VOLTEMPO®

Future Fleet Alpha

Work Package 5: Trial Protocol Document

Contents

1 Introduction

1.1 Purpose of this document

This document sets out the trial protocol for the Future Fleet project. It defines what the trial will test, how each phase is designed, the order in which activities happen, what must be true before each stage can start, and how results will be measured and evaluated. It builds on the work carried out in the Alpha phase, including:

- D2.1.1 Fleet and Charging Location Archetype Report
- D3.1.1 Future Fleet Smart Energy Management Schemes and Business Models
- D4.1.1 Future Fleet Geospatial Modelling of eHGV Demand Report
- D4.2.1 Future Fleet Energy System Cost Benefit Assessment Report
- D4.2.2 Fleet Operator Total Cost of Ownership Report

1.2 Executive Summary

The trials are set out to demonstrate that an eHGV (electric Heavy Good Vehicles) depot can be run within a smaller grid connection, and at a reduced connection and energy cost, than it would need if charging were left unmanaged, and that the ways of achieving this still work for the operator's schedules and costs. By proving this, fleets could be electrified faster both through the financial incentives created and because a smaller connection can be granted more quickly than a larger one.

Future Fleet is led by UK Power Networks and funded by Ofgem and UK Research and Innovation through the Strategic Innovation Fund, managed in partnership with Innovate UK. The consortium delivering the trials comprises UK Power Networks as lead network operator, logistics operators Maritime Transport and Voltloader, megawatt charging provider Voltempo, and industry partners Energy Systems Catapult and Baringa.

Four measures could cut the peak power draw. Three are proposed for testing, added one at a time so the effect of each can be seen on its own:

- **Phase 0** records how the site charges today, with no smart energy management applied, providing a baseline for the follow-on Phases.
- **Phase 1** explores the effects of smart charging, for example by only allowing charging inside a set overnight window, and would measure the effect on the site's peak power draw and on day-to-day operations.
- **Phase 2** adds a battery at the site, and possibly on-site generation, to test whether the site can reliably stay within an even lower limit on the power it draws from the grid, and whether the battery pays for itself without subsidy.
- **Phase 3** tests whether neighbouring nearby energy users whose demands peak at different times of day can share one grid connection that is smaller than the total of their individual peaks. This is the energy hub concept. It works where demand profiles are complementary, whatever type of site each participant is. A group could be two or more HGV depots that charge at different times, or a depot with nearby energy users or generators such as a daytime

industrial or commercial load, provided their peaks fall at different times. The trial would test how much capacity the combined profile saves against the sum of the individual peaks, and whether the commercial and connection arrangements needed to share a connection work in practice.

Vehicle-to-grid (V2G), where parked vehicles feed power back to the site or the network, may be studied using models built from the Phase 0 and Phase 1 data. It could be added as a live trial later if vehicle manufacturers and technical support are available.

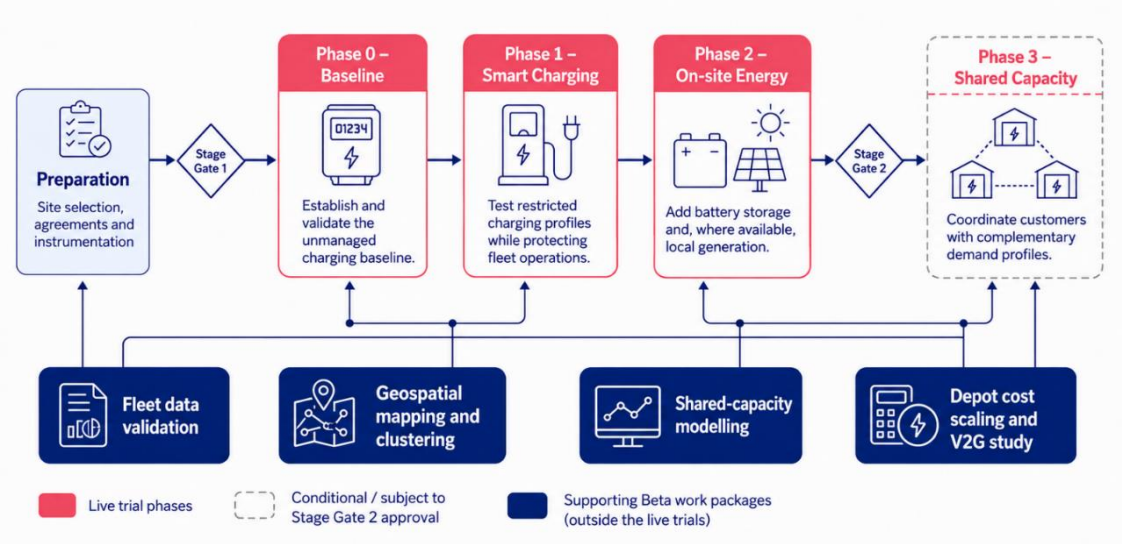
The trials should be conducted across multiple sites, with each site representing a different stage of electrification, site type, or level of grid-connection constraint. This will allow the same phases to be tested under different starting conditions and ensure that the findings are robust and not dependent on the experience of a single site. The trials should be spread out adequately to provide a representative understanding of the challenges faced across the network, while also covering a range of site archetypes. Four analysis strands extend the results beyond the trial sites: validating fleet data and archetypes; mapping and clustering at the national level; modelling synergy zones; and scaling depot costs.

Before a phase or analysis strand begins, the programme will ensure the data quality collected through engagement is robust enough to produce reliable and scalable conclusions.

Prior to commencing each trial, there will be a set-up period, which would turn this design into a confirmed set of trials, with sites agreed, a design of experiment produced for each site, monitoring equipment installed and contracts signed. The trials begin with carrying out Phase 0 and Phase 1 sequentially at every site, with Phase 2 applied only at those sites that have the physical space for on-site equipment and where Phase 1 has not already delivered the capacity reduction required. Where Phase 2 is not run at a site, its effect would be modelled using data from sites where it is. V2G modelling would proceed regardless, with Stage Gate 2 determining whether a live V2G demonstration is also taken forward.

The outputs are designed so that both the logistics industry and energy sector can see the benefits we are demonstrating and encourage the electrification of eHGV fleets.

Figure 1 – Future Fleet Beta trial at a glance



2 Programme Objectives

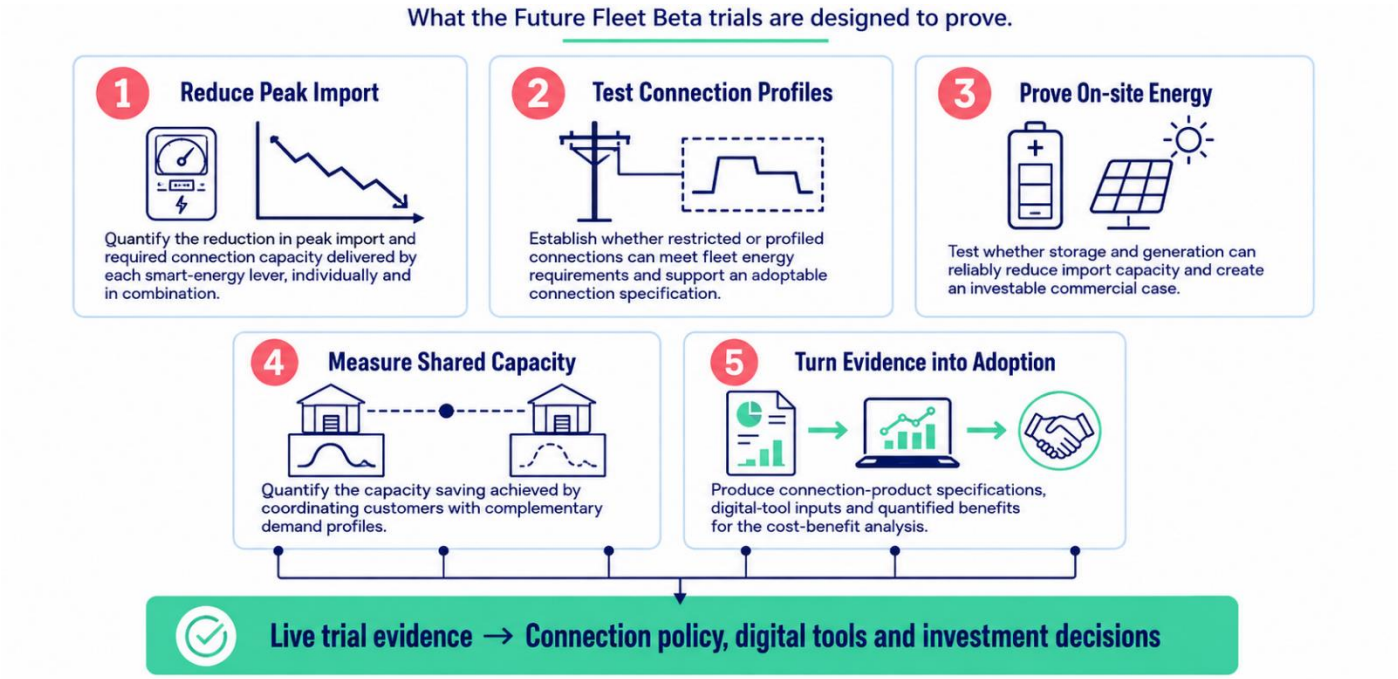
The trials aim to show that eHGV fleets can be charged in a way that limits their impact on the electricity network, while also benefiting the fleet operator. Smart charging, battery storage, on-site generation such as solar and shared capacity could cut the peak demand a site places on the network, which can lower the cost and time involved in getting a grid connection. The same measures could also cut the fleet operator's energy costs, through cheaper charging schedules, income earned from the battery, and sharing capacity with neighbouring sites.

The trials will seek to test this at working depots. They will measure how much peak demand and connection capacity each opportunity could avoid, whether the resulting arrangements could work for the operator, and whether the evidence might support a network operator changing how it makes connection offers.

2.1 Trial objectives

Figure 2 outlines the five proposed objectives of the trial phases:

Figure 2 – Beta trial objectives



2.2 Research questions

Below are the research questions the trial sets out to answer and the assigned phase or analysis strand that produces the evidence. The detailed sub-questions for each phase are set out with that phase in **Section 4**.

Table 1 – Primary research questions and where they are answered

Research question	Associated Phase/Analysis	Section
What is the minimum grid connection capacity required to meet the fleet's operational charging requirements without unmet energy demand, and what effect does charging within those limits have on the site's energy costs?	Phase 1 at each trial site	4.2, 4.3
Can a connection with agreed limits on when and how much power is used operate reliably enough for a network operator to offer a connection on that basis?	Phase 1 connection types, to be reviewed with UK Power Networks Connections and its Distribution System Operator (DSO) team	4.2
How much can an on-site battery and generation cut the power a site needs to draw from the grid, and is that enough to move it into a cheaper connection cost band?	Phase 2, following Phase 1 at each site	4.2
Do the energy cost savings and the income earned from the battery in different markets justify buying it?	Phase 2 payback modelling; handover to cost-benefit analysis	4.2
How much grid capacity is saved when neighbouring sites busy at different times coordinate, compared with each one sized for its own peak?	Phase 3 modelling stage and synergy zone modelling	4.2, 4.4
Can a group of neighbouring sites actually be brought together to share a connection, and on what legal and commercial terms?	Phase 3 live stage, conditional on Stage Gate 2	4.2
Do the findings hold for different types of fleets, different daily driving patterns and different parts of the network?	Sites 2 and 3; fleet data validation	4.3, 4.4
Does the cost of charging per unit of energy fall enough as depots get larger to support selling charging as a service to small fleets?	Depot cost scaling analysis	4.4
Can vehicles feed power back to the grid without disrupting their normal working day, and earn worthwhile income?	Vehicle-to-grid study, modelled against Phase 0 and 1 data	4.4

3 Trial design

3.1 Scope of this work package

This section covers the design, delivery and evaluation of the trials. It defines what each trial tests, how it is measured, the conditions under which it progresses, and what it produces. It also identifies the additional workstreams required to support the trials, including work that builds on the Alpha outputs or work to be introduced as part of the follow-on phase. This document sets the design at programme level. A site specific design of experiment would then be produced for each trial site during mobilisation, confirming the variables to be tested, the data required for a reliable result, and the length of each phase before it begins.

Table 2 – Scope of Trials, Outputs and Supporting Workstreams

Theme	In scope for this work package	Dependency, delivered elsewhere	Input/Output
Trial design	Defining the trials, site specific design of experiment, what each phase must achieve to finish, the monitoring equipment needed	None	Input
Trial delivery	Checks that sites are ready, evidence packs for each decision point, safety and change control	Consortium-level programme management and funding release decisions	Output
Baseline and measurement	How the baseline is rebuilt from past data, how things are measured, data quality checks, and assessing each phase against what it had to achieve	None	Output
Fleet data and archetypes	Validation work needed to interpret and weight trial results, and to rank candidate sites	Producing and publishing the national report on fleet types (archetypes) and the geospatial clustering platform	Input
Analysis and battery specifications	Specifications for how charging and the battery are controlled, draft definitions of the new connection types, and the evidence behind them	Adopting any new connection type into connections policy, and the wider work developing the smart energy measures	Output
Digital tools	Trial outputs supplied as calibration inputs, with handover points defined	Build and testing of the pre-application load estimator and the connection cost and timescale estimator	Output
Commercial and policy	Trial-level commercial arrangements: asset lease terms, participant contributions, data-sharing and intellectual property terms	Commercial model report, funding gap analysis, and the explainer on how the connections process works	Output
Engagement	Recruitment of trial sites, fleet participants and cluster members	The programme-wide stakeholder engagement plan and dissemination activity	Input
Reporting and deliverables	Trial protocol, phase reports, evaluation report, product specifications, lessons learned	Cost-benefit analysis, plan for adoption as standard practice, final dissemination	Output

3.2 Design rules

The trials should be designed to the following rules.

- **One measure at a time.** Each phase adds one measure, so its effect can be measured separately from the others.
- **Modelled where necessary.** Where appropriate, modelling will be used to establish a baseline or as a contingency if challenges or delays arise. This helps ensure trial outcomes can still be achieved, and all phases can be completed across all sites where unforeseen issues prevent live delivery. Any modelled results will be clearly labelled in reporting.
- **Spread across sites.** Sites should sit at different stages of electrification and in different network operator regions, so results are not drawn from a single fleet type or network.
- **Measurable and publishable.** Every site should have metering that records energy use at the point where the site connects to the grid, and permission to share and publish the trial data.
- **Operations first.** Fleet operations should take priority over the trial, and no condition should be applied that prevents a vehicle meeting its next departure.
- **Committed when ready.** The shared capacity and vehicle-to-grid parts of the trial go ahead only where the earlier phases and the modelling support them, and where the participants needed have signed up.
- **Trial length designed from data needed.** The length of each phase is set by the evidence it has to produce, rather than by a fixed period. During trial mobilisation we will work out how many charging sessions and site days each result needs and run the phase for as long as it takes to collect them. For example, if a vehicle completes around three charging sessions a day and the analysis needs 100 sessions, that phase would run for roughly 34 days at that site. Mobilisation will also account for seasonality, fleet growth and changes to site operations, which can distort a result.

3.3 Constraints and assumptions

The design rests on a small number of assumptions that are not yet resolved. Each is set out below with the part of the trial that depends on it.

- **A site already managing charging.** The trials assume at least one site that already has a grid connection, runs an eHGV fleet and manages its charging, with usable charging history.
- **Partner network operators.** Repeating the trials at two further sites assumes at least one more distribution network operator, the company that owns the local electricity network, takes part and gives access to its substation and connections data for the area.
- **Vehicles and infrastructure.** The trials assume vehicles are available at the participating sites for the whole of each phase, and that depot infrastructure is ready when the phase begins. This is what would confirm the proposed trials can be delivered in practice. Vehicle availability sits outside the consortium's control and is the most likely cause of schedule movement.
- **Operational priority.** Fleet operations should take priority over the trial at every site, and operators would keep the right to override any trial condition. This assumption would set the safeguards and overrides built into the design, and the requirement that no operational energy goes unserved.

- **Charging history and telemetry.** Participating sites are assumed to hold usable charging records and vehicle telemetry, and to release them for the trial. These are needed to reconstruct the baseline, measure each phase against it and build the supporting models.
- **Data sharing.** The trials assume data-sharing agreements are in place with clear intellectual property terms. Without them the results cannot be analysed across parties, validated or published.

3.4 Key Trial Assumptions and Dependencies

The main trial assumptions and dependencies are outlined in Figure 3.

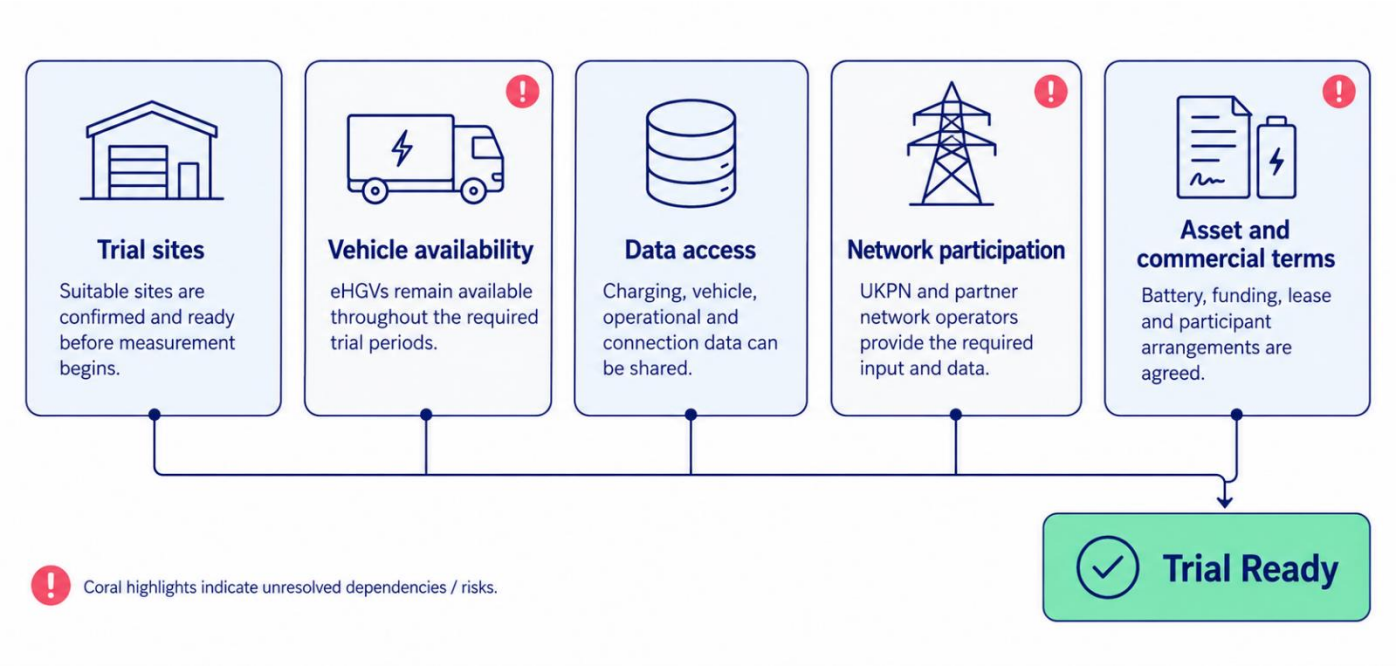


Figure 3 – Key trial assumptions and dependencies

4 Trial structure

4.1 Portfolio overview

The trials at different sites should be staggered to allow lessons learned and refinements identified from the initial trial location to be incorporated into subsequent sites, helping to reduce delivery risks and minimise the potential for delays. This staggered approach will also provide additional time for the complementary workstreams and stakeholder engagement to develop, helping to identify any gaps and ensure that subsequent site selections can take account of any new factors or insights that emerge.

Each site would work through the same phases in the same order (baseline and smart charging, then on-site energy, then shared capacity), and no site is treated as the primary one. Not every site starts at Phase 0: a site that already manages its charging and has enough past charging and vehicle data, can have its baseline rebuilt from that data and begin at Phase 1.

There are expected to be two decision points. The first would follow trial development and preparation and would confirm the sites and scope. The second would decide whether the shared capacity and

vehicle-to-grid parts of the trial go ahead, which happens only if the earlier phases and the modelling support them.

Several other pieces of work would run alongside the site trials: developing the smart energy measures at the start, modelling shared capacity and vehicle-to-grid in the middle of the programme, and the national mapping, clustering analysis and fleet-types report throughout. Where a phase cannot be run live at a site, it can be modelled.

Table 3 – Trial portfolio overview

Element	Measure	What it tests	Where	Mode
Phase 0 and 1: Baseline and smart charging	Smart charging	Whether a fleet can get the energy it needs while charging only inside a limited window, and whether a connection built around that pattern would work for a network operator	All sites	Live
Phase 2: On-site energy	On-site energy	Whether an on-site battery, with solar or other on-site generation, cuts the amount of power a site needs to draw from the grid while still meeting the fleet's demand	All sites	Live where deliverable, otherwise modelled
Phase 3: Shared capacity	Shared sites with spare capacity	Whether nearby sites that are busy at different times of day ie. depots and other energy users or generators, as an energy hub can share a connection smaller than the total of their individual peaks	Subject to a decision point; at least one site	Modelled first, live subject to a decision point
V2G trial	Vehicle-to-grid	Whether vehicles can feed power back to the grid without disrupting their normal working day, and whether that is worth doing	One site, subject to stage gate	Modelled first, live subject to a decision point
Smart energy measure development	All measures	Defining the measures with stakeholders and confirming they work, feeding into the trial designs	Non-site	Analytical
Shared capacity modelling	Shared sites with spare capacity	Finding areas where sites could share capacity (synergy zones) and modelling their combined demand	Non-site	Analytical
Geospatial mapping and clustering analysis	Cross-cutting	Where groups of fleets and parts of the network that are short of capacity sit in the same place, across GB and broken down by network operator region	Non-site, national	Analytical
Archetype report	Cross-cutting	Whether the fleet types and their daily driving patterns are representative across GB	Non-site, national	Analytical

Figure 4 – Trials plan

		Stage Gate 1			Stage Gate 2			
Trial site 1	**Mobilisation** Site selection, agreements, instrumentation	◆	**Phase 0 and 1** Baseline + smart charging	**Phase 2** On-site energy	◆	**Phase 3** Shared capacity, or map and redesign the connections process (Based on Stage Gate 2)		
Trial site 2		◆		**Mobilisation** Site selection, agreements, instrumentation	◆	**Phase 0 and 1** Baseline + smart charging	**Phase 2** On-site energy	**Phase 3** Shared capacity, or map and redesign the connections process (Based on Stage Gate 2)
Trial site 3		◆		**Mobilisation** Site selection, agreements, instrumentation	◆	**Phase 0 and 1** Baseline + smart charging	**Phase 2** On-site energy	**Phase 3** Shared capacity, or map and redesign the connections process (Based on Stage Gate 2)
Trial site x		◆			◆			V2G trial at one site (based on Stage Gate 2)
Supporting Work streams that input into the trials	**Engagement and data collection**							
	Shared capacity modelling				◆			
	V2G modelling				◆			
	National geospatial mapping and clustering analysis				◆			
	National archetype analysis				◆			

Orange denotes the site trials, blue the supporting analysis, green the national-scale analysis, amber a decision point and grey a part of the trial that goes ahead only if that decision is positive. The sites run in parallel and follow the same phases.

4.2 Trial phases

The structure of the trial is based around speed and ease of implementation, and the financial cost. After the initial baseline phase, smart charging would be tested first as it uses equipment the site already has and changes how much power is drawn without adding any assets or altering the connection. This is in comparison to the Phase 0 baseline, and also a baseline of its own, allowing fleets to learn from the trial regardless of their entry point (for example, a fleet new to electric vehicles that is not yet managing its charging, compared with an established one). On site generation and battery storage would follow, as it builds on the ability to understand and manage the fleet's demand and provides an additional means of reducing peak demand, and requires assets to be purchased and

installed on site. Shared capacity would be last because it depends on the earlier measures and on people outside the site's control: a neighbouring site that is busy at different times, someone to bring the parties together, and a site willing to host the connection. Its saving only counts once each participant has smoothed out its own demand as far as charging schedules and on-site equipment allow.

Arranging it also takes the longest: several operators have to agree to charge at one depot and share the site capacity. This phase would need a host site and commercial terms between the fleets. The benefits can only be measured once smart charging has been implemented for the Phase 1 period, so the benefits of shared capacity are not counted as smart charging benefits.

Table 4 – Trial phases

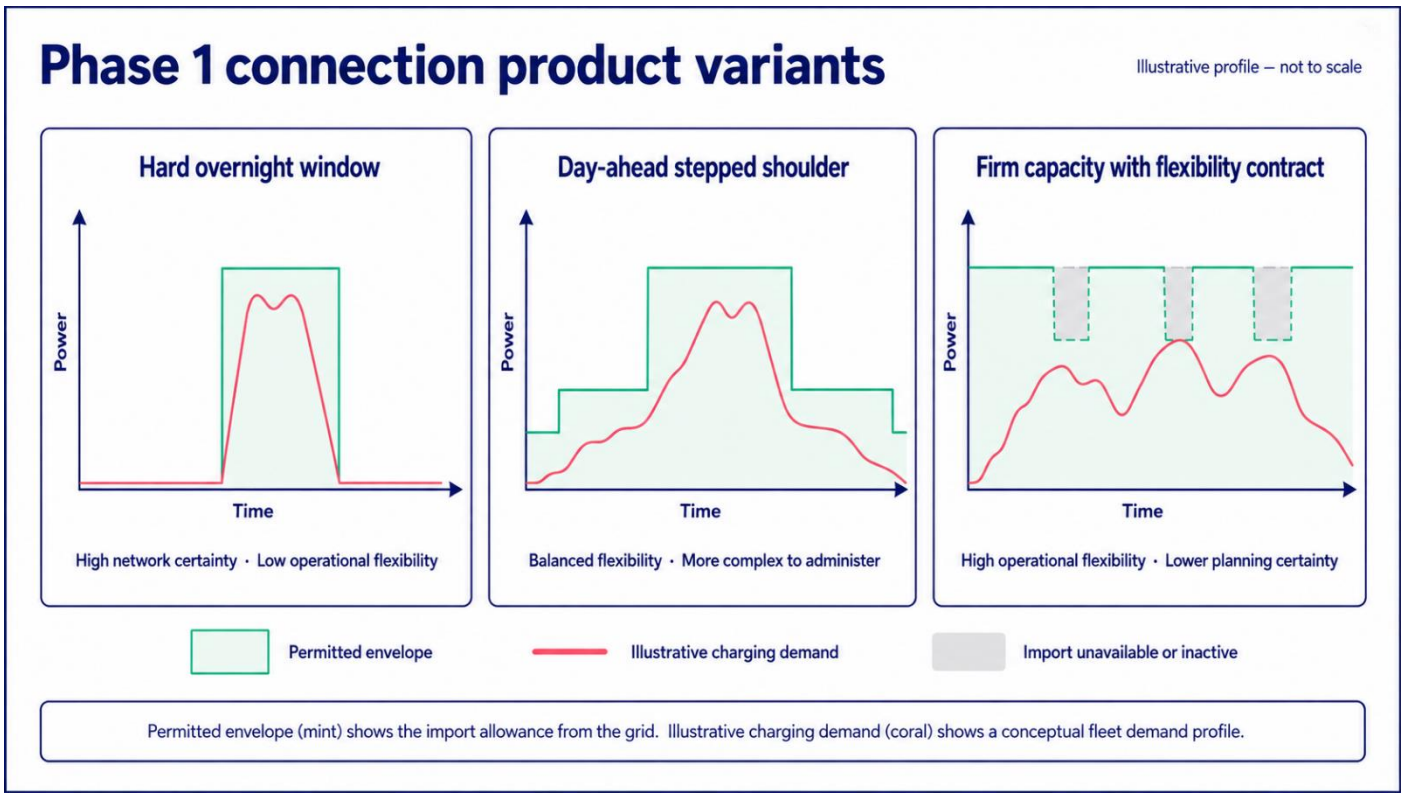
Phase	What it tests	Method	Phase closure criteria
0 and 1: Baseline and smart charging	Whether a fleet can take the energy it needs inside a restricted charging window and within a lower maximum import capacity (kVA) than its existing connection, and whether a connection built around that pattern is dependable enough for a network operator to offer connections on that basis, and what charging within those limits does to the site's energy costs	Establish the site's demand with no smart charging applied (rebuilt from charging history where the site already smart charges), then apply limits on both when the site can draw power and the maximum capacity (kVA) it can draw at any time, and measure against both. Three types of connection are tested (below)	The cut in peak demand and in the maximum capacity the site required, both against the no-smart-charging baseline, are measured for each type; the amount of charging left undelivered is within the agreed limit; the connection product is written up and reviewed by UK Power Networks connections; the operator confirms operations were not disrupted
2: On-site energy	Whether an on-site battery, with solar or other generation where available, lets a site run on less power drawn from the grid than the fleet would otherwise need	Install and run a battery to keep the site within a lower limit on the power it draws from the grid, measured against the smart-charging case so the battery's effect is separate from the charging schedule. Generation is installed on site or represented by metering a nearby site	The capacity reduction quantified against the smart-charging case; the battery has run reliably with no charging left unmet; payback has been modelled
3: Shared capacity	Whether a group of nearby sites that are busy at different times of day (an overnight depot alongside a daytime industrial or commercial site) can be served with less capacity than the total of their individual peaks	Find candidate areas using mapping data, the queue of customers waiting for a connection and data on existing customers, then model the group's combined demand against the total of their individual peaks. Subject to the second decision point, recruit a group and attempt coordinated operation, or redesign the connections process to make shared arrangements feasible instead	The capacity saving is quantified across candidate zones and the changes a network operator would need are written up. A live element proceeds only where a group and a host connection are in place

We anticipate that three types of connection will be tested in Phase 1. Each is defined by two limits applied together: the hours in which the site may import, and a maximum import capacity (kVA) below the site's existing connection, so the phase tests restricted timing and a smaller total capacity at the same time:

- A fixed overnight window, where the site can only draw power from the grid between set hours. This is simple for a network operator to rely on but leaves no allowance if a vehicle returns late.

- A stepped window, where a smaller allowance is added either side of the main window and the next day's limits are published a day ahead. This is more workable for the operator and more complex to administer, and
- A normal connection with a flexibility agreement, where the site keeps its usual capacity but agrees to cut demand when asked. This is the easiest operationally, but a network operator cannot rely on the reduction in the way it can rely on a fixed limit.

Figure 5 – Phase 1 connection product variants



4.3 Trial sites

Sites would be selected to sit at different stages of electrification so that the same phases are tested against different starting positions, for example: one already running managed charging, one earlier in its transition, and one earlier still or in a shared-site setting.

Where a phase cannot be run live at a site (because of the connection, the assets available, or difficulty installing monitoring equipment), it would be modelled using data from the sites where it did run live and reported as modelled.

The types of location the trials would target follow from the Fleet and Charging Location Archetype Report. Priority would go to depot-based sites running predominantly 'Day Driver' operations with long overnight dwell, where almost all daily energy can be delivered at the depot and 'Multi-Drop' or 'Shunting' duty cycles leave the most room to shift charging. These are broadly the restricted 'One-Man-Band' and restricted SME (Small and Medium Enterprise) archetypes.

Site details would be confirmed at the first decision point. The allocation below is indicative.

Table 5 – Trial sites

Site	Stage of electrification	What it adds	Phases
Trial site 1:	Operating an eHGV fleet and already managing charging	Past charging records, so the no-smart-charging baseline can be rebuilt from real data instead of assumed. Already connected and running, so the measures can be tested without waiting for a new connection	Phases 0 and 1 live; Phase 2 live; Phase 3 modelled, with a live trial or a redesign of the connections process subject to the decision point
Trial site 2	Electrifying, charging not yet actively managed	A different fleet type and daily driving pattern, and a second network operator's region and connections process	Phases 0 and 1 live; Phase 2 live where it can be delivered, otherwise modelled; Phase 3 subject to the decision point
Further trial sites	Early in transition, or a shared or third-party connected site	A fleet at the start of its transition, and a setting where the connection is shared or owned by another party	Phases 0 and 1 live; Phase 2 modelled; Phase 3 subject to the decision point

Figure 6 – Trial site portfolio

4.4 Supporting analysis

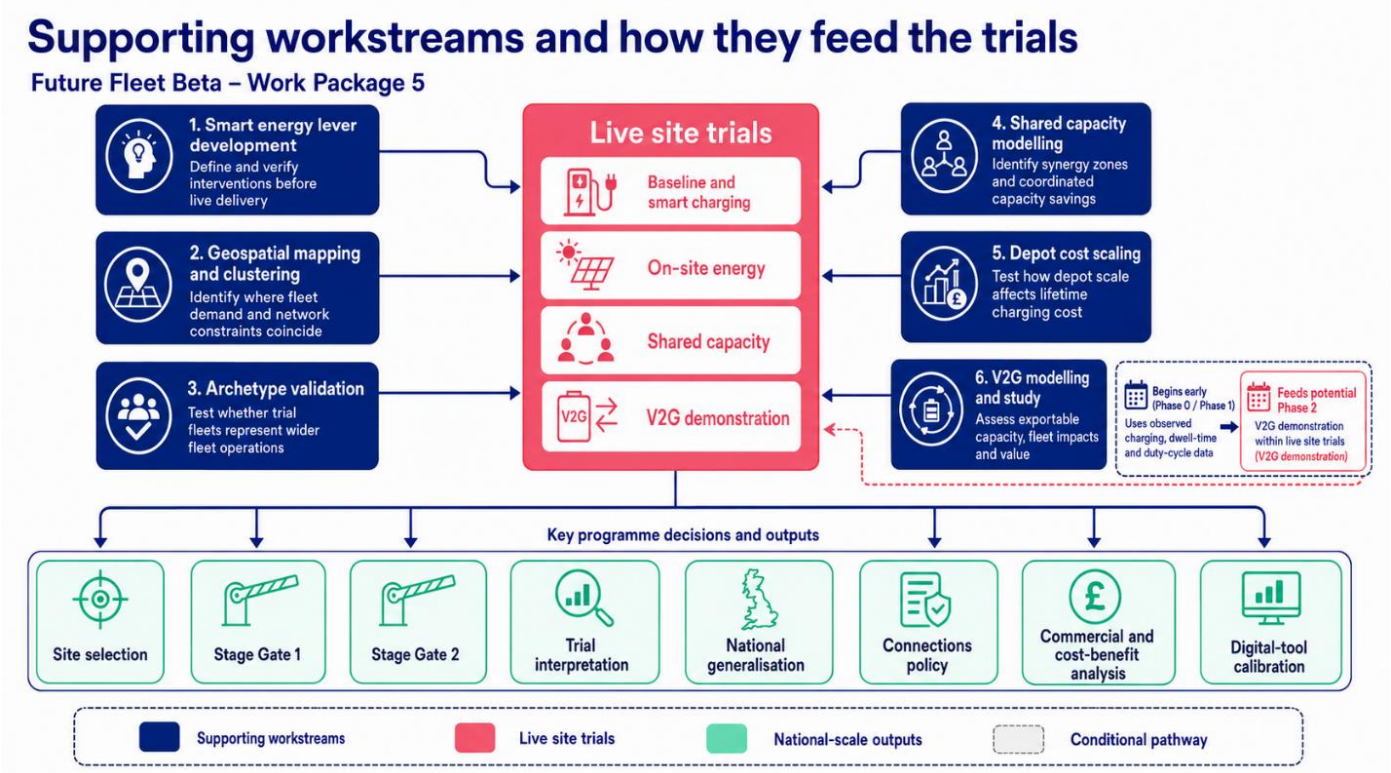
The following workstreams support the trials by doing one of two jobs: it prepares a measure before the trials use it, or it takes what a trial finds at one site and scales it up to national level:

1) Geospatial mapping, clustering and archetype validation would show where high fleet demand and a network short of capacity sit in the same place across Great Britain. That is how the trial sites are chosen, and how their results are applied to the rest of the fleet.

2) Shared capacity modelling would find groups of nearby sites that could share one connection and work out how much capacity each group would save. This happens before any live group trial is committed to.
3) Depot cost scaling would test whether the lifetime cost of charging per unit of energy falls as depots get larger, and whether that supports selling charging as a service to small fleets.
4) Vehicle-to-grid would test whether vehicles can export power during their working day without disrupting operations, and what that income is worth to the investment case. It would be modelled from the duty-cycle data the trials capture, with a live demonstration at one site if modelling permits.

Where this work is also delivered under another work package, this document describes only the part that feeds the trials.

Figure 7 – Supporting workstreams and how they feed the trials



1) Geospatial mapping, clustering and archetype validation

Non-site, national scope. *Analytical. Would feed site selection and the interpretation of all site results.*

Proposition. The fleet types identified in Alpha, and the geospatial model, reflect how fleets really behave across GB, and the scope to shift energy use that the model predicts is real and representative, not an artefact of the dataset.

Research questions. Are the archetypes representative, and which segments are missing? Does the model hold against real routes, how long vehicles stand idle, and daily driving patterns? Do the charging strategies and flexibility the model assumes match how fleets actually run?

Method. Recruit fleets to share trip data. Take in available third-party datasets and anonymise them. Re-run the grouping of fleets into types, and the conversion from driving patterns into energy use,

against the larger dataset. Extend the geospatial model to GB coverage and overlay it on partner DNO substation data, producing a ranked site shortlist cut by DNO region so that each network operator can filter to its own area.

Inputs. Diesel and eHGV telematics; substation headroom data; the connections queue; participating logistics operators, both existing consortium members and new recruits; and data-sharing agreements with clear intellectual property terms, or budget to buy data. Getting access to the data is the main thing that could hold this work up.

Contribution to the trials. Would supply the ranked shortlist of sites used at the first decision point, and the set of fleet types used to weight each site's results when the findings are applied more widely.

2) Shared capacity modelling

Non-site, national scope. *Analytical. Would go ahead regardless; would run before the live Phase 3 stage and reduce its risk.*

Proposition. A network operator can find, model and plan for these opportunities using data it already holds, and a coordinated group needs much less capacity than the total of its members' individual peaks.

Research questions. How much capacity does coordination save against sizing to each peak, across a range of real candidate zones? What process and data would a DNO need to identify these zones as a matter of routine rather than as a one-off study?

Method. Combine geospatial demand and generation mapping with the connections queue and connected-customer metering to identify candidate synergy zones. Build a matchmaking view that identifies customers whose demand peaks at different times and whose connection timescales overlap. Model the group profile using collected metering data and a virtual battery and compare the coordinated requirement with the sum of individual peaks.

Inputs. Geospatial demand and distributed generation mapping; connections queue data; connected-customer metering and demand profiles; input from UK Power Networks connections and its distribution system operator team on what could be adopted as standard process.

Contribution to the trials. Would produce the shortlist of candidate groups and the measured size of the saving that the second decision point is judged against, so recruitment effort goes to areas with a proven saving.

3) Depot cost scaling

Non-site, multi-depot data. *Analysis of the business model; nothing built.*

Proposition. Larger depots have a lower lifetime cost per unit of charging once fixed costs are spread across more vehicles, and selling charging as a service on that basis is attractive to small fleets. Small fleets account for the large majority of operators and face the highest upfront cost.

Research questions. Does the lifetime cost per unit of energy fall as depots get bigger, and what drives that? Can pooling demand across small fleets give them affordable and reliable access to

charging? What operational barriers block it, such as detour distance against service levels, driver hours, and trailer, cable and security arrangements?

Method. Collect cost, utilisation and operational data across a range of eHGV depot sizes. Work out the lifetime cost per unit by depot type and test how size relates to cost. Model a charging-as-a-service business model and use live shared-capacity operations from the site trials as supporting evidence where available.

Inputs. Cost, utilisation and operational data across depot sizes; charge point operators and shared-capacity providers; cost-modelling support; small-fleet operators for demand-side input.

Contribution to the trials. Would set out how the findings from individual sites could apply more widely, including to operators who cannot fund a depot of their own.

4) Vehicle-to-grid (V2G) study

One site, to be confirmed. *Modelled first; a live demonstration depends on the decision point.*

Proposition. Vehicles can feed power back to the grid during their normal working day without disrupting fleet operations, and the income earned is large enough to affect the investment case for depot charging infrastructure.

Research questions. When during a vehicle's day is there genuinely spare power to export, once departure times and the charge that must be kept in reserve are respected? How much income could that earn, and through which markets? What are the implications for battery warranty and asset life, and how do vehicle manufacturers view them? What would a DNO need in place to treat fleet-based export as a planning assumption rather than an unknown?

Method. Model exportable capacity against the duty-cycle and dwell datasets captured in Phases 0 and 1, so the study is based on how the fleets actually behaved. Put a value on that capacity using current and expected markets. Subject to stage gate, run a limited live demonstration at one site, on a small number of vehicles, with manufacturer agreement.

Inputs. Duty-cycle and dwell data from the site trials; vehicles and chargers able to both charge and discharge; manufacturer engagement on warranty; a route to market for exported energy or services; approval at the decision point and release of funding for any live element.

Status. The study would proceed as modelling regardless of the outcome of the site phases. A live element is an option, not a commitment, and no other part of the programme depends on it.

4.5 Commercial arrangements for shared capacity

Phase 3 requires a commercial arrangement between the participating sites as well as a capacity saving that can be modelled. The arrangement is part of what the phase tests, and the live stage cannot proceed without it.

Form of the arrangement. Two forms would be considered. In the first, one party holds the connection and allocates capacity to the others. In the second, the connection is held jointly and capacity is divided by agreement between the members. The form chosen determines who holds the

connection agreement with the network operator, who is accountable for keeping the group within the agreed limit, and how a member joins or leaves.

Terms to be agreed. Each group would need to settle how capacity is split between members, what happens when a member exceeds its share, how the cost of the connection and the ongoing charges are divided, and how long members are committed for. These terms would be drafted during the modelling stage and tested with candidate participants, so that the second decision point is informed by willingness to sign as well as by the capacity saving available.

Output. The phase would produce heads of terms, or a model agreement, that a future group could use without starting from scratch. Where a group cannot be formed, the reasons would be reported alongside the modelled capacity saving.

5 Assessment and measurement

5.1 Basis of assessment

Each phase looks to be assessed on two things: whether the trial was run to a standard that supports a conclusion, and whether the measure delivered the effect the design assumed. The first depends on the length and completeness of the measurement period and on the baseline being established; the second may be measured against the thresholds in Table 6.

5.2 Success criteria by phase

Each phase would have two tests. The first is whether enough good-quality data was collected for the trial to be relied on. The second is whether the measure delivered what the design assumed. Both should be set in advance so that neither can be adjusted once results are known. Values in square brackets are proposed and must be confirmed at the first decision point, with the participating operator, before the phase begins.

Table 6 – Validity and performance thresholds by phase

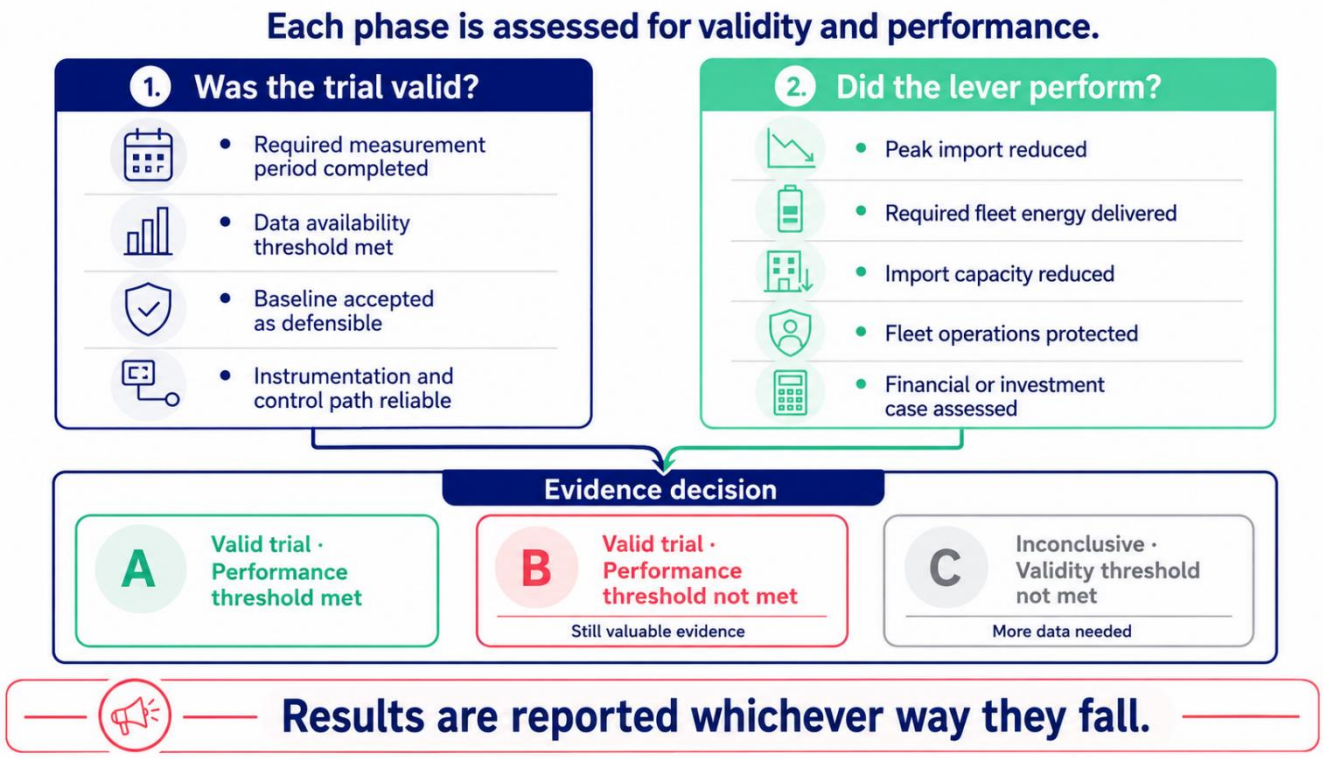
Phase / analysis strand	Primary metric	Data needed for a valid result	Result needed to pass
Phase 0: Baseline	Peak demand and energy use rebuilt from past data, with no charging management applied	At least [12] months of historical charging data, plus [8] consecutive weeks of live metering at [95%] data availability	Not applicable. The baseline is accepted or rejected, not scored. Acceptance requires UK Power Networks to agree that the rebuilt baseline is sound
Phase 1: Smart charging	Cut in peak power drawn from the grid against the baseline; share of the energy needed that is delivered within the connection limits; change in energy cost against the baseline	At least [8] consecutive weeks per connection type at [95%] telemetry availability, covering at least one seasonal peak period	Peak power drawn from the grid reduced by at least [30%] against the baseline; at least [99%] of the energy operations need delivered within the limits; the limits exceeded no more than [2] times a month
Phase 2: On-site energy	Further cut in the power the site needs to draw from the grid against the Phase 1 case; how often the	At least [12] weeks of operation with the battery available for at least [95%] of scheduled hours	The power the site needs to draw from the grid reduced by at least a further [25%] against the Phase 1 case; no charging left unmet; modelled payback within [10]

	battery was available to run		years using central price assumptions
Phase 3: Shared capacity (modelled)	The capacity a coordinated group needs against the total of their individual peaks	At least [3] candidate zones modelled using at least [6] months of metering per participant	Coordinated requirement at least [25%] below the sum of individual peaks in at least [2] of the [3] areas; the changes needed to the connections process written up as recommendations that could be adopted
Phase 3: Shared capacity (live)	Group peak held within allocated shared capacity	A group of at least [3] participants recruited, with a confirmed host connection and at least [8] weeks of coordinated operation	Terms agreed and signed by all members before the live period begins; group peak held within allocated capacity on at least [95%] of occasions, with no participant's operations disrupted
Fleet data validation	How many fleet types are covered, and how accurately the model predicts	Usable data from at least [8] operators and [150] vehicles spanning at least [4] fleet types	Energy per vehicle per day for each fleet type reproduced within [±15%] of observed values; GB-wide geospatial model delivered and broken down by network operator region
Depot cost scaling	Lifetime cost per unit of charging against depot size	Cost and utilisation data from at least [10] depots across at least [3] size bands	A relationship between depot size and lifetime cost per unit shown at [95%] confidence, with the reasons for it identified
V2G study	Spare power available to export during the working day, and what it is worth	Modelled against at least [8] weeks of driving-pattern data from Phases 0 and 1	At least [X] kWh per vehicle per day able to be exported without affecting any scheduled departure, at a modelled net revenue above [X] per vehicle per year

The thresholds in Table 6 are indicative. During mobilisation, the site specific design of experiment would determine how much data each result requires and how long that would take to collect at the site, and the thresholds would be adjusted to match. The periods shown here are a planning guide.

Figure 8 – Phase assessment: validity and performance

5.3 Measurement and data



The table below defines each quantity the trials measure and the data required to measure it. The same definitions would apply at every site; where a site cannot provide an item, the affected measurement would be reported with that limitation stated.

Table 7 – Measurement definitions and data required

Quantity	Definition	Data required	Source
Power drawn from the grid, and peak demand	Highest half-hourly average power drawn at the site's connection point across the measurement period	Half-hourly power drawn at the connection point, and power exported where applicable	Site metering
Baseline (unmanaged) profile	The demand profile that would arise if every charging session began at the earliest point the vehicle was plugged in and capacity was available	At least [12] months of historical charging data; any pre-smart-charging period for validation	Charging platform
Power the site needs to draw from the grid	The lowest limit the site could have run within with no charging left unmet. This is not the same as the capacity in the site's connection contract	Worked out from the measured demand	Site metering
Energy unserved	Energy a vehicle needed before its scheduled departure and did not receive, as a percentage of energy required	Charge level at departure; energy needed for the day's driving; departure times	Telematics and operator systems
Charging window breach	Any half-hour in which the power drawn exceeded the connection limit being tested	Half-hourly power drawn against the limit being tested; instructions issued and carried out	Site metering and scheduling partner
Charging activity	Energy and power delivered per session, and charger availability	Session start and end, energy delivered, power delivered at [1]-minute intervals, faults	Charge point operator or charging platform

Vehicle energy use	Energy consumed and distance travelled per vehicle	Charge level at plug-in and at departure, energy used, distance	Vehicle telematics
Operational impact	Departures affected, and reasons for any suspension of a trial condition	Planned and actual departures, missed or delayed departures and cause, load type	Operator systems and operator log
Asset availability and dispatch	Proportion of scheduled hours the battery or flexible asset was available to respond	Battery charge level, charging and discharging power, availability, losses; generation output	Asset telemetry
Coordination saving	Difference between the capacity a coordinated group needs and the total of members' individual peaks	Member demand profiles; group peak against allocated capacity	Participants and host
Cost of charging	Cost of delivering energy at a site, including the connection, infrastructure, equipment and energy	Tariffs and prices paid, flexibility revenues, connection charges, asset lease and maintenance costs	Operator and partners
Network context	Spare capacity, and any shortage of it, at the substation the site connects to	Spare capacity at the substation, times when it was short of capacity, and position in the queue for a connection	UK Power Networks and partner network operators
Data availability	Proportion of expected data points received at the level of detail required	Received records against expected records per stream	Project data store

Fleet operations should take priority over the trial**.** No trial condition would be applied that would prevent a vehicle from having the charge it needs for its next scheduled departure, and the participating operator can suspend a condition at any point. Suspensions would be logged with the reason, and the affected period would be excluded from measurement.

Where a condition is suspended, the site would return to the arrangement in place at the end of the previous phase. Safety arrangements at each site are governed by the operator's own safety management system.

5.4 How results are compared

Smart charging would be measured against the no-smart-charging baseline. On-site energy and shared capacity would each be measured against the smart-charging case, so each measure would be compared with the position a site could reach using smart charging alone. This would show what each measure adds beyond smart charging, instead of stacking one comparison on top of another.

Sensitivity: Each headline figure would be reported with the range produced by varying the assumptions it is most sensitive to energy prices and how heavily the site is used for cost figures, and fleet growth and changes in driving patterns for capacity figures.

Reporting: Results would be reported per site, with the fleet type and stage of electrification stated. Where results are combined into a national statement, the fleet types they are based on would be named.

Modelled results: Modelled results would be labelled as modelled wherever they appear.

6 Site requirements

6.1 Site characteristics

Candidate sites would be identified from the geospatial and clustering work and through the consortium's existing operator relationships. The characteristics below make a site usable for the trials. They describe what is needed; they are not a scoring system. Sites would be confirmed at the first decision point.

Figure 9 – Trial site selection and readiness

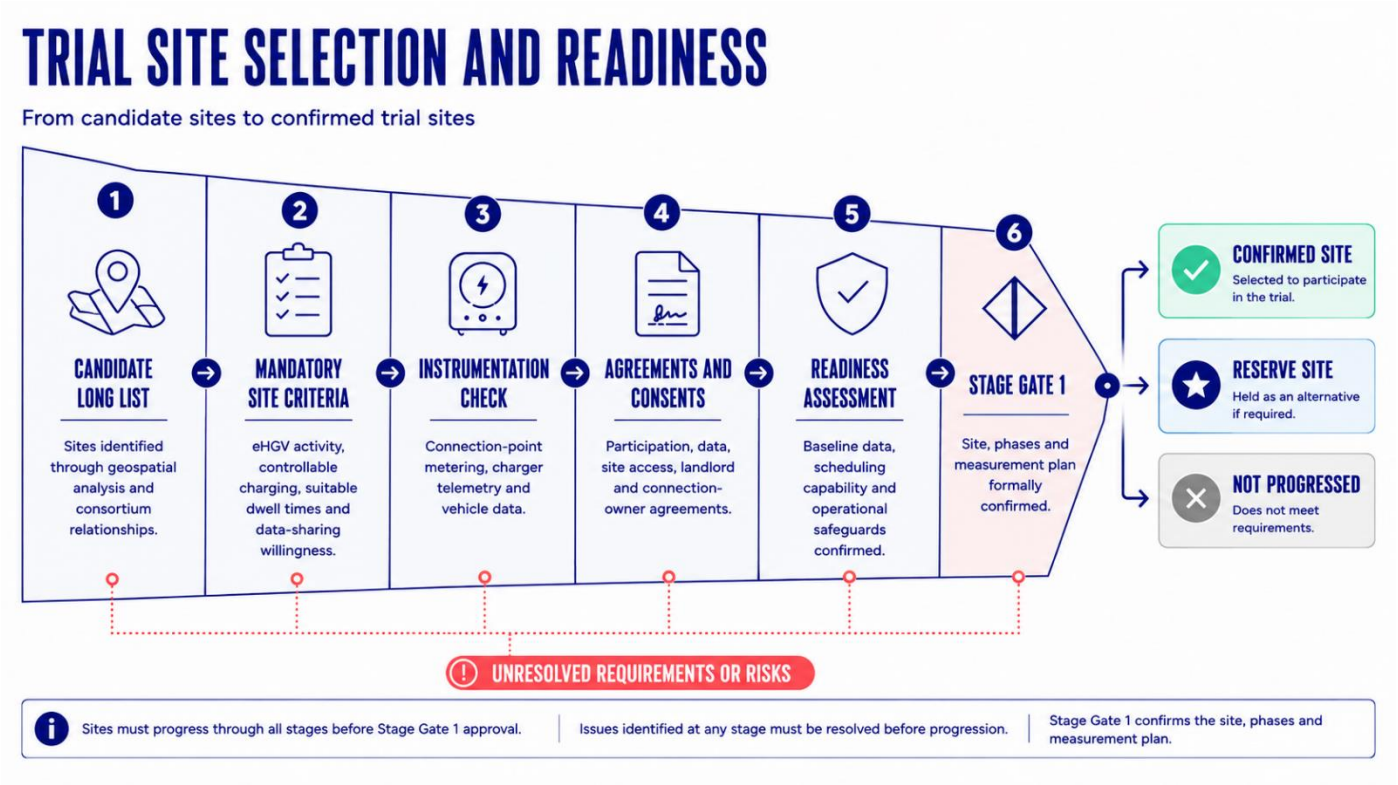


Table 8 – Site characteristics

Characteristic	Why it is needed
Half-hourly metering at the connection point, or the ability to install it	The measurements in Section 5 are based on the power drawn from the grid at the connection point
Charger-level and vehicle-level data available	Needed to link charging sessions to driving patterns and departure times
An eHGV fleet in service, or arriving before the phase starts	The trials measure real driving patterns, not modelled ones
Agreement to share trial data with the consortium and for results to be published	The programme is publicly funded, and results are expected to be published
Charging that can be controlled or scheduled	Phase 1 applies limits on when the site can charge
Space and an electrical arrangement for a battery, and generation where available	Needed for Phase 2 where it runs live at the site
Vehicles standing long enough for charging to be moved to another time	Decides how much charging can be moved into a limited window
Stage of electrification, fleet type and network operator region	Used to spread the sites across different starting positions and regions

6.2 Site readiness

Readiness would be assessed against the requirements below and must be complete before Phase 0 measurement begins at a site.

Table 9 – Site readiness requirements

Requirement	Complete when	Needed before
Connection-point metering	Half-hourly metering of power drawn from the grid installed, commissioned and reporting into the project data store at the level of detail required	Phase 0
Charger and vehicle telemetry	Per-charger consumption and per-vehicle session data available, with vehicle identifiers consistent across systems	Phase 0
Historical data transfer	At least [12] months of historical charging data received, checked for completeness and gaps documented	Phase 0
Duty schedule data	Departure times and the energy each day's driving require, in a form that supports the energy-unserved definition in Table 7	Phase 0
Data agreements	Data-sharing, intellectual property and publication terms signed with the fleet operator, site host and connection owner as applicable	Phase 0
Participation agreement	Scope, phase allocation, operator override rights and the operational limits in Section 3.3 agreed in writing	Phase 0
Baseline acceptance	Baseline rebuilt from past data, with no charging management applied, produced and accepted as sound	Phase 1
Scheduling capability	Charging control able to follow an imposed limit, tested end to end before the trial condition is applied	Phase 1
Connection type definition	The connection limits being tested defined and agreed with UK Power Networks connections and its distribution system operator team	Phase 1
Battery siting and consents	Battery location, electrical arrangement, safety case and any planning or landlord consents confirmed	Phase 2
Battery commercial terms	Lease or purchase terms, participant contribution, and what happens to the battery at the end of the trial, all agreed	Phase 2
Shared-capacity agreements	Participants recruited, host connection confirmed, and cost and capacity allocation between members agreed	Phase 3 (live)

A site may become unavailable for several reasons: an operator's circumstances change, a vehicle delivery slips, or a landlord withholds consent. Because the sites would run in parallel, the remaining sites would continue.

Reserve candidates. A reserve candidate would be identified for each site position during preparation. Swapping in a reserve before the baseline is captured is straightforward. If it happens afterwards, the replacement site would have to capture its own baseline before the later phases can run there.

Loss of the site already managing charging. That site is the one where the no-smart-charging baseline can be rebuilt from real data. If it becomes unavailable, a replacement with existing charging management would be sought first, and the phase timing would be adjusted.

If a site cannot be replaced. The phases planned at that site would be covered by the two remaining sites, and any results that would have come from it would be reported as absent rather than substituted with modelling. Where modelling is used in its place, it would be calibrated against the sites that ran live and labelled as modelled.

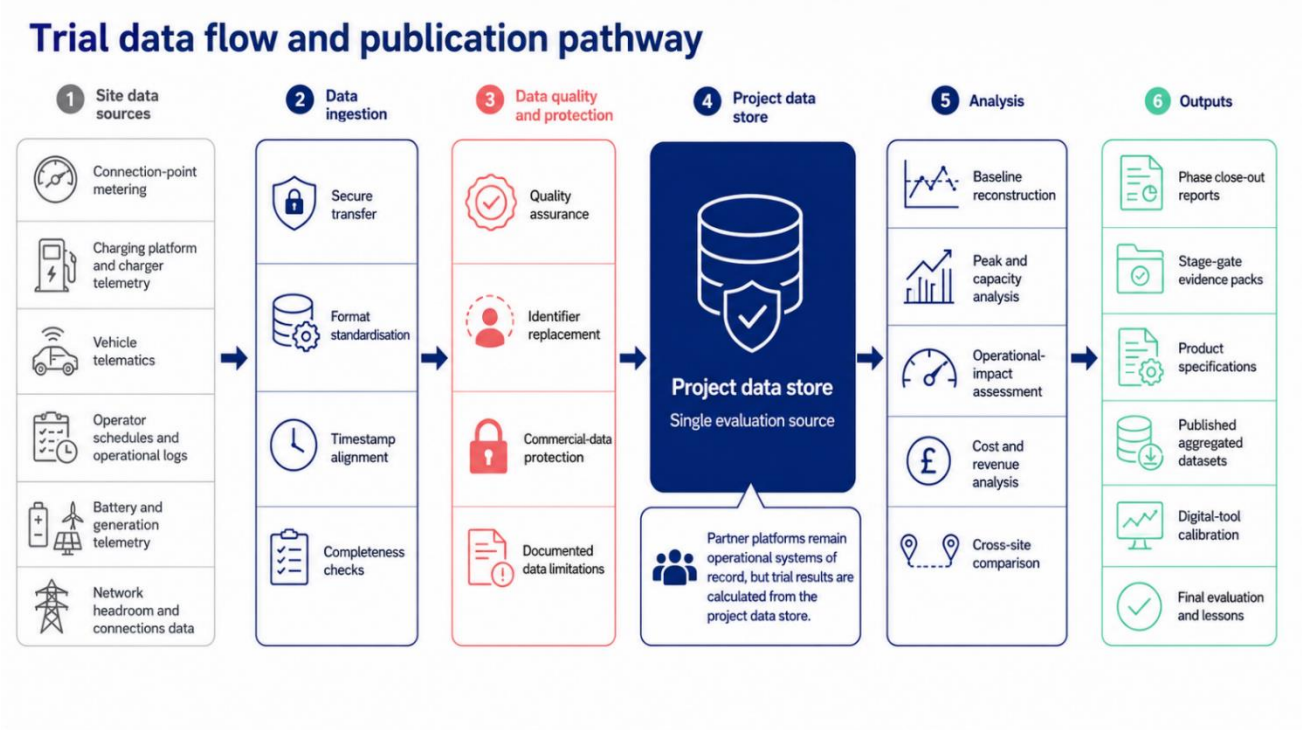
Withdrawal or replacement of a site after the first decision point would be agreed by the steering board. Data already collected at that site would be retained and reported unless the participation agreement requires otherwise.

7 Data handling and publication

Trial data would pass through the stages below, from collection at site through to publication. Vehicle, driver and site identifiers would be replaced with project references before analysis, so results can be published without identifying anyone or exposing commercial terms. Published results would be combined across sites and vehicles.

A single project data store would hold the trial data once it has been collected and would be the only source used for evaluation. Partners' own systems (charging platforms, telematics providers, charge-scheduling tools) would remain the official record for their own operations, but no result would be calculated from them directly, because each system is different and each represents the data in its own way.

Figure 10 – Trial data flow and publication pathway



8 Deliverable list

The deliverables below are what this work package would produce, with the point they are due and where each one goes.

Some deliverables would be produced more than once: a baseline report for each site, and a closing report for each phase at each site. These are listed once, with a note of how often they recur. Deliverables that depend on a decision point are marked.

Figure 11 – From trial delivery to business-as-usual adoption

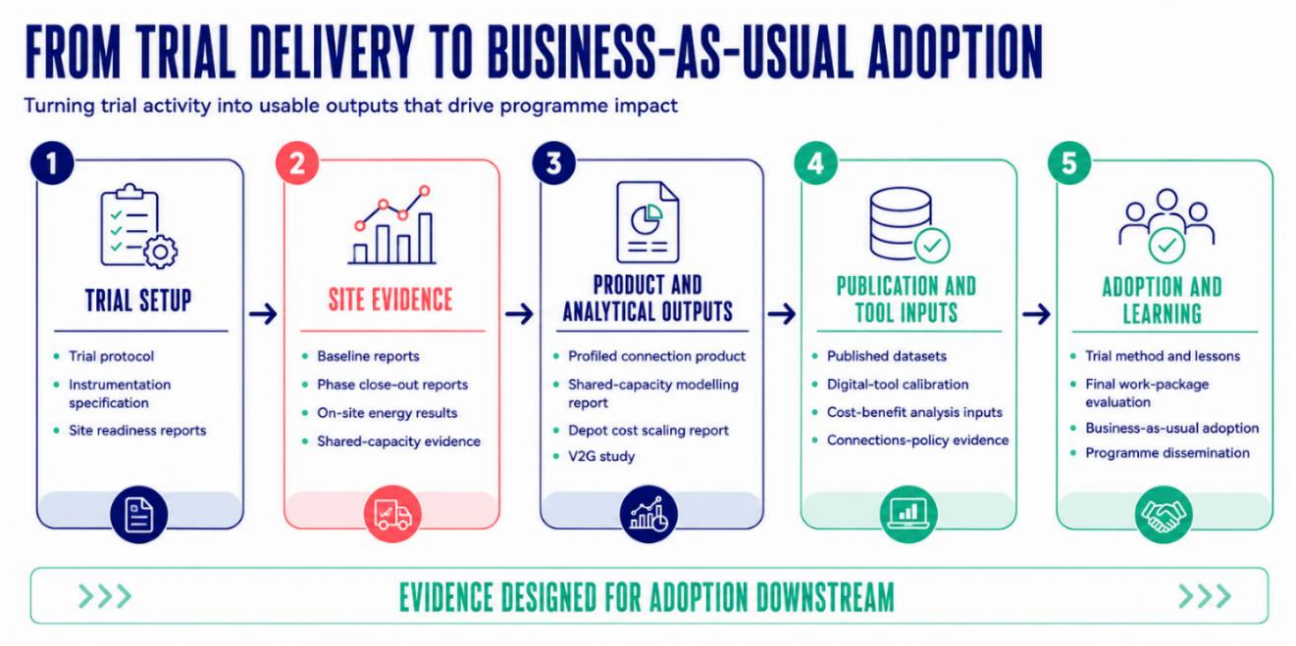


Table 10 – Trial-related deliverables

Deliverable	Due
Trial protocol (this document)	Preparation close; reissued after the first decision point
Monitoring equipment and measurement specification, per site	Before baseline capture at each site
Site confirmation and readiness report	First decision point
Baseline report and dataset, per site	Baseline close at each site
Phase closing report, per phase per site	Each phase close
Specification for the new connection type	Phase 1 close at the first site; updated as others complete
On-site energy results and investment case	Phase 2 close
Shared capacity modelling report	Before the second decision point
Live shared capacity report (subject to the decision point)	Phase 3 close
Fleet types and geospatial validation report	Before the first decision point; updated annually
Depot cost scaling report	Year [3]
Vehicle-to-grid study report	Year [3]
Published trial datasets	Progressively at each phase close
Trial method and lessons report	Programme close
Final work package evaluation report	Programme close
Shared capacity commercial terms: heads of terms or model agreement	Before the live Phase 3 stage; final version at Phase 3 close
Shared capacity commercial terms: heads of terms or model agreement	Before the live Phase 3 stage; final version at Phase 3 close
Shared capacity commercial terms: heads of terms or model agreement	Before the live Phase 3 stage; final version at Phase 3 close

9 Business As Usual Adoption and Learning

The learnings from the trials will determine the overall conclusions of the project and are largely designed to demonstrate the benefits to two key audiences: the logistics industry and the energy system.

For operators, the outcomes of the trials will demonstrate whether the smart energy measures stand up commercially in practice and deliver value for their businesses.

For network operators, the value lies in closing the knowledge gap between how the logistics industry operates in reality, how it will electrify, and how the energy system plans for this transition. Depot electrification is still not well characterised at the point when a connection is requested. The trials and supporting workstreams will help to close this gap through measured duty cycles, dwell patterns and managed charging profiles. Predicted loads and geospatial analysis will feed into network build-out and reinforcement strategies, as well as forecasting models.

Adoption as business as usual (BAU) will require logistics operators to be engaged in the solutions proposed through these trials, DNOs to support operators through published reports, a connections tool, and other means, and alignment with policymakers and regulators to support the logistics industry through its transition to eHGVs. These factors will all be considered during the Beta project to maximise the potential for successful BAU adoption.