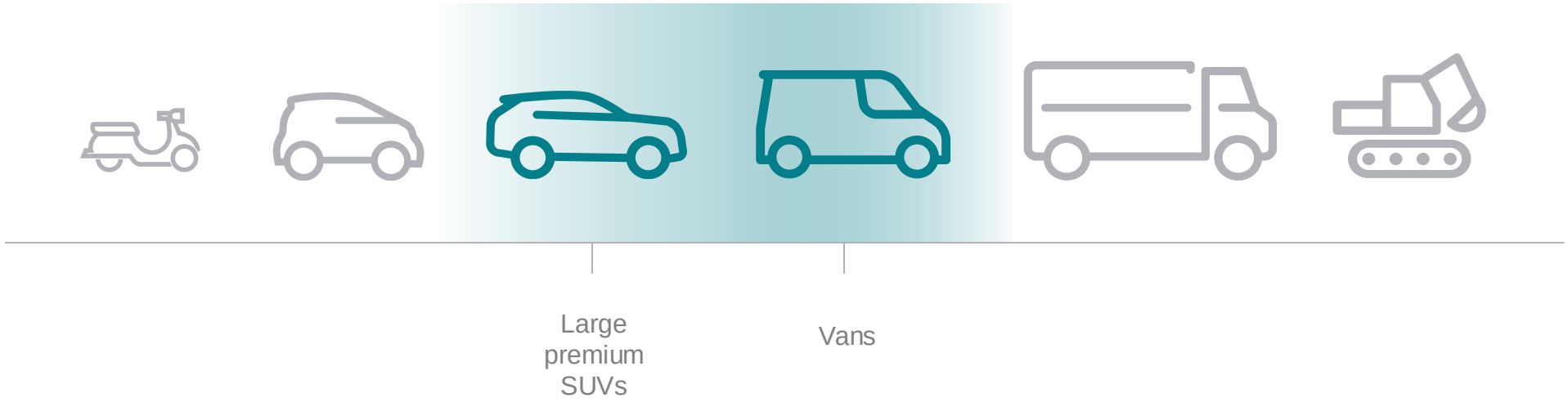
Scope of this study

The focus of this study is on installed powertrain costs for the heaviest of light duty vehicles: large premium SUVs and vans.

Typical vehicle characteristics

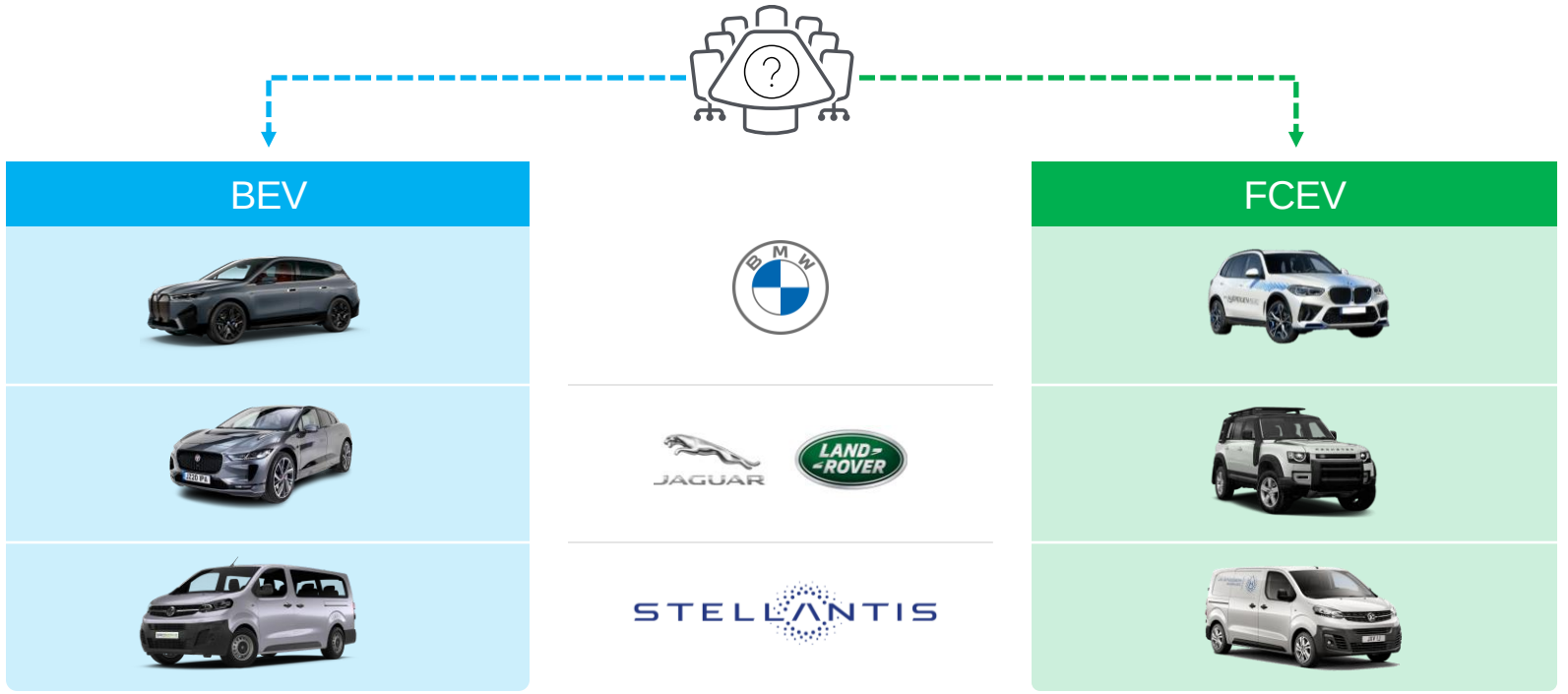
- Medium to high power (150 – 200 kW)
- Long ranges (300+ miles)



Source: APC Technology Trends

Some OEMs are agnostic to the choice between battery and fuel cell powertrains

OEMs are deciding if BEVs are the best option for all vans and SUVs, or if FCEVs can better accommodate some of the more demanding journeys.



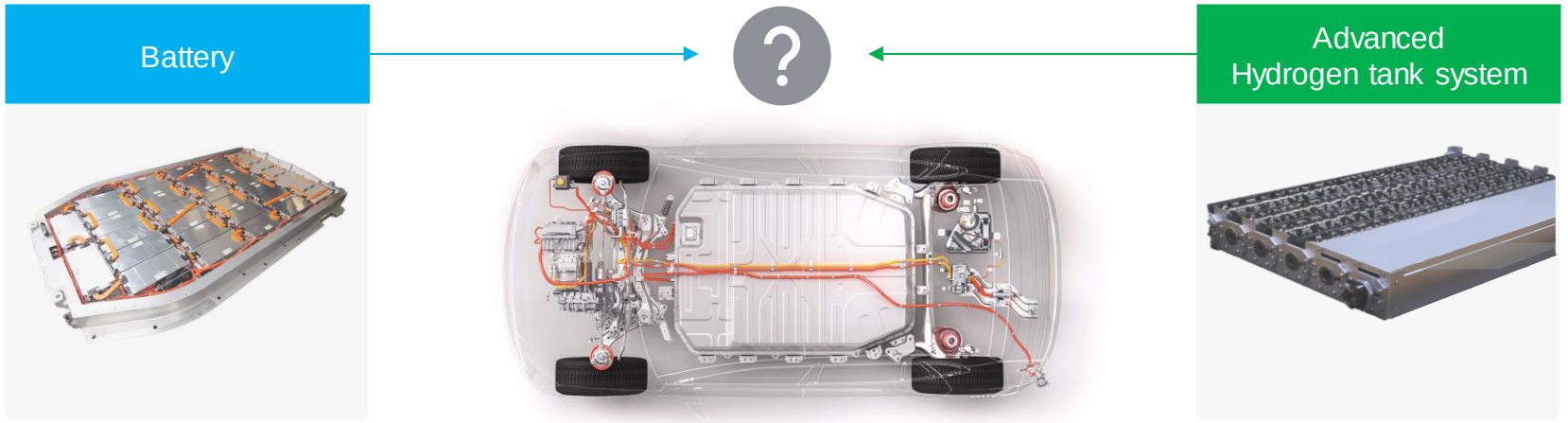
European OEMs that have publicly announced an interest in battery and fuel cell electric SUVs or vans

Source: APC Technology Trends | Images: BMW website, Jaguar Land Rover website, Stellantis website, electrifying.com, ccarprice.com, gridserve.com

Developing a modular electrified platform allows greater adaptability

Major investments in BEV platforms have preceded FCEV production, but some OEMs could consider a modular electrified platform with interchangeable energy storage options to future-proof vehicle production.

This study assumes that future FCEV models would have a fuel cell system in the front or back of the vehicle, and that the hydrogen tank system would be designed to fit where the battery normally would in a BEV.



Source: APC Technology Trends | Images: secondlife-evbatteries.com, Bloomberg

Main assumptions of this study

The results presented in this study are based on the ‘best case’ scenarios across all 3 technologies, which are: Ni-rich NMC, LFxP & fuel cells

	Technology	2021	2025	2030
BEV	NMC	• NMC811 • 5% silicon anode • 2021 material prices	• NMC9.5.5 • 20% silicon anode • 2021 material prices	• NMC9.5.5 • 100% silicon anode • 2021 material prices
BEV	LFxP	• LFP • 0% silicon anode • 2021 material prices	• LFMP • 5% silicon anode • 2021 material prices	• LFMP • 20% silicon anode • 2021 material prices
FCEV	H_2	• PEM FC • Type IV tanks • EoS[1] @ 10,000 units • 50% efficiency	• PEM FC • Type IV tanks • EoS @ 100,000 units • 55% efficiency	• PEM FC • Type IV tanks • EoS @ 500,000 units • 60% efficiency

Vehicles analysed

Large premium SUV

Van

Source: APC Technology Trends | 1: Economies of scale | Images: JLR website, Toyota website

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Cost analysis for **Large premium SUVs**

Large premium SUVs

Large premium SUVs are one of the largest vehicle segments in the light duty category with relatively low vehicle range efficiency but generous packaging freedoms

Large premium SUV	Vehicle	Packaging space dimensions
Length (m)	5.00	2.25
Width (m)	2.00	1.60
Height (m)	1.85	0.15
Mass (kg)	2,500	750

Powertrain attributes	Value
Vehicle efficiency	3 miles per kWh
Minimum range requirement	300 miles
Energy to travel 300 miles	100 kWh
Maximum packaging volume[1]	533 litres
Maximum packaging mass[2]	750 kg

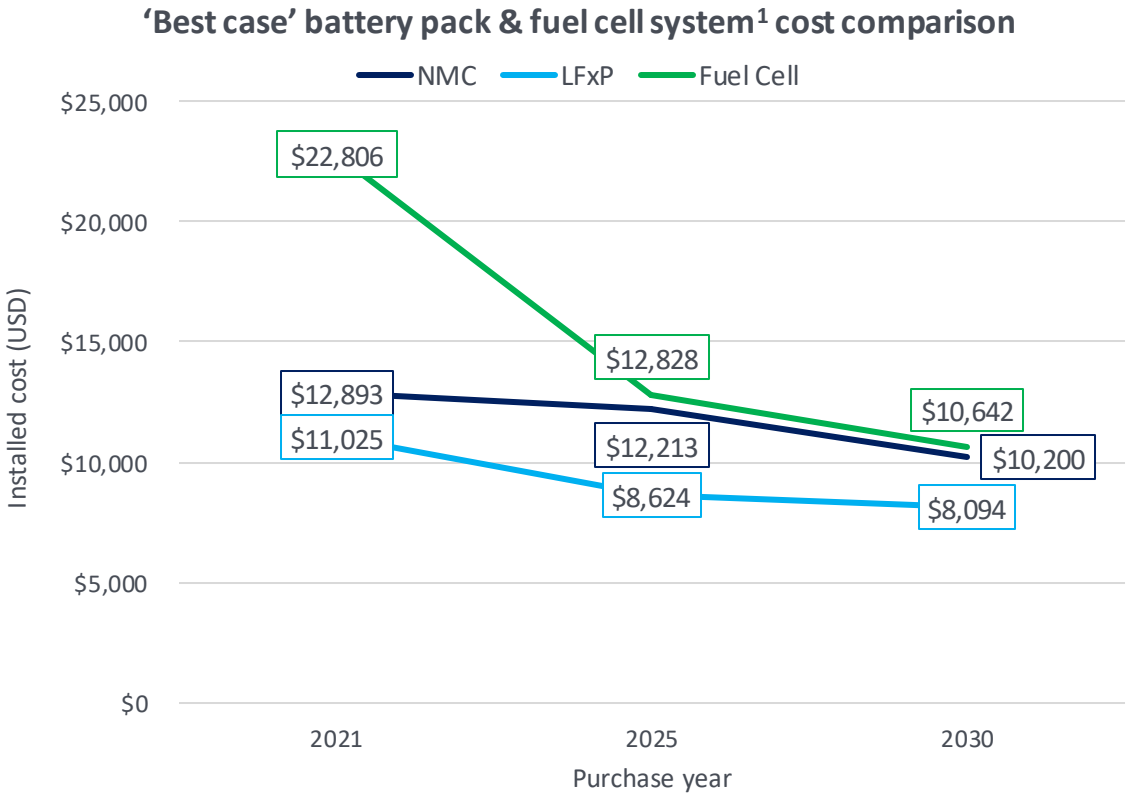
[1] **Max packaging volume** = *45% vehicle length x 80% vehicle width x 8% of vehicle height*

[2] **Max packaging weight** = *30% of total vehicle weight*

Source: APC Technology Trends, Warwick Manufacturing Group (WMG) | Images: JLR website, dreamstime.com

Batteries expected to be the cheapest option for large premium SUVs

Batteries expected to be the cheapest option for large premium SUVs if the desired range is 300 miles.
LFxP battery is cheaper than NMC and can achieve 300 miles



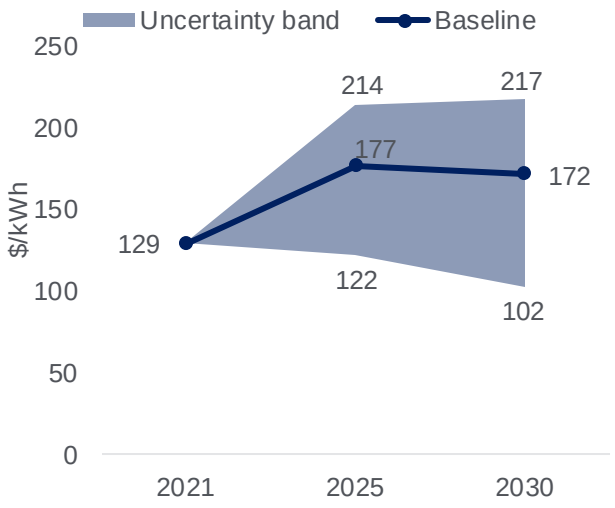
	Technology	2030 Spec.
BEV	NMC9.5.5	• 100 kWh • 328 Wh/kg • 305 kg pack
BEV	LFMP	• 100 kWh • 223 Wh/kg • 449 kg pack
FCEV	H_2	• 120 kW system • 60% efficiency • 4.8 kg of H2 • 5 kWh battery

Source: APC Technology Trends | 1: Fuel cell system cost includes: fuel cell stack, balance of plant, hydrogen storage system and supporting battery pack

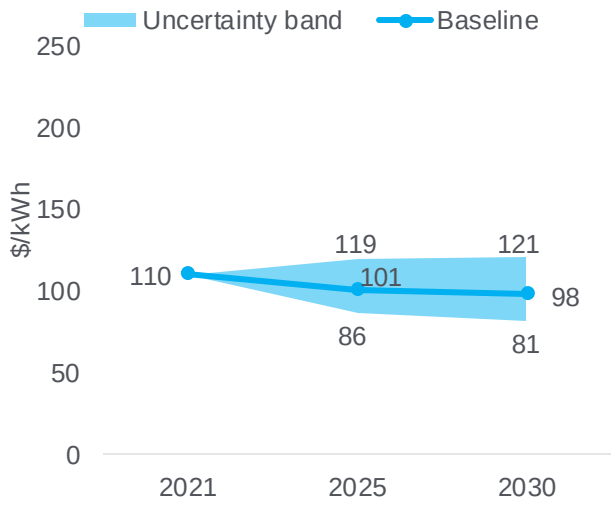
Future cost uncertainty varies across each technology

LFxP and fuel cell systems are expected to have a narrower future cost range. NMC is more exposed to the fluctuations in raw material prices and supplies, resulting in a larger cost spread and uncertainty.

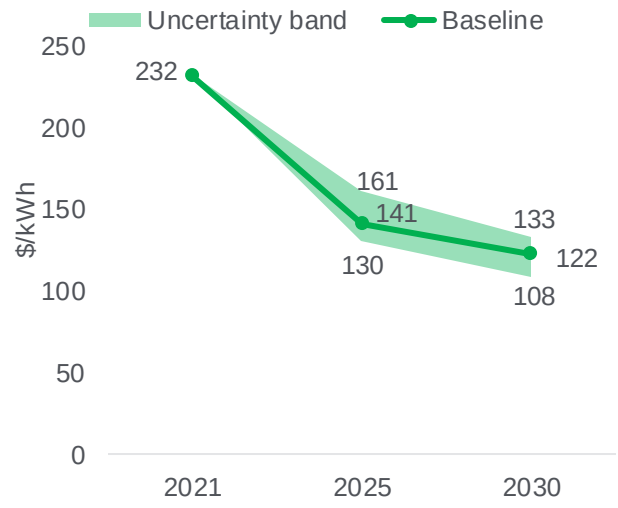
NMC pack cost range



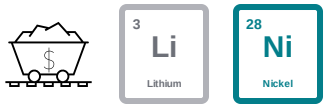
LFxP pack cost range



Fuel cell system[1] cost range



Main cost sensitivity



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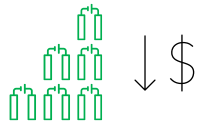
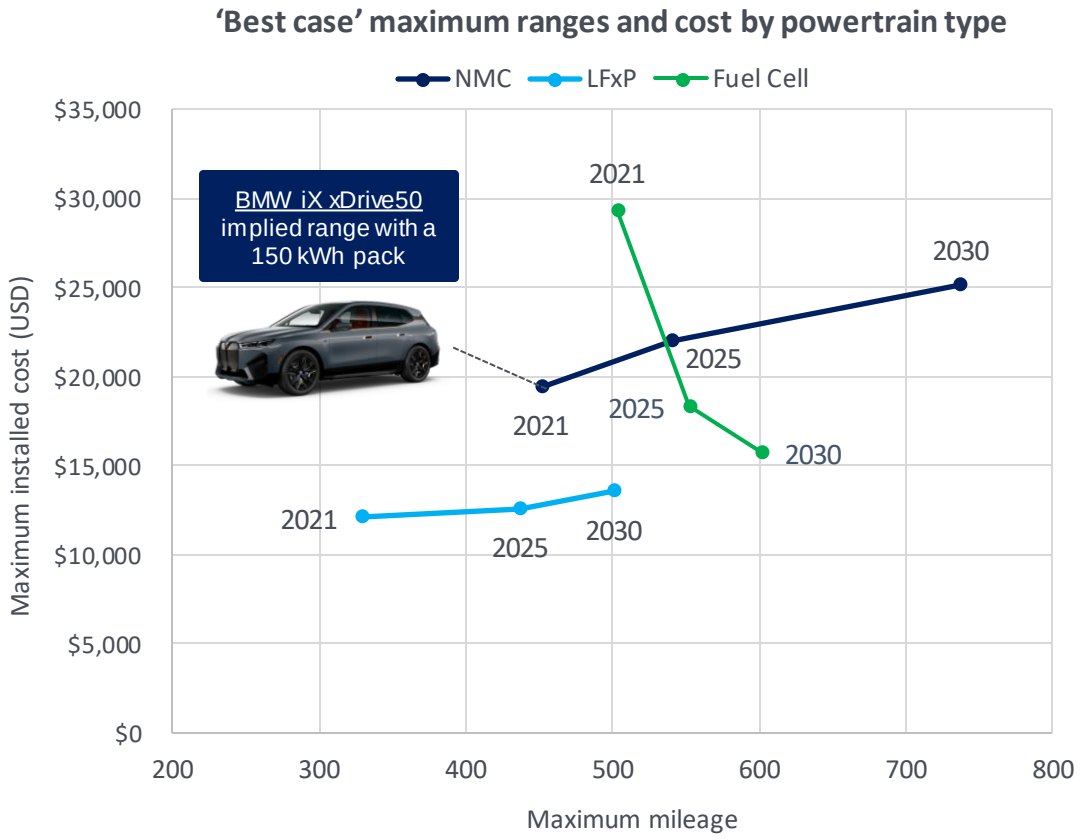


Source: APC Technology Trends | 1: Fuel cell system cost includes: fuel cell stack, balance of plant, hydrogen storage system and supporting battery pack

Technology selection can also be based on ‘cost per mile’ economics

If the powertrain packaging space in a large premium SUV is optimised to achieve the highest range possible, then fuel cells & LFxP are likely to provide the lowest ‘cost per mile’ by 2030



Battery assumptions

- For NMC and LFxP, continued energy density improvements increase the maximum allowable pack size / range
- The line trends upwards for NMC & LFxP because the increasing battery size is not offset by reduced $/kWh

	NMC (Pack)			LFxP (Pack)		
	Max kWh	Wh/kg	Wh/l	Max kWh	Wh/kg	Wh/l
2021	150	201	328	110	146	216
2025	180	240	383	146	194	301
2030	246	328	557	167	223	352

Fuel cell system[1] assumptions

- Cost reduction in FC systems is driven by economies of scale while the range increases due to system efficiency gains

	Fuel cell system		Hydrogen storage tanks	
	Max kW	Cont. efficiency (%)	Max kg H_2	Max # tanks
2021	120	50%	9.8	10
2025	120	55%	9.8	10
2030	120	60%	9.8	10

Source: APC Technology Trends | 1: Fuel cell system cost includes: fuel cell stack, balance of plant, hydrogen storage system and supporting battery pack

Conclusions for large premium SUVs

Under the 'best case' scenarios for all three technologies, LFMP would be the most cost-effective option by 2030

	Technology	Status today	Status in 2030	Future cost uncertainty
BEV	NMC	NMC is the leading option for electric 400-mile SUVs ranges, but NMC packs are more expensive than LFP	Can achieve the highest mileage of all three technology options, but more expensive than LFMP and may struggle to compete with fuel cells	NMC cells are exposed to lithium, nickel and cobalt price volatility, which means final pack costs are highly sensitive to input material prices
BEV	LFxP	LFP is already a cost-competitive option for 300-mile SUVs, but the pack would be 180 kg heavier than the equivalent NMC pack	LFMP expected to be the cheapest option for 300-mile SUVs and has the potential to deliver 500 miles at the lowest cost	LFxP has a much narrower uncertainty band than NMC, and will likely be preferred by high volume SUV OEMs that operate at lower profit margins
FCEV	H_2	Fuel cell system[1] are currently uncompetitive from a cost perspective and face significant challenges around hydrogen tank packaging	Expected to compete closely with NMC for longer-range SUV models, assuming hydrogen tank packaging challenges are overcome	Future cost uncertainty band is much lower than NMC and similar to that of LFxP. The main cost driver is economies of scale

Source: APC Technology Trends | 1: Fuel cell system cost includes: fuel cell stack, balance of plant, hydrogen storage system and supporting battery pack

Cost analysis for **Vans**

Vans

Vans benefit from generous packaging freedoms but are typically less efficient than large premium SUVs

Van	Vehicle	Packaging space dimensions
Length (m)	5.00	2.25
Width (m)	2.00	1.60
Height (m)	2.10	0.17
Mass (kg)	2,500	750

Powertrain attributes	Value
Vehicle efficiency	2.3 miles per kWh
Minimum range requirement	300 miles
Energy to travel 300 miles	130 kWh
Maximum packaging volume[1]	605 litres
Maximum packaging mass[2]	750 kg

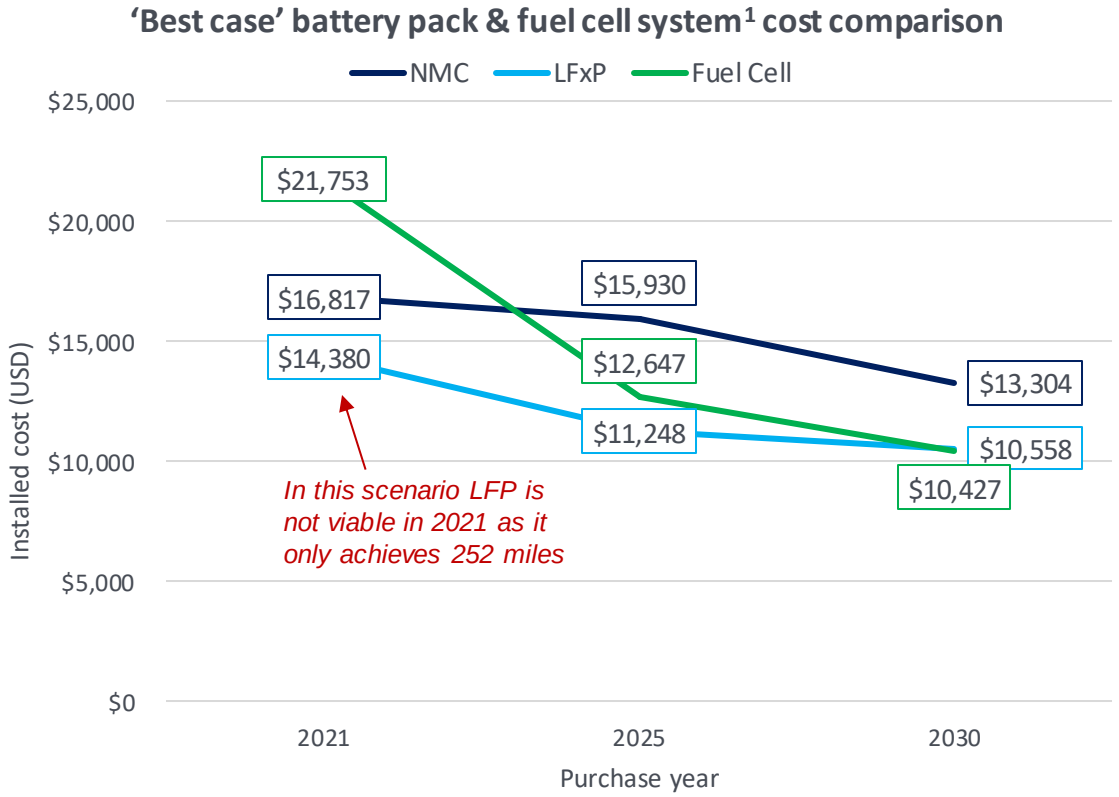
[1] **Max packaging volume** = *45% vehicle length x 80% vehicle width x 8% of vehicle height*

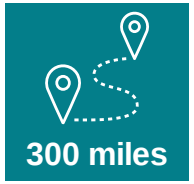
[2] **Max packaging weight** = *30% of total vehicle weight*

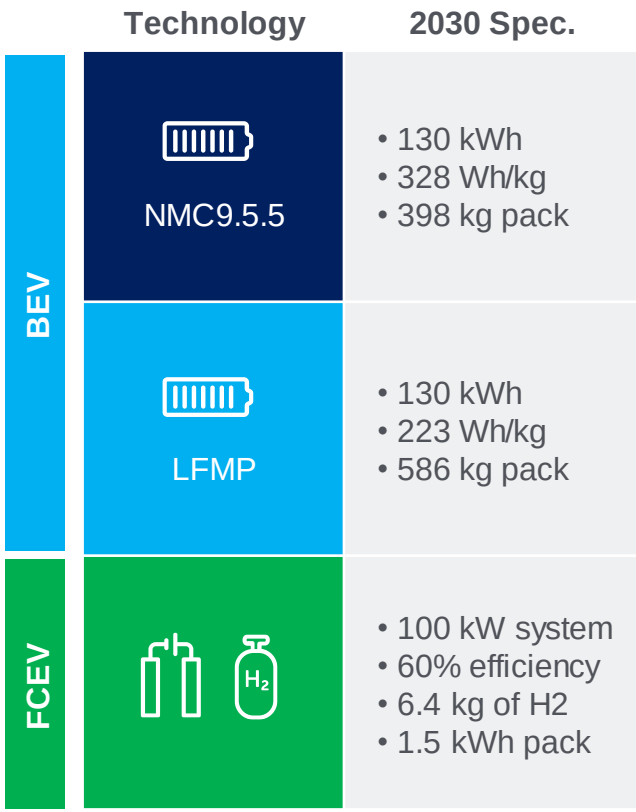
Source: APC Technology Trends, Warwick Manufacturing Group (WMG)

Fuel cell systems are likely to be the cheapest option for 300-mile vans by 2030

LFxP batteries are cheaper than NMC and can achieve 300 miles by 2025



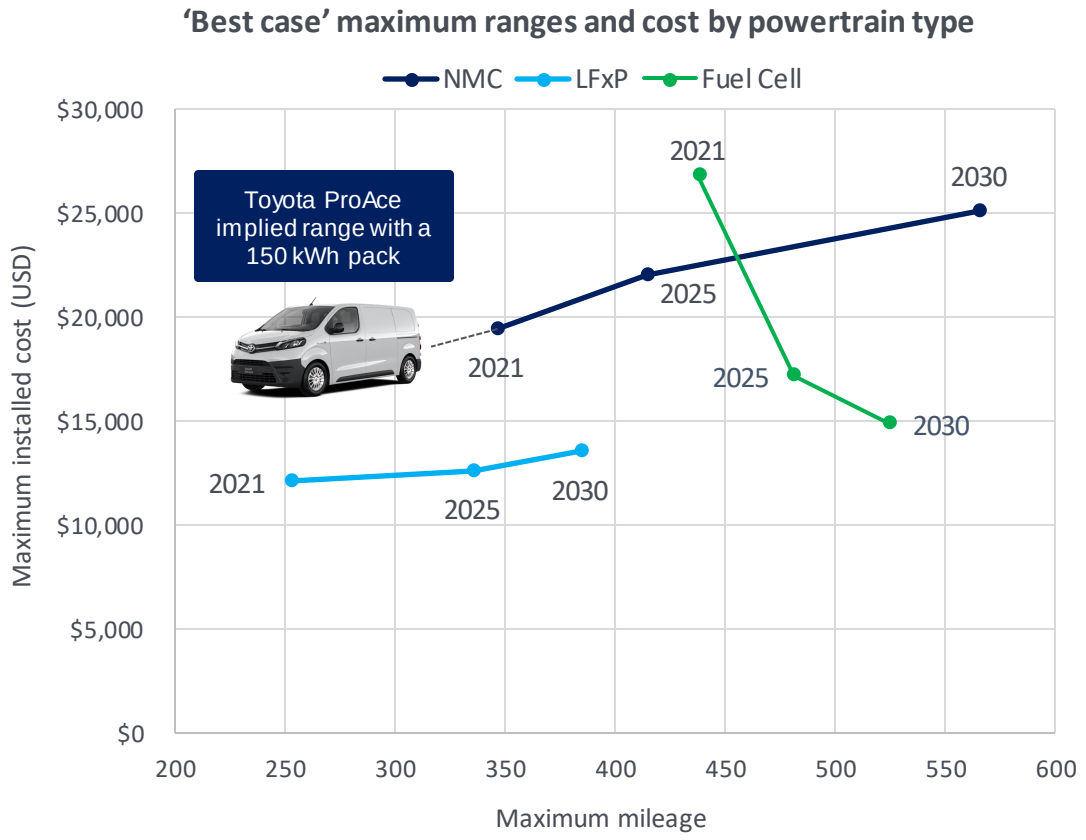




Source: APC Technology Trends | 1: Fuel cell system cost includes: fuel cell stack, balance of plant, hydrogen storage system and supporting battery pack

Fuel cells systems offer best cost option for long-range vans

By 2030, fuel cells have the lowest installed cost for long-range vans typically doing >400 miles, whereas LFMP batteries would comfortably satisfy the lower range options



Battery assumptions

- For NMC and LFxP, continued energy density improvements increase the maximum allowable pack size / range
- The line trends upwards for NMC & LFxP because the increasing battery size is not offset by reduced $/kWh

	NMC (Pack)			LFxP (Pack)		
	Max kWh	Wh/kg	Wh/l	Max kWh	Wh/kg	Wh/l
2021	150	201	328	110	146	216
2025	180	240	383	146	194	301
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Fuel cell system[1] assumptions

- Cost reduction in FC systems is driven by economies of scale while the range increases due to system efficiency gains

	Fuel cell system		Hydrogen storage tanks	
	Max kW	Cont. efficiency (%)	Max kg H_2	Max # tanks
2021	100	50%	11.3	9
2025	100	55%	11.3	9
2030	100	60%	11.3	9

Source: APC Technology Trends | 1: Fuel cell system cost includes: fuel cell stack, balance of plant, hydrogen storage system and supporting battery pack

Conclusions for vans

Under the 'best case' scenarios for all three technologies, LFxP and fuel cell systems are forecast to be the most cost-effective options by 2030

	Technology	Status today	Status in 2030	Future cost uncertainty	
BEV	NMC	High-nickel NMC is the cheapest option for 300-mile vans, but limited to 350 miles. Lower mass than LFP favourable for higher payload in vans	$ MILES $ MILES	Can achieve the highest mileage of all three technology options, but more expensive than LFMP and fuel cells	$ MILES $ MILES $ MILES	NMC cells are exposed to lithium, nickel and cobalt price volatility, which means final pack costs are highly sensitive to input material prices	? ? ?	
BEV	LFxP	LFP is not a viable option for 300-mile vans today because it can only achieve 252 miles of range. It also faces pack mass challenges	$ MILES ⚠	LFMP expected to be the cheapest powertrain option for vans requiring less than 300 miles of range and where payload is not a priority	$ MILES	LFxP has a much narrower uncertainty band than NMC, and will likely be preferred by high volume OEMs that operate at lower profit margins	?	✓
FCEV	H_2	Fuel cell systems[1] are in theory the only viable option today for 400+ mile ranges but command a significant price premium over batteries	$ MILES $ MILES $ MILES	Expected to be the cheapest option for 300+ mile vans by 2030 with the added benefit of having a lighter powertrain for higher payload by mass	$ MILES $ MILES	Future cost uncertainty band is much lower than NMC and similar to that of LFxP, but uptake will depend on availability of H_2 refuelling	? ?	✓

Source: APC Technology Trends | 1: Fuel cell system cost includes: fuel cell stack, balance of plant, hydrogen storage system and supporting battery pack

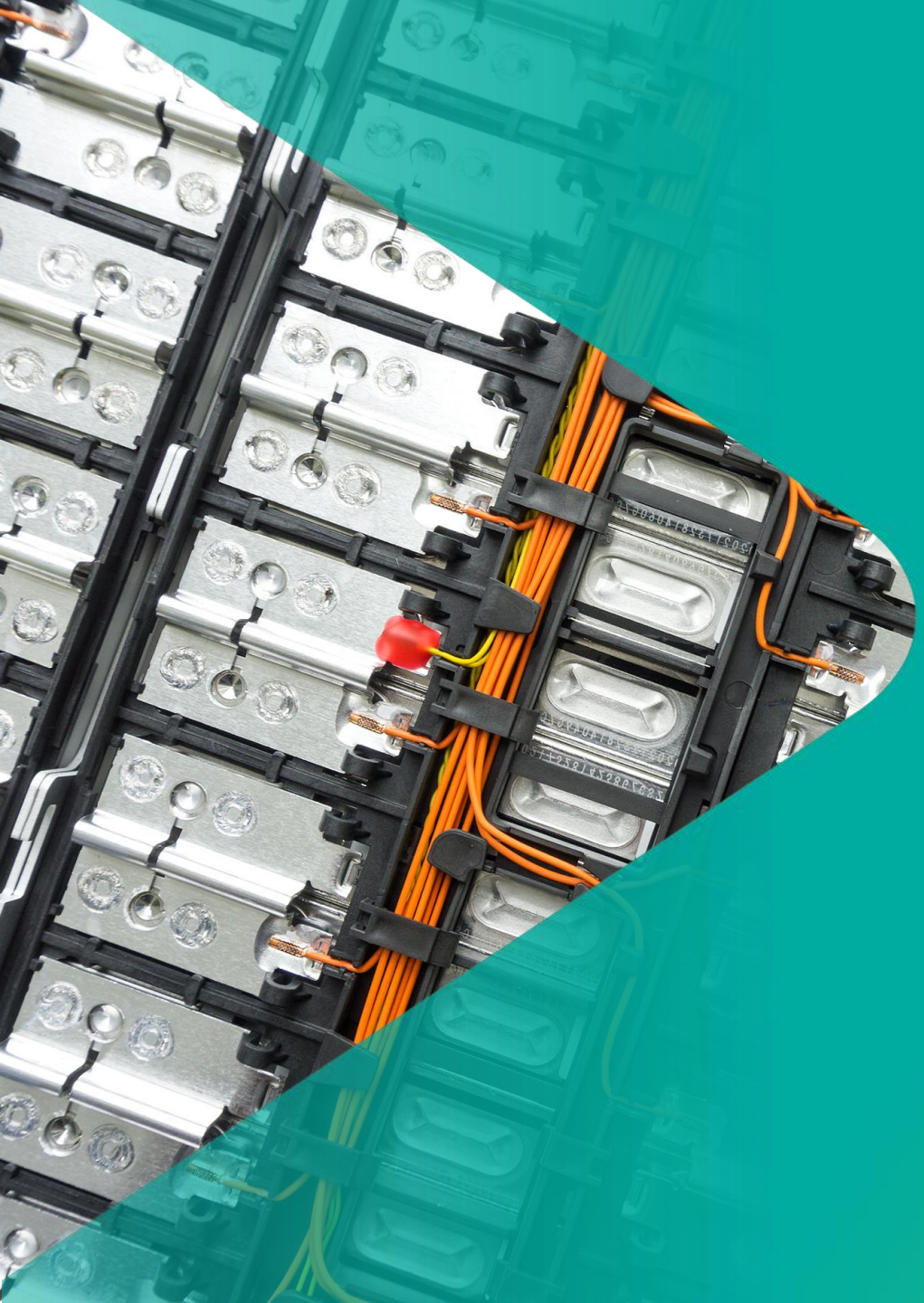
Summary: what to expect in 2030

By 2030, we expect LFMP batteries will be preferred over high-Ni NMC and fuel cells in most large premium SUVs. Hydrogen fuel cells are likely to be more widely adopted in vans.

Desired attribute	2030 technology choice (SUV)	2030 technology choice (van)	
Lowest powertrain cost	LFxP is the cheapest option in any year and has the lowest cost ceiling of all 3 technologies	Lowest cost ceiling of all 3 technologies	Cheapest option for 300-mile+ vans
Highest vehicle range	NMC9.5.5 with 100% silicon anodes in 2030 would enable >700 miles of range on a single charge	100% silicon anodes enable a step change in energy density	Increased height limit relative to SUV allows for more hydrogen storage
Lowest powertrain mass	The combined mass of the fuel cell system, hydrogen tanks and supporting power battery is significantly lower than that of its closest competitor, NMC	The combined mass of a fuel cell powertrain is significantly lower than the battery equivalent, providing a key payload advantage in vans	
Expected trend	It is likely that, by 2030, LFMP will be the preferred option for large premium SUV manufacturers because of its lower exposure to input material prices and its energy density-led range improvements	It is likely that hydrogen fuel cell systems will be mass produced for / by leading van manufacturers to include in their product offering, as long as investments in hydrogen refuelling stations occur in parallel	

Key: NMC | LFxP | Fuel cell

Source: APC Technology Trends | Images: JLR website, Toyota website

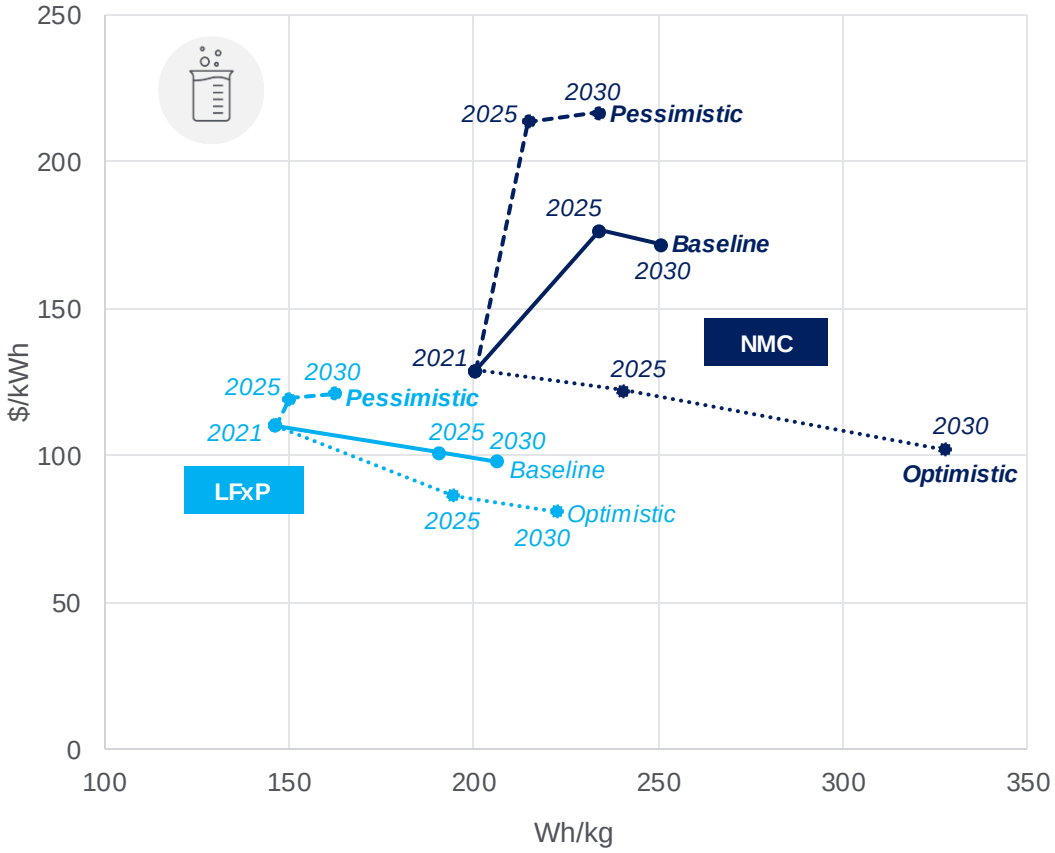


Sensitivities

Battery technology progression and material prices

Battery costs are sensitive to technology progression and material prices:
LFxP is less sensitive to material prices whereas NMC is greatly affected by nickel price fluctuations

3 scenarios of pack $/kWh vs energy density (Wh/kg)



Battery assumptions

	NMC Wh/kg (Pack)			LFxP Wh/kg (Pack)		
	Pes.	Baseline	Opt.	Pes.	Baseline	Opt.
2021	201	201	201	146	146	146
2025	215	234	240	150	190	194
2030	234	251	328	162	207	223

	Lithium hydroxide prices			Nickel sulphate prices		
	Pes.	Baseline	Opt.	Pes.	Baseline	Opt.
2021	$17/kg	$17/kg	$17/kg	$10/kg	$10/kg	$10/kg
2025	$35/kg	$22/kg	$17/kg	$25/kg	$17/kg	$10/kg
2030	$35/kg	$22/kg	$17/kg	$25/kg	$17/kg	$10/kg

	Lithium carbonate prices		
	Pes.	Baseline	Opt.
2021	$15/kg	$15/kg	$15/kg
2025	$33/kg	$20/kg	$15/kg
2030	$33/kg	$20/kg	$15/kg

Source: APC Technology Trends

Mileage sensitivities in BEVs and FCEVs

While the mileage of BEVs is limited more by the allowable mass for the battery, FCEVs are more volume-constrained when it comes to maximising mileage in 2030

	Technology	Sensitivity to mass limit	Sensitivity to height limit
BEV	NMC9.5.5	Mileage is very sensitive to pack gravimetric energy density, ranging from 234 to 328 Wh/kg	Increasing the height of the battery does not enable further mileage as the mass limit takes priority
BEV	LFxP	Mileage is very sensitive to pack gravimetric energy density, ranging from 162 to 223 Wh/kg	Increasing the height of the battery does not enable further mileage as the mass limit takes priority
FCEV	H_2	The combined mass of the hydrogen fuel cell system[1] is significantly within the limit	For each additional cm of height provided, an FCEV could achieve ~50 miles extra in range

Source: APC Technology Trends | 1: Fuel cell system includes: fuel cell stack, balance of plant, hydrogen storage system and supporting battery pack

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