White Paper

Electric Avenues to Electric Nations – Lessons in Managing EV Demand

Bridging the gap between EV behaviour and network need.



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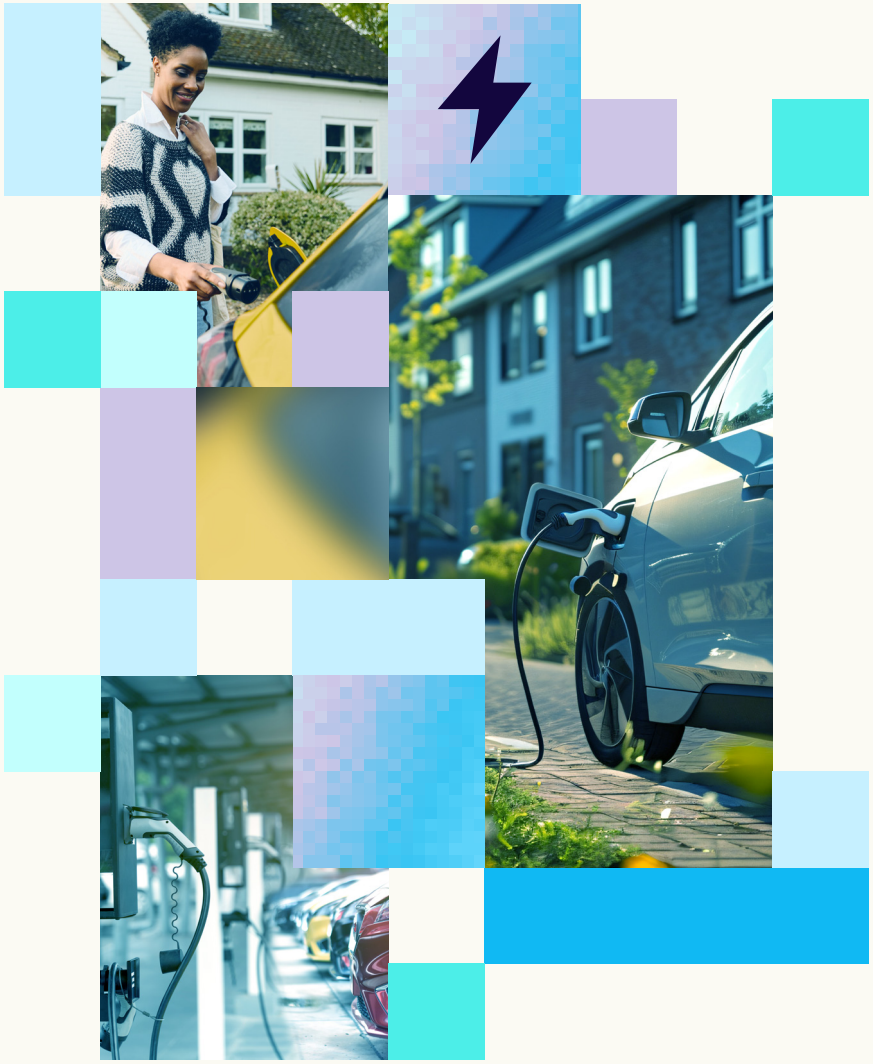
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Introduction

Electric vehicles (EVs) are rapidly becoming mainstream in the UK, driven by decarbonisation goals and a 2030 phase-out of new petrol/diesel cars, requiring vehicles to at least be hybridised.

This surge in EV uptake presents opportunities for cleaner transport, but it also poses significant challenges for electricity networks, particularly at the low-voltage (LV) level with most charging occurring at homes. Distribution Network Operators (DNOs) must ensure that streets full of charging EVs do not overload cables or transformers, nor cause voltage drops beyond statutory limits.

Recognising these challenges early, EA Technology's Net Zero Transition (NZT) consultancy team led pioneering trials to investigate how clusters of EVs impact LV networks and how smart technologies could mitigate these impacts. This white paper discusses key findings from two landmark projects: My Electric Avenue and Electric Nation. It summarises the technical lessons demonstrated (including the proof-of-concept Esprit system and later smart charging and Vehicle to Grid control platforms). Alongside direct project outcomes and learning, this white paper will also examine the broader implications of growing EV adoption for network operators, policymakers, and international stakeholders.



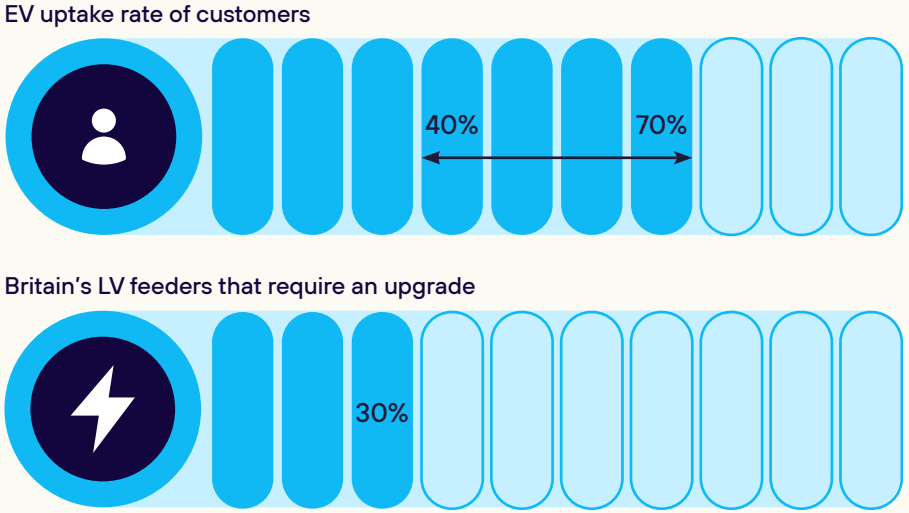
EV Uptake and Challenges for Local Electricity Networks

Electrification of transport introduces new load patterns on distribution grids. The addition of EV charging to a traditional UK household can add substantial additional steady load for extended periods.

When multiple properties on a circuit have EVs, this risks significant levels of concurrent load on a circuit, greatly reducing diversity. During earlier trials within the My Electric Avenue project, a typical home EV charger was rated at 3.5kW. However, 7kW is now the standard power of which is comparable to, or exceeds, the normal evening demand of a typical UK household. As EV battery capacities have increased since commencement of My Electric Avenue, from c25kWh in 2012 to c65kWh in 2025, this doubling of domestic charging rate hasn't necessarily resulted in a significant reduction in charging durations, when EVs are charged. The increased battery capacities have correspondingly increased effective real-world range capabilities, and consequently more drivers are able to rely on an EV for their needs, even with longer commutes. Alternatively, drivers simply don't feel the need to charge as frequently.

Whilst the latter will introduce diversity to EV charging behaviours, if adoption of EVs in a neighbourhood is high (leading to a high uptake cluster in a small area), where charging does occur concurrently, there will be little to no variability for extended periods risking the local feeder or transformer experiencing peak demand far above original design limits.

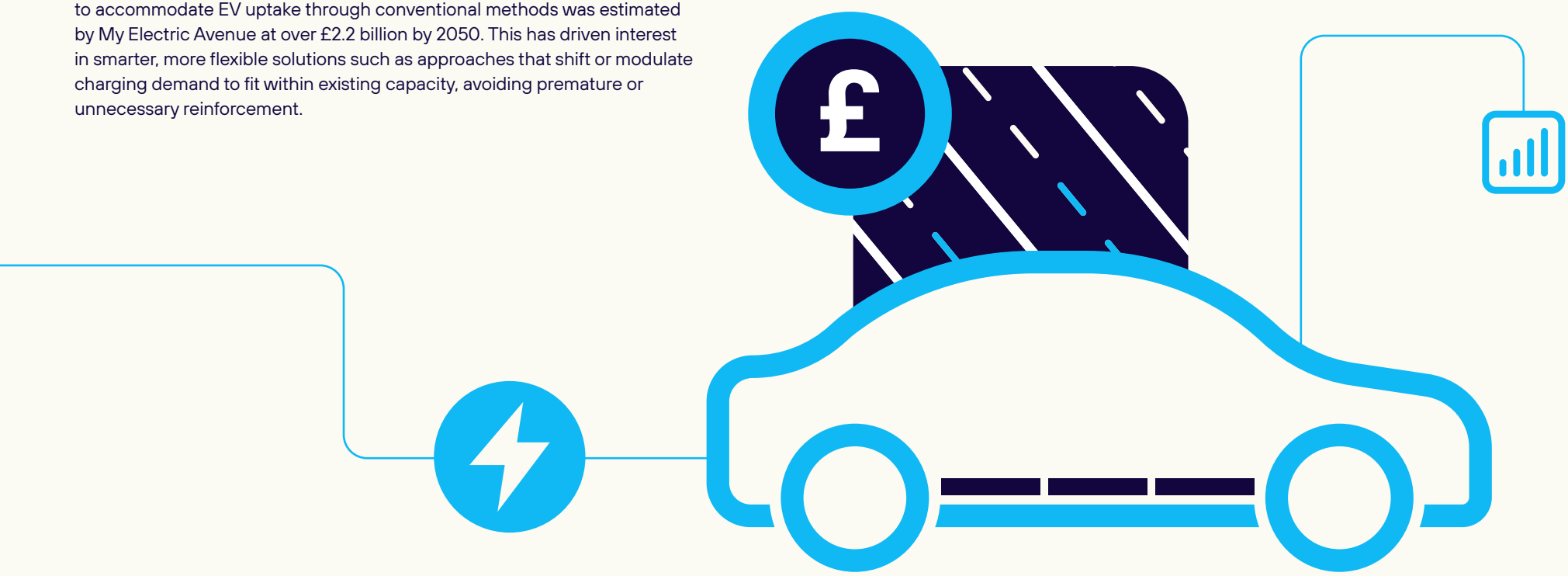
Studies and trials in the UK quantified this risk. Analysis of My Electric Avenue data indicated that around 30% of Britain's LV feeders could require upgrades at an EV uptake rate of between 40%–70% of customers. These issues include thermal overload (cables or transformers exceeding safe amperage) occurring at moderate EV penetration, and voltage drop (where the measured voltage falls below statutory limits of -6% of nominal voltage) problems emerging as uptake increases.



Thermal limits tend to be reached first because cables and transformers have strict ampacity ratings: current flowing through them causes them to heat up, and current higher than the rating results in temperatures exceeding design tolerances which, unlike voltage excursions, does not rectify immediately upon the current reducing to within rating. Underground cables in particular can remain hot for extended periods, meaning repeated overloads can accumulate and damage insulation. Voltage, by contrast, can fluctuate more dynamically around demand peaks and recover as load eases, giving it more headroom before breaching statutory limits.

Conventional mitigation methods are expensive and could require disruptive grid reinforcement works (i.e. digging up streets to lay thicker cables or adding transformers). The projected cost for the DNOs and their customers to accommodate EV uptake through conventional methods was estimated by My Electric Avenue at over £2.2 billion by 2050. This has driven interest in smarter, more flexible solutions such as approaches that shift or modulate charging demand to fit within existing capacity, avoiding premature or unnecessary reinforcement.

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My Electric Avenue: Proof of Concept with Esprit

My Electric Avenue (2013–2015) was the first UK project to trial clustered EV charging on real residential networks. The project, managed by EA Technology, in partnership with SSE Power Distribution, (now SSEN – Scottish and Southern Energy Networks) leased EVs to clusters of neighbours so their charging could be monitored and controlled under realistic conditions.

The project's central innovation was the Esprit system, a proof-of-concept network-focused charging control. Esprit monitored feeder load and, when a pre-set current threshold was reached, could temporarily pause EV charging for some users. Once load dropped, charging resumed.

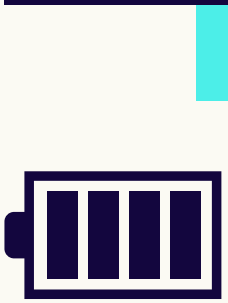
Whilst it was utilised for control during My Electric Avenue, Esprit was never intended as a product to be rolled out for long-term and wider public use. Instead, it served to demonstrate two critical ideas:

1. Technical viability – local LV demand from clustered EVs can be actively managed to stay within safe network limits, avoiding overloads.

2. Driver acceptance – customers will accept DNO-driven charging interruptions if they are short, fair, and transparent. Trial results showed most participants were unaffected, as cars typically had ample dwell time (i.e. the vehicle was plugged in and available to charge for longer than was required to charge the vehicle) overnight to achieve a full charge.

Key findings:

- Around 32% of LV feeders would require intervention at between 40–70% EV uptake, if charging remained unmanaged.
- Esprit successfully demonstrated that real-time load management could increase network headroom, delaying the need for reinforcement.
- Customer surveys confirmed high acceptance: over 80% of participants who experienced curtailment reported neutral or positive views.







Electric Nation: Scaling Smart Charging with Real Users



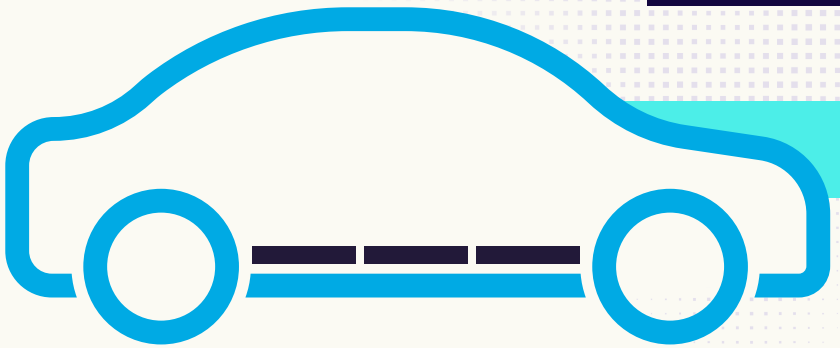
Building on the learning from My Electric Avenue, a follow on project, Electric Nation - which ran from 2016-2019 - was the world's largest domestic charging trial.

Nearly 700 EV drivers across National Grid Energy Distribution (NGED), (at the time Western Power Distribution (WPD)) licence areas participated in the trial. Each participant had a smart charger installed, enabling remote monitoring and time-shifting of charging. Over 140,000 charging events covering 2 million+ hours of charging data were recorded.

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Insights into charging behaviour

The vast amounts of data collected across both My Electric Avenue and Electric Nation allows insights into the charging behaviour of EV drivers and potential patterns that we may observe as the transport sector electrifies.

Some of the key learnings were:

- EVs were often plugged in for 12+ hours overnight, but actual charging time was typically only 2–4 hours.
- Battery-electric drivers charged on average 3 days per week, not every day.
- EV charging was found to coincide with the existing evening peak, effectively doubling per-household After Diversity Maximum Demand (ADMD) in some cases, and driving feeders towards their thermal limits well before voltage issues became apparent.
- While vehicle-to-grid services can support the network at peak times, they also reduce charging diversity — discharged vehicles require deeper and more frequent recharging, creating higher and more coincident overnight demand than conventional EV charging.

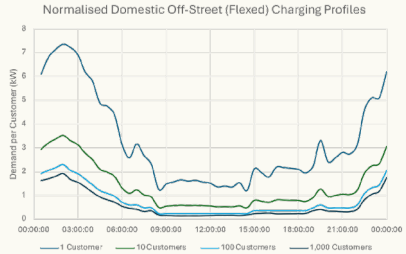
Smart charging in practice:

Various smart charging regimes were trialled during the Electric Nation project, with participants using apps to interact with the smart charging system. In the final part of the trial, participants were rewarded financially if they delayed charging until after the evening peak. **61% of participants** chose to do this, leading to significant shifts of charging into overnight low-demand periods. This validated that tariff-driven nudges can meaningfully flatten demand, aligning charging with both network headroom and renewable generation availability.

The inclusion of distribution network needs within the smart charging control hierarchy is necessary to ensure that a control system approach that only considers user requirements and market pricing do not create a new peak. Not considering network limitations risks unplanned 'herding behaviour' (e.g. all EV charging commences at 1am) . Whereas, it would have previously been naturally distributed by variations in the time when people arrive home in the evening, in some cases being coincident with the normal evening peak load.

Network impact:

Analysis of the Electric Nation data confirmed that unmanaged clusters still risk overloading about a third of feeders once uptake is between 40–70%, which will result in more costly reinforcement of the distribution networks. However, when ADMD[1] charging profiles developed from the trial datasets values were incorporated into DNO planning tools, the resulting reduction in the assumed peak load avoided over investment. My Electric Avenue found that smart charging had the potential to defer or avoid over £2 billion of reinforcement by 2050.



Example of Normalised Domestic Off-Street ADMD Charging Profiles, showing how considering increased numbers of vehicles increases the charging diversity and lowers the ADMD per charging point / vehicle.

My Electric Avenue found that smart charging had the potential to defer or avoid over £2 billion of reinforcement by 2050.

[1] **ADMD** is the average maximum demand per customer on a feeder, observed when the demand of many customers is aggregated. Because not all households use their peak loads at the same time, the **diversity effect** means the per-household contribution to the feeder's peak reduces as the number of connected customers increases.

Electric Nation V2G: Exploring Bi-Directional Flexibility

The Electric Nation – PoweredUp project (2020–2022) extended the concept of smart EV charging into Vehicle-to-Grid (V2G)[2].

Around 100 homes were equipped with bi-directional 7 kW chargers, managed by multiple suppliers via the CrowdCharge platform. EA Technology's role in this project was the development of demand profiles based on the trial data. Demand profiles enable network operators to model the impact of demand on their networks.

Key findings:

- Customers discharged to the grid during peak hours when incentivised, and charged overnight at low rates.
- A major learning was that diversity, normally relied upon in network planning, broke down under V2G: tariff incentives and the need to replenish larger amounts of energy (beyond normal driving use) caused customers to behave in a highly coincident way.
- This created reduced diversity and higher coincident overnight demand, challenging the assumption of normally distributed load profiles.
- Where different tariff designs were tested, they could help stagger behaviours to some degree, but without very careful design, synchronised charge and discharge peaks emerged, creating new stresses.
- Practical issues such as slow grid connection approvals (average 62 days) highlighted the need for streamlined processes to enable scalable V2G.

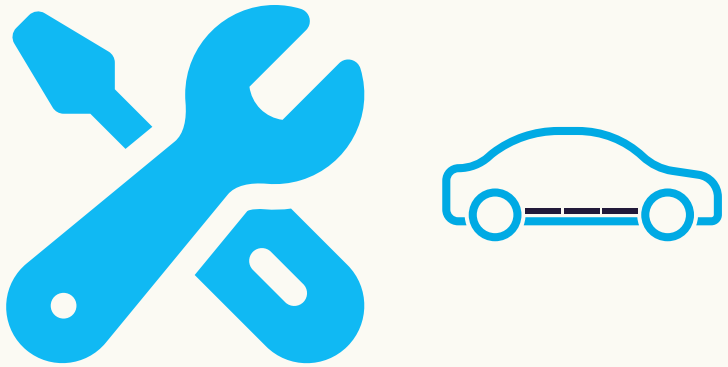
This trial showed that while V2G can support LV networks, its success depends on alignment between energy markets, customer incentives, and network constraints.

[2] V2G is the operation of plug in EVs to both charge and discharge to the grid.

Smart Grid Solutions Emerging from These Trials

Across My Electric Avenue and Electric Nation, a toolkit of solutions has emerged:

- **Direct demand response** – proven by Esprit's proof-of-concept, now evolving into integrated smart chargers with embedded control.
- **Tariff-based management** – demonstrated at scale in Electric Nation, showing customers will respond to ToU price signals.
- **Load rotation/cycling** – simple algorithms can pause some chargers to avoid feeder overload.
- **Vehicle-to-Grid** – offers future bidirectional flexibility, provided market and network coordination evolve in tandem.
- **Data-driven planning** – trial data improved ADMD estimates, helping DNOs target interventions more precisely.





Bridging the Data Gap: Aligning Flexibility with Network Needs

A critical challenge emerging from the transition from trials to business-as-usual is the misalignment between data held by flexibility providers and network operators.

- **Flexibility providers** (e.g. aggregators managing fleets of EVs) typically have good visibility of their customers' charging patterns and forecasted demand. This allows them to predict when their pool of EVs is available for load shifting or V2G services. However, they have no direct view of how those vehicles' charging sessions map onto specific LV feeders or transformers.
- **Distribution network operators (DNOs)**, on the other hand, increasingly have detailed data on total network loading particularly with the increased installation of LV monitoring solutions such as VisNet® from EA Technology. Network operators have visibility of periods where a feeder is approaching thermal or voltage limits, but cannot disaggregate that load to determine how much comes from EV charging, nor which part of that is "flexible" versus inflexible.

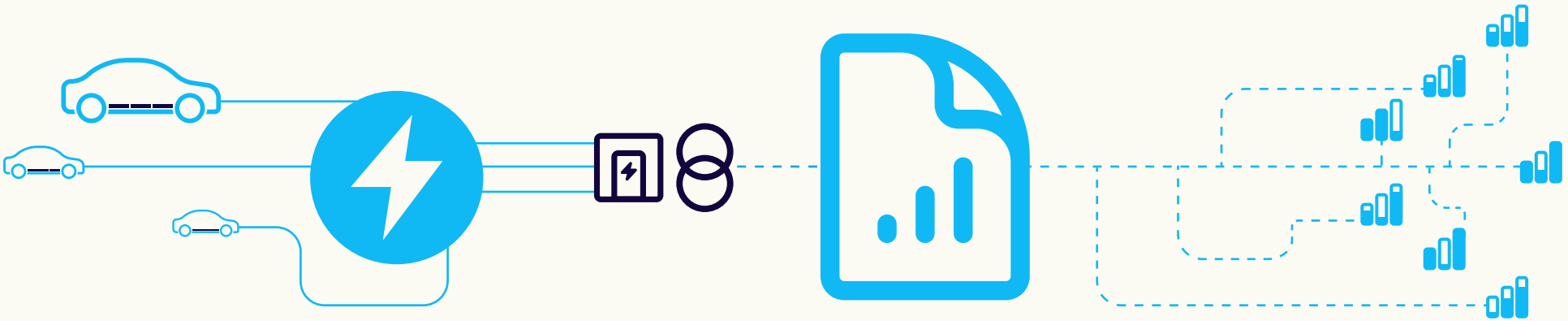
This creates a structural gap:

- Flexibility providers know how much controllable demand they hold, but not its impact on the local network.
- DNOs know the total stress on their assets, but not how much of that can realistically be shifted.

Further complexity arises as some EV charging will be associated with registered flexibility services, while others will not - and the DNO currently has no way to distinguish between the two.

Without bridging this gap, the risk is that flexibility signals do not align with network need. For example, a flexibility provider may reduce charging in one cohort, yet this may not meaningfully relieve stress on the specific feeder at risk. Conversely, a DNO may call for flexibility services, but find the provider's portfolio poorly located or insufficient to address the issue.

Narrowing this data gap is essential.



Potential solutions include:

- Secure, anonymised data sharing between DNOs and aggregators to map controllable demand to network topology.
- Standardised data exchange protocols that allow both parties to understand the overlap between overall network load and flexible assets.
- Development of "visibility tools" that integrate LV monitoring data with flexibility portfolios to create a common operational picture.

Counterfactual uncertainty:

Another complication is the lack of robust counterfactual data. Once flexibility services are implemented, historic load traces no longer represent "natural" customer behaviour — they already include the impact of previous interventions. Without knowing what charging would have looked like in the absence of control signals, it becomes difficult to forecast future loading accurately.

This risks creating a self-reinforcing feedback loop: charging patterns shift in response to past flexibility signals, future forecasts are based on these altered behaviours, and subsequent interventions are then shaped by those forecasts. Over time, this can create a closed-loop system that constantly shifts its own baseline, making it harder for DNOs and flexibility providers alike to plan interventions with confidence.

Crucially, any approach must respect GDPR and wider data protection requirements. Household-level EV charging data is highly sensitive and could reveal personal behaviour patterns. This means raw customer data cannot simply be shared between parties. Instead, solutions must:

- Rely on aggregated or pseudonymised datasets that provide actionable insight without exposing individual identities.
- Establish clear governance frameworks to define what data can be shared, who can access it, and for what purposes.
- Build customer trust by ensuring transparency about how charging data may be used to support grid reliability.

Only by addressing these privacy considerations can DNOs and flexibility providers collaborate effectively to ensure LV networks fully benefit from EV charging flexibility.



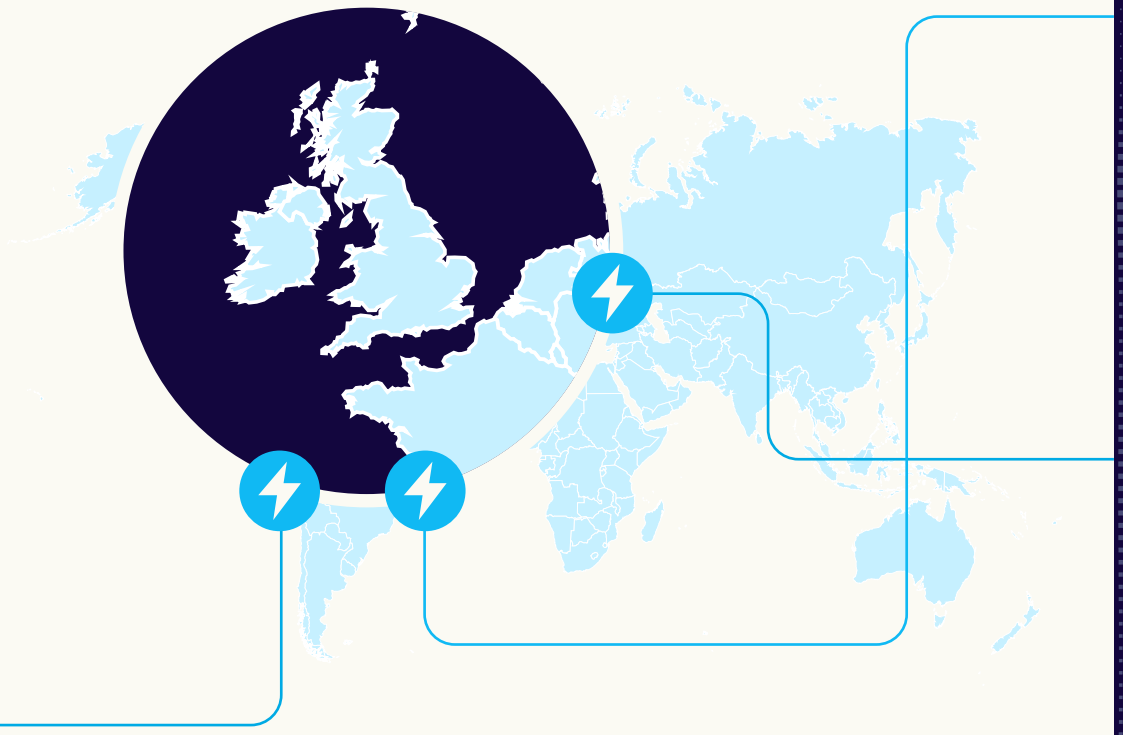
Policy and Collaboration Implications

The projects highlight several policy and industry needs:

- **Mandating smart chargers** – this is now in place in the UK, and was influenced by innovation project learnings such as those discussed within this white paper. However effective roll-out is slow, as just because EV chargers have the capability to be utilised in a 'smart capacity' this doesn't result in customers choosing to do so.
- **Enabling DNO access to flexibility** – regulators must ensure DNOs can procure demand response as an alternative to reinforcement. The current price control period saw DNOs move to a 'flexibility first' approach to reinforcement – examining whether flexibility can be used as an alternative to conventional reinforcement. This includes flexibility from EV charging.
- **Aligning market signals with network needs** – tariffs and flexibility services must be designed to complement, not conflict with, local constraints.
- **Streamlining connections** – especially for V2G, processes must be faster and more consistent.
- **Cross-industry collaboration** – automotive, energy, and regulatory sectors must continue to align on standards, communications, and consumer engagement.

International Relevance

While rooted in UK trials, the findings are globally relevant. Any country with rising EV uptake will face similar LV network clustering issues. The UK's approach, running large-scale consumer trials and publishing data openly, provides a model for others. The principle that smart management can defer costly reinforcement is universal.



Conclusion

The transition to electric mobility need not overwhelm distribution grids. The Esprit proof-of-concept in My Electric Avenue showed that network-driven charging control is technically viable and socially acceptable, while Electric Nation demonstrated that scalable smart charging and tariff-based flexibility can work in practice.

The follow-on Electric Nation V2G project further highlighted the opportunities and complexities of bi-directional flexibility.



The key overarching outcome of the analysis is clear; EVs can be part of the grid solution, not just a problem.

Collectively, these projects have:

- Quantified the scale of the EV challenge for LV networks.
- Demonstrated the effectiveness of smart solutions to defer billions in reinforcement costs.
- Highlighted the importance of customer engagement, market alignment, and regulatory support.
- Shown the need to bridge the data gap between DNOs and flexibility providers, so that network visibility (top-down) and controllable EV charging data (bottom-up) can be aligned. This integration is vital for ensuring flexibility services actually relieve network stress where and when it matters.
- Underscored that data protection regulations (e.g. GDPR) are not barriers but design parameters: any solution must safeguard privacy while enabling the secure exchange of aggregated or anonymised insights.
- Drawn attention to the challenge of counterfactual uncertainty: once flexibility services alter behaviour, historical data can no longer be taken as a baseline. Without accounting for this, forecasting risks creating feedback loops where interventions continuously reshape the very patterns they are intended to predict.

The key overarching outcome of the analysis is clear; EVs can be part of the grid solution, not just a problem. By adopting smart charging, refining data-sharing frameworks under GDPR-compliant models, and aligning incentives across the energy value chain network operators and policymakers worldwide can enable an EV future that is both cost-effective and reliable.

Next Steps

The My Electric Avenue and Electric Nation programmes have provided a strong foundation of evidence on the network impacts of EV uptake and the effectiveness of managed charging solutions.

They demonstrated that:

- Thermal constraints typically arise before voltage issues, requiring proactive management of LV feeders.
- Smart charging and tariff-driven interventions can mitigate evening peaks, but alignment between flexibility providers and DNOs remains incomplete.
- V2G offers export benefits at the evening peak, but introduces additional complexity by increasing overnight recharging demand and reducing diversity.
- Data sharing, counterfactual baselines, and GDPR-compliant frameworks remain unresolved challenges that limit the ability to target flexibility precisely where it is most valuable.

The logical next step is to translate these insights into practical business-as-usual tools and processes for network operators. EA Technology is already advancing this through projects such as NIEV (Northern Ireland Electric Vehicle) for Northern Ireland Electricity Networks (NIEN).

This programme is focused on:

- Addressing the counterfactual challenge by testing approaches that separate "natural demand" from "controlled demand," to avoid closed-loop forecasting errors.
- Evaluating potential charging management approaches to determine the best approach to ensure customer requirements are met, whilst minimising impact on the distribution network.
- Identification of technical and commercial challenges to implementation of these approaches.
- Determining requirements for secure and anonymised data exchange frameworks between DNOs and aggregators, ensuring GDPR compliance while enabling effective coordination.

Through NIEV, we aim to identify the solutions necessary to close the capability gaps highlighted in this white paper – in particular the alignment of bottom-up flexibility data with top-down network visibility, and the incorporation of EV and V2G load profiles into standardised planning and operational tools.

EA Technology's work with NIEN will therefore provide the next layer of evidence, building on the UK's earlier trials to deliver practical solutions for EV-ready networks. These outcomes will not only inform NIEN's planning and operations, but also offer replicable models for other utilities facing the same challenges worldwide.

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