National Engineering Policy Centre

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Critical materials: demand-side resource efficiency measures for sustainability and resilience

Methodology supplement for quantitative analysis

Introduction

In the report Critical Materials: demand-side resource efficiency measures for sustainability and resilience, we have explored challenges and opportunities for demand-side management of critical materials in the UK. The breadth and complexity of the subject, and relative lack of existing data and relevant policies to analyse, required taking a broadly qualitative approach in report's development, through consulting with experts and reviewing relevant literature. However, it was decided to supplement the exploratory approach of by the report with some quantitative analysis, focusing on one sector as an example. As a results, we performed analysis with the aim understand how different policy and technology interventions in the battery electric vehicle (BEV) market may affect the UK's demand for critical materials through consumer purchases of BEV.

We recognise that the factors affecting the UK's BEV market complex and long-term predictions come with large amounts of uncertainties. Our ambition is to provide a high-level illustrative example of how the scale and timing of demand reduction interventions may change the level of growth in demand for critical materials. As a result, however, the study is limited in immediate practical policy implications by the paucity of existing policy options or market influence for accomplishing design changes within the UK alone. Any such changes would require more far-reaching shifts which reflect the global nature of the automotive sector, and the production and import of specific components. However, this analysis is a valuable illustration of the potential extent to which such demand management interventions would reduce the UK's contribution to the significant global growth of demand for specific critical materials, and therefore the UK's consumption-based responsibility for the environmental, social and economic costs associated with both supply shortages and increased extraction. Notably this means that the potential for demand management from regional or global interventions of this type are even more significant.

We have focused this scenario analysis on one type of product within one sector – passenger car and light duty BEVs, a choice that has been made for several reasons. Electric vehicles are a growing market across the world and their batteries currently use several critical (or watchlisted) materials, including cobalt, nickel, lithium, manganese graphite and increasingly silicon. Electric vehicles are far from the only commodities that currently rely on these materials, with use in electronic devices, chemical processes, as well as other energy storages including in electricity networks.[1] However, over half of annual lithium use per year is estimated to be directed into electric vehicle production.[2] Additionally, the UK market for electric vehicles has been growing substantially – with 19 times the number of new battery electric car registrations in 2022 compared with five years earlier – representing a success in the crucial goal of decarbonising transport but potentially introducing new and different environmental concerns.[3] This combination of growing consumer interest in owning EVs and policies driving their replacement of petrol, diesel, and hybrid vehicles raises concerns about the extent to which the EV market's current trajectory is sustainable.

Data and methodology

The BEV sales data was provided by Rho Motion and includes projections for Passenger Car and Light Duty Vehicle sales in the UK with historic data for 2018–2023 and projections for 2024–2040, both broken down by battery cathode and vehicle size groups. Rho Motion also provided annual average battery pack size for each of the three size categories (in kWh). Material intensity data was provided for each cathode type (in kg/kWh) for lithium, nickel, manganese, cobalt, aluminium, and sodium.[4] This data was provided in terms of the mass of the metal component net of any additional mass from the compound formed with the metal, where it exists such as in its oxide form. This data is not available for <0.1% of vehicles predicted to be in the 'Other' category as of 2040. Vehicle size groups are categorised by vehicle class (Small= A, B; Medium = C, D, SUV-B, SUV-C, MPV; Large = E, F, SUV-D, SUV-E, LDV)[5] and by cathode types (LFP, LMFP, LMO, NCA, NCM111, NCM523, NCM622, NCM712, NCM811+, NM/LMNO, Na-ion, Other).

Our analysis uses the projections provided by Rho Motion as a baseline scenario, and model cumulating annual changes based on the model type. There are different modelling methods for each of the three model types. For model type 1 (Battery Size), the approach is a simple reduction is battery size (or energy capacity) in kWh. For model type 2 (Battery Chemistry), we model a proportion of sales that would have been for one battery type vehicles that are 'replaced by' another. We look at three subsets of replacement models. Firstly, we model the replacing sales of vehicles using lithium-ion batteries (LIB) with (equivalent size) vehicles using sodium-ion batteries (NIB) vehicles (2a). NIBs do not contain lithium but currently NIBs almost all contain some other critical materials. Secondly, we look at replacing sales of vehicles using lithium nickel manganese cobalt oxide (NCM) batteries (LIB) with (equivalent size) vehicles using lithium iron phosphate (LFP) batteries (2b). NCM batteries have a higher intensity of lithium for the energy they hold/generate compared with LFP batteries, and they also contain nickel, manganese, and cobalt (though manganese and cobalt quantities are reduced in more energy dense versions of the batteries, e.g., NCM811 compared with NCM 622). For model type 3 (Vehicle Size), we model a replacement of the proportion of sales from one vehicle size segment (Medium or Large) into the segment one size below.

For each model type, we test how different results vary by changing several parameters to create different 'scenarios'. These parameters include: vehicle size segments affected; first year of intervention effects; final year of intervention effects; maximum intervention effect size (or, conversely rate of change per year); NIB chemistry (cobalt-intensive NCO, manganese-intensive NMO, nickel intensive NNO, or an equal mixture / average). The default scenarios for each model type, i.e., where the parameters are set for the main part of our analysis are detailed in Table 1.

Decisions where parameters should be set for the default scenarios were largely determined through consulting with experts on what was a meaningful and ambitious, but likely feasible when accounting for the inherent uncertainty associated with continuous innovation. When choosing values, there has often been no equivalent literature or data to draw from, and so a figure has been chosen as a default value and sense checked with expert reviewers. We do not believe this approach is too problematic for the analysis, as the aim is to provide an illustration on how different factors can affect change down the line rather than draw hard predictive conclusions.

Additionally, where some changes come with more uncertainty, then alternative scenarios have been tested as part of the sensitivity analysis as also outlined in Table 1. Across all the model types, we are exploring what happens when the rate of change remains the same, but there is a delayed start to the intervention effect's onset. We are conscious that reductions in battery size may be more practically achievable for larger batteries than smaller ones, so for Model 1, we have explored what the effects are when battery size reductions only affect those in Medium and Large vehicle sizes. We explore a few alternative parameter settings for models of changes in battery chemistry (Model 2), including modelling changes only affecting Small vehicles, as NIBs may be more likely to be used in entry level vehicles, as they have relatively low power and energy compared to equivalent LIBs. We have also looked at the impact of limiting the NCM based LIB vehicles being replaced to one with LFP packs as they are likely the most similar to current NIBs in terms of the customer market. Although we have identified manganese-based NMO as the NIB chemistry that is most likely to scale up in the market, we will also be looking at how material demand changes if the NIBs in the market are mostly cobalt-based (NCO) or nickel-based (NNO). For modelling changes to customer choice in vehicle size (Model 3), we speculate whether buyers of the Large passenger vehicles may be more likely to downsize to the Medium size segment compared with Medium buyers choosing Small vehicles, as the practical returns to power and range that affect users on a day-to-day basis is lower for the former group than the latter. Additionally, policy levers that reduce sales in new Large vehicles are arguably more likely than those that affect both Medium and Large vehicles equally.

Due to nature of this analysis as being illustrative and containing high levels of uncertainty, we have not attempted to draw statistical conclusions, for example, using confidence intervals, as this would imply a level of precision that our results are not claiming to provide.

Assumptions

In addition to choosing and testing different model parameters, our analysis comes with several assumptions that may inform how likely the findings are to materialise. In all scenarios we are assuming that the total number of BEVs sold during the period examined does not differ from the baseline scenario. We recognise that there are many policy levers and external factors that could affect not just the type of BEVs sold, but also the UK population's overall reliance on personal vehicles. These mechanisms are critical considerations for the wider material and sustainability system but sit outside the scope of this analysis.

Arguably the greatest set of assumptions we are making relate to customer behaviour. Our approach assumes the changes to the vehicle sales modelled – in terms of battery size (Model 1), battery type (Model 2), and vehicle size (Model 3) – will still meet the owners' transportation needs and therefore they will be willing to purchase them. Changing battery size will have impacts on range, power, storage etc, however we assume that either these can be mitigated through other design changes or that there will be other ways of meeting transportation needs. For example, more vehicles with lower ranges (resulting from smaller batteries or different chemistries) would require more frequent charging. This would have implications in terms of the need for a greater number of suitably located and maintained charging stations. Customer behaviour is critical for policymakers to thoroughly explore before introducing any specific interventions, but modelling this is out of scope for this illustrative analysis.

Our approach assumes that change of the intervention's effect can be reasonably modelled in a linear way, i.e., a steady annual % increase between the agreed years. For example, a 20% change over 10 years (2030 to 2040) will be modelled by a 2% change from the baseline each year (2% difference in 2031 change from baseline, 4% in 2032, etc). This simple approach has been chosen because a) we are not positing a set of interventions with a known change mechanism for each model, and b) our aim is to create an illustrative set of results rather than a predictive one.

Model type number	Intervention type being modelled	Methods of modelling	Default scenario parameters	Alternative scenario parameters tested in sensitivity analyses
1 | Battery Size	Design change: battery packs size reduction	Increasing annual reduction in battery size from the baseline scenario to reach a target reduction amount by 2040	The start year, i.e., when deviation from the baseline begins, is 2025. In 2040, it reaches 30% reduction in battery pack mass from the baseline scenario, meaning the deviation increases by 2 percentage points each year. All three vehicle sizes segments are affected equally.	i) Only Large and Medium vehicles are affected ii) The intervention has a delayed start (2032), leading to a 16% battery size reduction by final year (2040) with same annual rate of change.
2a | Battery Chemistry: LIB>NIB	Design change: replacement of all LIBs with NIBs	Increasing annual replacement of vehicles sold with LIB batteries to those with NIB batteries from the baseline scenario to reach a target replacement amount by 2040	The start year, i.e., when deviation from the baseline begins, is 2025. In 2040, it reaches 30% of sales for cars that would otherwise have LIB batteries in the baseline scenario instead have NIBs, meaning the deviation increases by 2 percentage points each year. All three vehicle size segments are affected equally. NIB vehicles will use sodium manganese oxide (NMO) battery material.	i) Only Small vehicles are affected ii) The intervention has a delayed start (2032), leading to a 16% replacement by final year (2040) with same annual rate of change. iii) The only LIB vehicles that are replaced have LFP batteries iv) NIBs use cobalt-intensive NCO or nickel-intensive NNO chemistries
2b | Battery Chemistry: NCM>LFP	Design change: replacement of NCM battery vehicles with LFP battery vehicles	Increasing annual replacement of vehicles sold with NCM batteries to those with LFP batteries from the baseline scenario to reach a target replacement amount by 2040	The start year, i.e., when deviation from the baseline begins, is 2025. In 2040, it reaches 30% of sales for cars that would otherwise have NCM batteries in the baseline scenario instead have LFPs, meaning the deviation increases by 2 percentage points each year. All three vehicle size segments are affected equally.	i) Only Small vehicles are affected ii) The intervention has a delayed start (2032), leading to a 16% replacement by final year (2040) with same annual rate of change.
3 | Vehicle Size	Demand change: shift in sales from larger vehicles to smaller ones	Increasing annual replacement of vehicles sold in the Large vehicle class category to the Medium class category and in the Medium class category to the Small class category from the baseline scenario to reach a target replacement amount by 2040.	The start year, i.e., when deviation from the baseline begins, is 2025. In 2040, 30% of cars that would have been in the Large segment are now in the Medium segment, and 30% of cars that would have been in the Medium segment are now in the Small segment. This means the deviation increases by 2 percentage points each year. Medium and Large vehicle segments are affected equally.	i) Only Large vehicles are affected ii) The intervention has a delayed start (2032), leading to a 16% vehicle size shift by final year (2040) with same annual rate of change. iii) Increase final affect to 60% by final year (2040), with same start date and annual rate of change

Table 1 | Summary of model features, default parameters, and alternative parameter settings for sensitivity testing

We have a number of technical assumptions about the composition and production of the batteries. We assume that the average BEV pack size for a given year (kWh) will be similar for all cathode types within a vehicle size category and therefore can be used to estimate material usage (kg) for that year. For each battery cathode type, material intensity (kg/kWh) will not change substantially over time and is stable across battery size (kWh). We also apply an assumed 'good' manufacturing yield in terms of amount of critical material input utilisation through manufacturing (in kg), which has been taken as 85%. There are significant uncertainties in manufacturing yield, arising from unknown in-factory recycling rates and the individual manufacturing processes. Manufacturing yields are not published or publicly discussed.

NIB vehicles are very young market, and our assumption around future production and sales are informed by those provided by the market experts at Rho Motion. An assumption we have added is that future vehicles sold with NIBs will use manganese intensive NMO chemistries as manganese may be more challenging to design out compared with cobalt or nickel in alternative NIB compositions.

In communicating the real impact of these findings in the briefing we estimate amount of rock mining such material would come with. Specifically, we use rock-to-metal ratios provided by Nassar et al (2022). This comes with the assumption that 100% of the lithium acquired for the BEVs modelled are sourced from rock mines. Globally a substantial portion comes from brine production (around 30% in 2018) (source). Brine facilities have very high water use impacts which may be more environmentally harmful. Concentrations of dissolved lithium in aquifers, and recovery rates of extraction operations, vary significantly, which makes any assessment of ultimate impact difficult to estimate.

Results

Our baseline forecast model predicts that we are moving to a future of all new cars purchased in the UK being battery powered. Under current conditions, expected penetration rates of BEVs into the passenger car and light duty market is around 78% by 2030 and 100% by 2040. By 2040, around 2,777,000 new battery electric cars are forecast to be sold that year – over eight times the amount for 2023. Vehicles in the Medium size segment are forecast to remain the most popular of the three sizes segments across the period examined, as seen in Figure 1.

As demand for BEVs increases without demand management interventions, so does demand for the critical materials needed for the battery

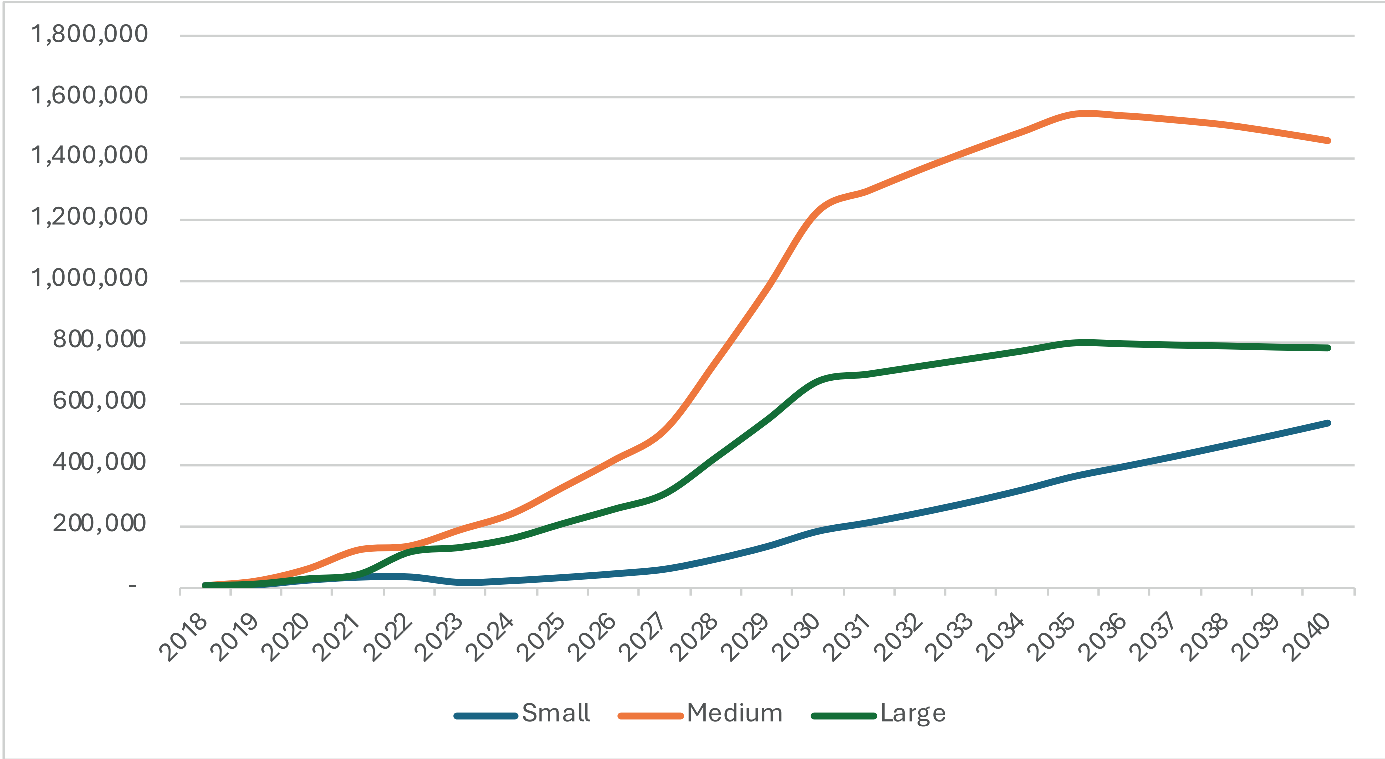
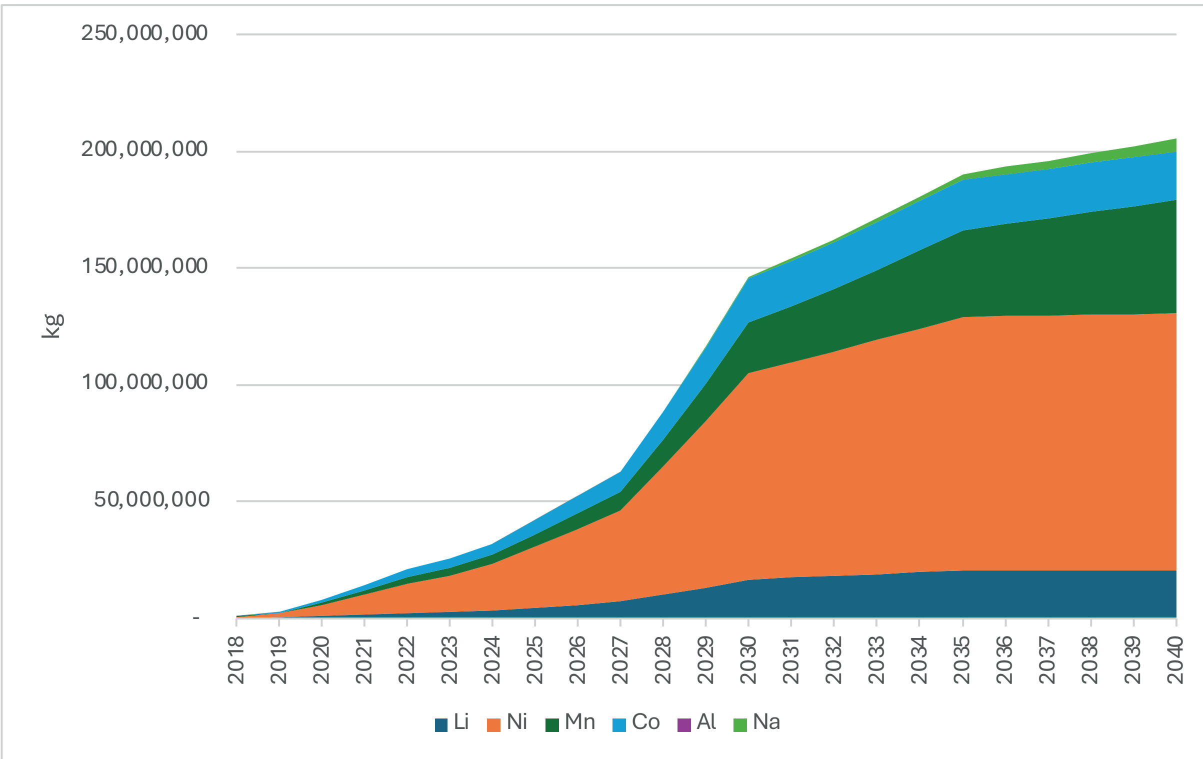


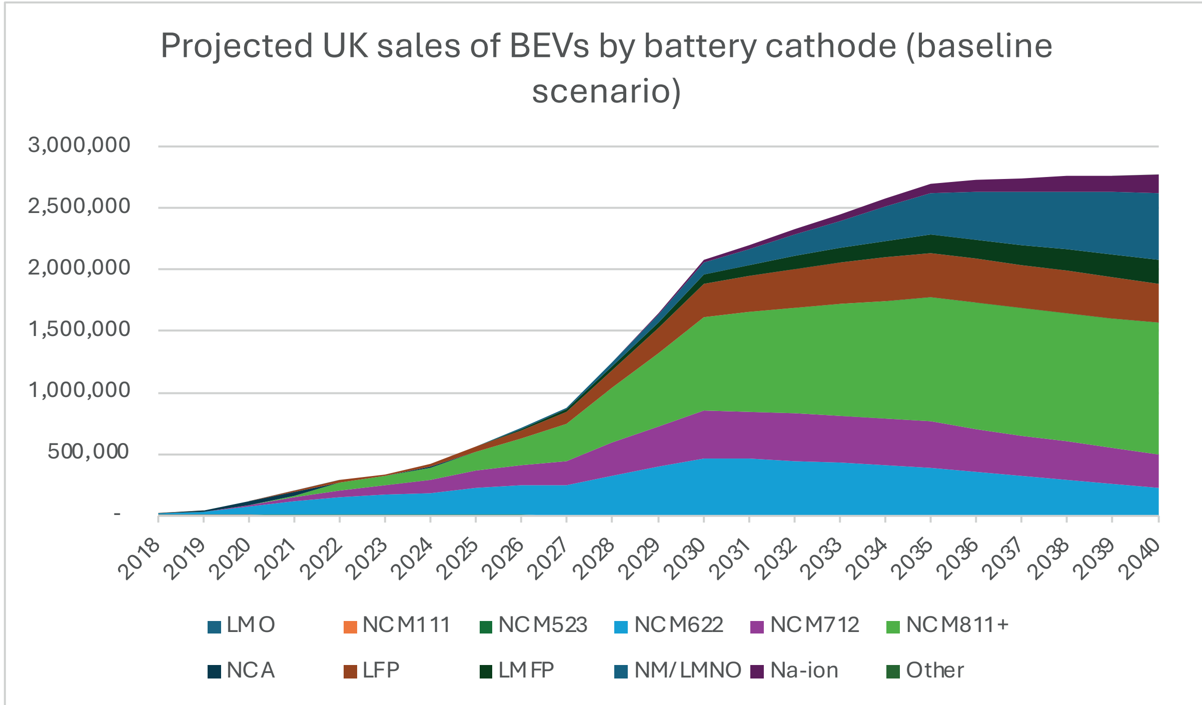
Figure 1 | Projected annual units sold of passenger car and light duty BEVs in the UK (baseline scenario)

components, including lithium, cobalt, manganese, and nickel. However, there are some trends in battery chemistry that are predicted to alter demand for specific materials. Figure 2 and 3 show how, over time, more vehicles are expected to use batteries that are more efficient in their use of cobalt and manganese in their cathodes, but which also use more nickel (for example NCM811 cathodes compared with NCM622). This is especially the case in larger vehicles. From 2025, the forecast also sees vehicles frequently being built with manganese-dense cathodes (NM/LMNO). Overall, the baseline forecasts do not anticipate any relief on demand for these core materials in the BEV market in the coming years.

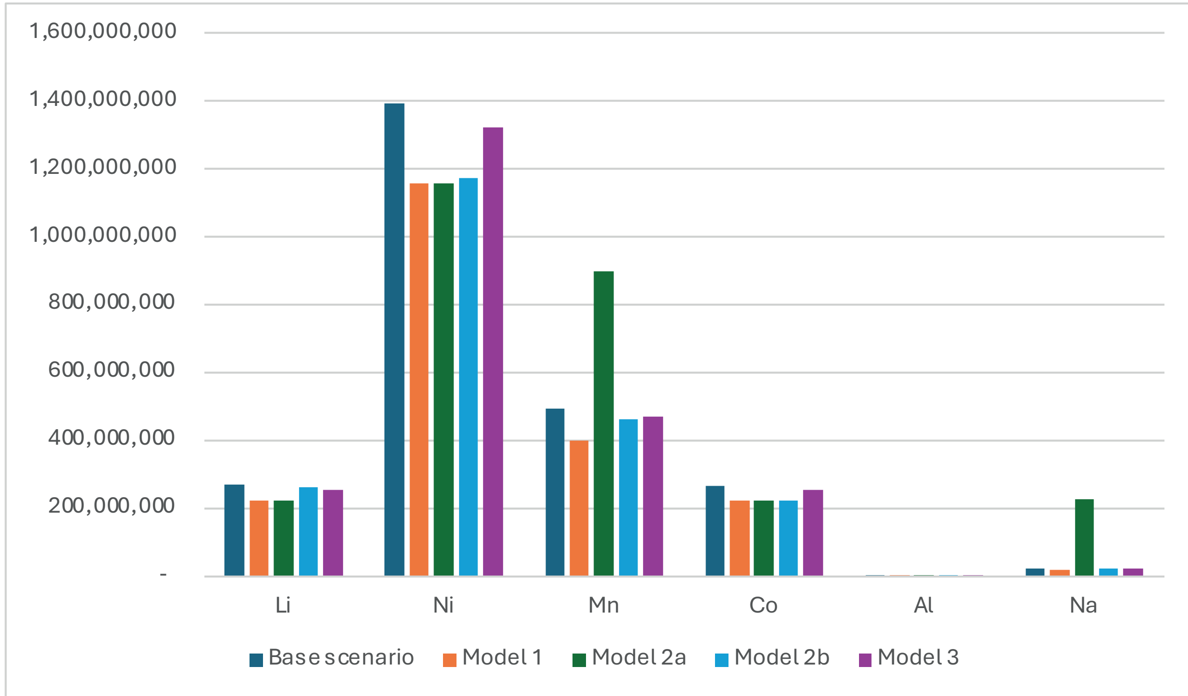
Figures 4 and 5 show the total demand created by UK consumption for lithium, nickel, cobalt, aluminium, and sodium across each of the model types. A summary of the differences compared with the baseline scenario is presented in Table 2.



■ **Figure 2 | Projected annual material usage through passenger car and light duty BEVs in the UK (baseline scenario)**



■ **Figure 3 | Projected annual sales of passenger car and light duty BEVs in the UK by cathode type (baseline scenario)**



■ **Figure 4 | Total material usage from passenger car and light duty BEVs sold in the UK – 2018–2040, by model type**

In the baseline scenario from 2018 to 2040, 268,000 tonnes of lithium metal will be needed to supply the UK's forecast demand for BEVs alone. Reducing battery sizes by 30% by 2040 could generate reductions of 17%, amounting to 46,000 tonnes of lithium. With a current rock-to-metal ratio estimation of 1,634:1, this equates to 75,000,000 tonnes of rock that would otherwise be mined to meet UK demand.[6]

Cumulative material use, 2018-2040	Baseline	Difference from baseline							
		Model 1 Battery Size		Model 2a Battery Chemistry: LIB>NIB		Model 2b Battery Chemistry: NCM>LFP		Model 3 Vehicle Size	
	kg	kg	%	kg	%	kg	%	kg	%
Lithium	268,199,390	- 45,925,016	-17%	- 45,925,016	-17%	- 7,128,007.60	-3%	- 13,491,789	-5%
Nickel	1,392,457,959	- 236,371,731	-17%	- 236,371,731	-17%	- 221,734,347.90	-16%	- 71,209,510	-5%
Manganese	493,632,569	- 96,120,750	-19%	401,007,473	81%	- 33,224,814.95	-7%	- 25,165,785	-5%
Cobalt	266,649,590	- 41,986,915	-16%	- 41,986,915	-16%	- 41,984,226.91	-16%	- 12,206,817	-5%
Aluminium	145,236	- 410	0%	- 410	0%	-	0%	- 91	0%
Sodium	24,764,895	- 5,691,910	-23%	202,342,199	817%	-	0%	- 1,058,740	-4%

Table 2 | Total material usage from passenger car and light duty BEVs sold in the UK 2018–2040, differences from baseline by model type

Sensitivity analysis

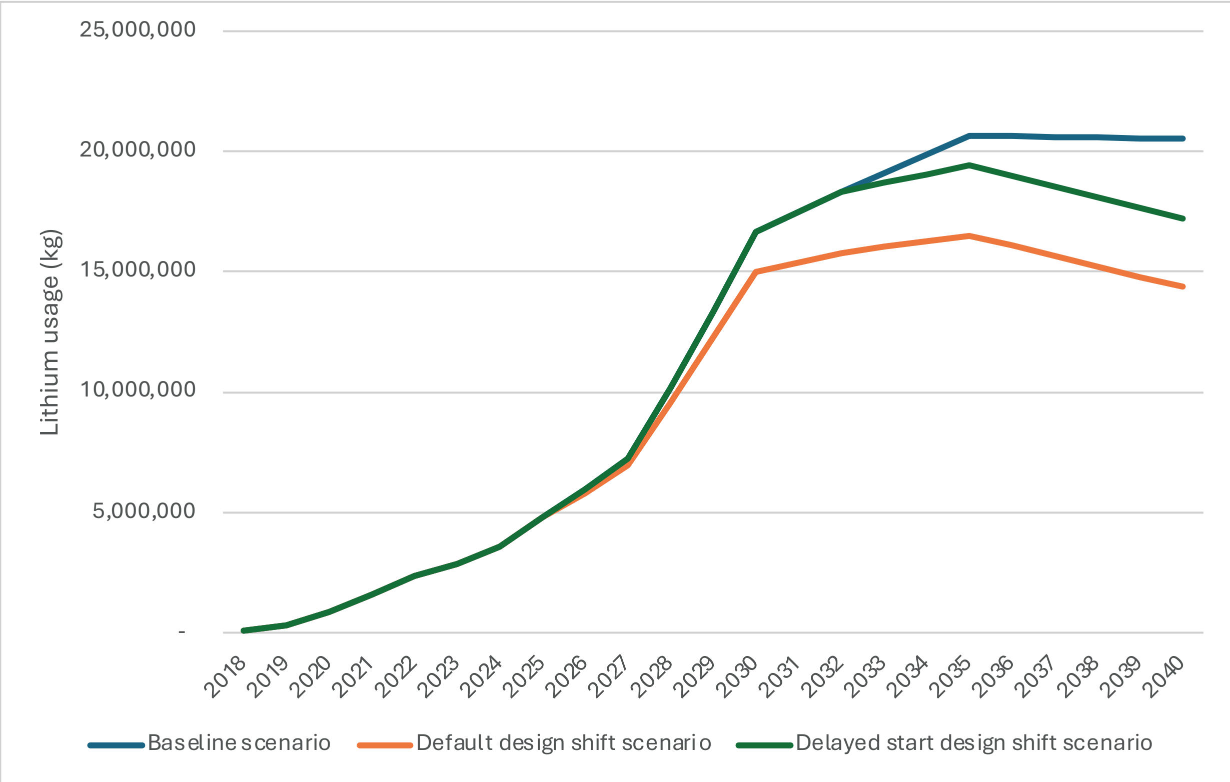
Model 1. Battery Size

In reaching an annual average reduction in total battery size by 30% across all BEVs sold, a 16–19% reduction in cumulative use of nickel, manganese, lithium, and cobalt is achieved across 2018–40. We looked at what would happen if we were to restrict the change to medium and large vehicles only (arguably where there is more 'room' for change). In this scenario, the cumulative effect only drops marginally – to 14–17% – compared to when all vehicle sizes are included, confirming that the capacity for demand reduction is much greater in larger vehicles with larger batteries. Around half of the benefit comes from the largest vehicle class examined, despite them only making up less than a third of the sales during that period.

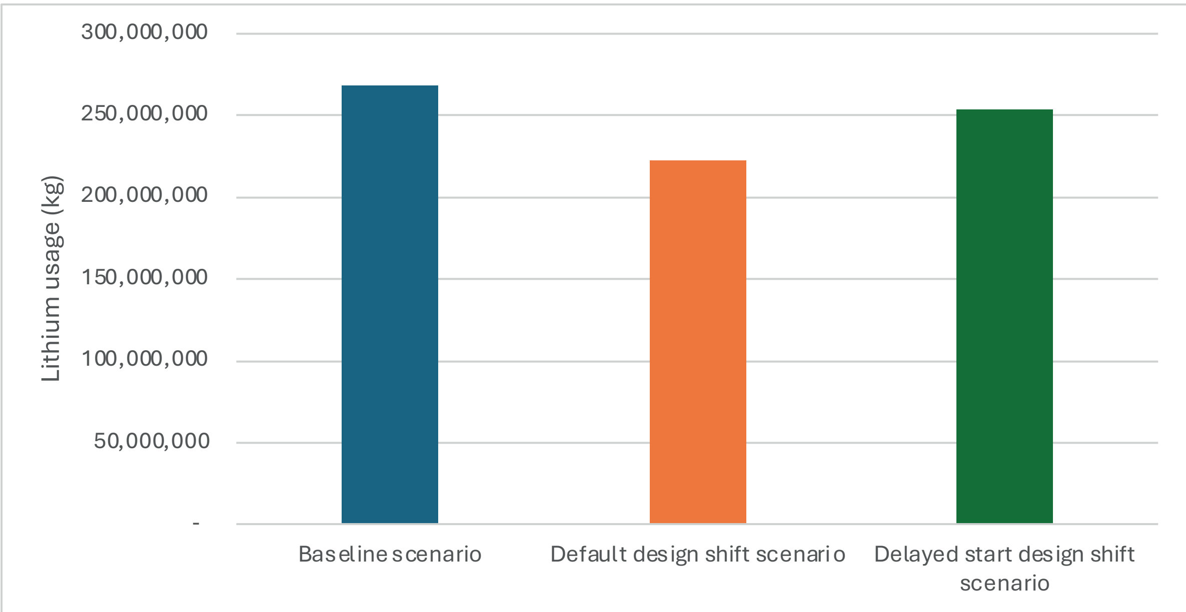
We tested the outcomes of a 'delayed start' scenario, where the rate of change (2 percentage points per year) remained the same, but the start year is 2032 rather than 2025. This scenario means that by 2040, the difference in average battery size from the baseline scenario is 16% – just over half that of the default scenario (30%). However, the cumulative demand reduction across the four materials drops to 5–7% – around one third of the effect compared to a scenario of starting in 2025. Results by material are presented in Table 4 and delayed start findings visualised in Figures 6 and 7.

Difference from baseline in cumulative material use, 2018–2040	Alternative parameter scenarios		
	Default	Excluding Small	Delayed start
Lithium	-17%	-16%	-6%
Nickel	-17%	-16%	-5%
Manganese	-19%	-17%	-7%
Cobalt	-16%	-14%	-5%

Table 4 | Differences from the baseline model in cumulative demand for materials from BEV sales across Model 1 (Battery Size) scenarios. 'Default' scenario = immediate change (2025), 30% battery size reduction by final year (2040), all vehicle sizes. 'Excluding Small' scenario = Medium and Large vehicles only included in intervention. 'Delayed start' scenario = intervention starts in 2032, with same 2% annual rate of change, all vehicle sizes



■ **Figure 6 | UK BEV market lithium usage in baseline and design (Model 1) scenarios (default and delayed start) – battery size reduction, over time**



■ **Figure 7 | UK BEV market cumulative lithium usage in baseline and design (Model 1) scenarios (default and delayed start) – battery size reduction, 2018–2040**

Model 2a. Battery Chemistry LIB->NIB

When modelling a change whereby 30% of all LIBs are replaced with NMO NIBs by 2040, the amount of lithium required drops by 17%, or 46,000 tonnes. Similarly, the amount of nickel and cobalt also decreases as the NIB modelled assumes a chemistry that uses manganese and has designed out the other two elements. As a result, the amount of manganese increases by 81%, or 402,000 tonnes over the 2018–2040 period. When we limit the LIB vehicles being replaced by NIB vehicles to those with LFP batteries, the amount of lithium used in BEV sales decreases by only 2%. In contrast, the amount of nickel, manganese, and cobalt increase by 2%, 5%, and 10% respectively. Results by material are presented in Table 5. However, these results are of limited policy relevance given the much earlier stage of innovation of NIBs and what is estimated to be greater prospects for designing out critical materials.

Difference from baseline in cumulative material use, 2018-2040	Alternative parameter scenarios			
	Default	**Small only**	**Delayed start**	**LFP replaced only**
Lithium	-17%	-1%	-6%	-2%
Nickel	-17%	-1%	-5%	2%
Manganese	81%	7%	26%	5%
Cobalt	-16%	-2%	-5%	10%

■ **Table 5 | Differences from the baseline model in cumulative demand for materials from BEV sales across Model 2a (Battery Chemistry – LIB->NIB) scenarios. 'Default' scenario = immediate change (2025), 30% additional 'conversion' of LIB to NIB by final year (2040), all vehicle sizes. 'Small only' scenario = Small vehicles only included in intervention. 'Delayed start' scenario = intervention starts in 2032, with same 2% annual rate of change, all vehicle sizes. 'LFP replaced' scenario= the only LIB vehicles that are replaced have LFP batteries**

If we assume that the cobalt-based version of the cathode (NCO) will become the prevalent chemistry for NIBs in future BEV sales, the demand for cobalt during 2018–2040 would increase by 255%, and for nickel-based NIBs (NNO) the amount of nickel used in BEVs would increase by 43%. In both cases the demand for manganese would drop from the baseline scenario by 29% compared to the increase of 81% seen in the default NMO scenario. An equal mix of the three NIB battery chemistries (NCO, NNO, NMO) is also modelled, though there is not a high likelihood of a market where all three become equally prevalent. The results are summarised in Table 6.[7] However, these results are of limited policy relevance given the much earlier stage of innovation of NIBs and what is estimated to be greater prospects for designing out critical materials.

Difference from baseline in cumulative material use, 2018-2040	Alternative parameter scenarios			
	NMO only (default)	NCO only	NNO only	Equal NMO / NCO / NNO mixy
Lithium	-17%	-17%	-17%	-17%
Nickel	-17%	-17%	43%	3%
Manganese	81%	-29%	-29%	8%
Cobalt	-16%	255%	-16%	75%

Table 6 | Differences from the baseline model in cumulative demand for materials from BEV sales across Model 2a (Battery Chemistry – LIB->NIB) IB chemsitry scenarios: manganese-based (NMO), cobalt-based (NCO), nickel-based (NNO), and an equal mix of all three. Default parameters apply: immediate change (2025), 30% additional 'conversion' of LIB to NIB by final year (2040), all vehicle sizes

Model 2b. Battery Chemistry NCM->LFP

For Model 2b, limiting the effects to Small vehicles only, drastically lowers the magnitude on the reduction in material usage. This was modelled due to the pattern of NCM batteries, particularly NCM-811, being predicted to make up a larger part of Medium and Large market. The scenario therefore assumes that the switch to LFP would happen in smaller vehicles since this is where they are projected to be used more. Also, large vehicles have larger batteries that naturally use more materials, but the expansion of battery pack sizes is expected to increase substantially, especially in later years. The results of this analysis are summarised in Table 7.

Difference from baseline in cumulative material use, 2018-2040	Alternative parameter scenarios		
	Default	Excluding Small	Delayed start
Lithium	-3%	0%	-1%
Nickel	-16%	-1%	-5%
Manganese	-7%	-1%	-2%
Cobalt	-16%	-2%	-5%

Table 7 | Differences from the baseline model in cumulative demand for materials from BEV sales across Model 2b (Battery Chemistry NCM-> LFP) scenarios. 'Default' scenario = immediate change (2025), 30% additional 'conversion' of NCM to LFP by final year (2040), all vehicle sizes. 'Small only' scenario = Small vehicles only included in intervention. 'Delayed start' scenario = intervention starts in 2032, with 16% 'conversion' of NCM to LFP by final year (2040), all vehicle sizes

Model 3. Vehicle Size

The results for Model 3 are presented in Table 8. Although limiting the change to Large vehicles or delaying the start reduces the effect of the intervention on material use reduction, the total effect from the default scenario is relatively low in any case. Doubling the total intervention effect by 60% as of 2040 (with no change to the start date or rate of change) roughly doubles the overall material reduction during the 2018-2040 period.

Difference from baseline in cumulative material use, 2018-2040	Alternative parameter scenarios			
	Default	Large only	Delayed start	60% final effect
Lithium	-5%	-3%	-2%	-10%
Nickel	-5%	-3%	-2%	-10%
Manganese	-5%	-1%	-2%	-10%
Cobalt	-5%	-2%	-1%	-9%

Table 8 | Differences from the baseline model in cumulative demand for materials from BEV sales across Model 3 (Vehicle Size) scenarios. 'Default' scenario = immediate change (2025), 30% downsizing for Large and Medium vehicles (2040). 'Large only' scenario = Large vehicles only included in intervention. 'Delayed start' scenario = intervention starts in 2032, with 16% downsizing by final year (2040), all vehicle sizes

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2 https://www.iea.org/data-and-statistics/charts/overall-supply-and-demand-of-lithium-for-batteries-by-sector-2016-2022

3 https://www.gov.uk/government/statistics/vehicle-licensing-statistics-2022/vehicle-licensing-statistics-2022

4 Phosphate and graphite are also critical materials in some EV batteries, but their material intensity data was not made available.

5 Range of annual average pack sizes in kWh (2018-2040): Small = 44-48; Medium = 59-66; Large = 78-112. For the Large size group, the average pack size increases annually from 2024 projections onwards.

6 https://pubs.acs.org/doi/10.1021/acs.est.1c07875

7 Although the proportions of additional demand on each of the component materials differ greatly depending what chemistry of NIB we model, the difference in total tonnage is as drastic. 43% increase in nickel is 605,000 additional tonnes. 81% increase magnesium is 401,000 additional tonnes. 255% increase in cobalt is 680,000 additional tonnes.

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