Innovate UK
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CATAPULT Energy Systems

Connecting HGVs and Electricity

Enabling systems and sites for eHGV charger integration

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Contents

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1. Executive summary

Heavy Goods Vehicles (HGVs) play a critical role in the UK's economy but remain a major source of emissions. In 2023, HGVs were responsible for 16% of the UK's domestic transport greenhouse gas emissions, and 4.7% of emissions in the UK across all sectors. Therefore, decarbonising this sector is essential to achieving the UK's net zero targets.

Energy Systems Catapult is a partner in the eFREIGHT 2030 consortium, which sits within the Zero Emission HGV and Infrastructure Demonstrator (ZEHID) programme. eFREIGHT 2030, led by megawatt charging infrastructure developer Voltempo, brings together the charging sector, vehicle OEMs, HGV fleets and Energy Systems Catapult. The project aims to deliver electric HGVs (eHGVs) and charging infrastructure across the consortium's fleets and depots and explore, understand and build an evidence base to support the uptake of zero emissions HGVs beyond the ZEHID demonstrations.

A crucial component of the roll out of eHGVs is the connection of eHGV chargers to the electricity networks. This report looks at the industry-wide system improvements that are needed to better enable the connection of eHGV charging sites and then zooms into individual sites to look at what options site operators can consider when optimising the electricity usage on their site.

The transition to electric HGVs is vital for decarbonising freight but poses major challenges for electricity networks and depot operators. Success depends on coordinated action across network operators, freight operators, regulators, and policymakers. At a system level, better communication, standardisation, and data sharing are key to streamline connections and enable strategic planning. These system-level improvements will not only benefit the freight sector, but also other new or increased demand sources such as housing and data centres. At a site level, strategies like smart charging, flexible connections, and on-site generation can make efficient use of chargers and ease grid constraints, though tailored solutions are essential.

Delivering scalable, cost-effective electrification will require technical innovation, regulatory reform, and collaboration to ensure infrastructure keeps pace with fleet transition. In this report we outline the challenges, opportunities, and actions required to enable the integration of eHGV charging infrastructure.

Recommendations

From engagement with key stakeholders, modelling of three case study sites, and reviewing standards, codes, and reports, we identified challenges and recommend the actions to enable the uptake of eHGV chargers connected to the electricity network.

We took two viewpoints:

System-level: what needs to happen to systems and processes throughout the industry to make it easier to connect eHGV chargers to the electricity network.

We interviewed key industry stakeholders and reviewed standards, codes, and reports to explore the challenges of connecting eHGV chargers to the electricity network and make recommendations on how systems and processes can be updated to make it easier.

Site-level: what technological and operational opportunities can depot operators consider on their sites.

For this analysis we used three case studies from the eFREIGHT 2030 demonstrations as examples. Optimisation of the case study sites was analysed using the Catapult's Co-location Model which can explore interactions between site demands, connections limitations, onsite generation and storage assets, and smart charging. From the case studies, we drew insights of technologies, designs, and operational arrangements fleet operators can consider implementing to optimise sites when installing eHGV chargers.

The recommendations from both the system-level and site-level view are summarised in the following pages.

Short term actions – within 1 year

Challenge	Recommendations	Action owner
Freight and electricity industries speak different languages	Assign points of contact for fleet operators within Distribution Network Operators (DNOs).	DNOs
	Engage with each other's industry forums such as the Energy Networks Association (ENA) and Road Haulage Association (RHA).	ENA, RHA
	Recruit representatives from both freight and electricity industries for innovation project consortia.	FLEET OPERATORs, DNOs
There is a steep learning curve for fleet operators at the beginning of their electrification journey	Disseminate findings from programmes like ZEHID, collaborate across and beyond the ZEHID projects, hold regular events and workshops to share learnings.	ZEHID
	Have a "one stop shop" for consistent and clear connections guidance.	DNOs, ENA
The energy needed to charge an eHGV significantly exceeds existing depot site energy usage	Plan for increasing the size of depots' connection to the electricity network.	FLEET OPERATORs
	Explore options to optimise site energy usage such as smart charging, scheduling changes, co-location of generation and storage assets, and flexible connection options.	FLEET OPERATORs
Upgrading the size of a connection repeatedly as site demand grows can be very costly and disruptive	When applying for connections, fleet operators should consider what their future growth needs might be and assess whether it's cost-effective to install equipment which is future-proof.	FLEET OPERATORs

Medium term actions – 1-3 years

Challenge	Recommendations	Action owner
Forecasting eHGV uptake is tricky	Develop and share eHGV uptake plans and forecasts.	FLEET OPERATORs
	Have a clear path and point of contact for freight companies to share data with energy industry stakeholders through the Regional Energy Strategic Planning (RESP) process, led by the National Energy System Operator (NESO).	NESO
Connection application processes and design standards differ between DNOs	Standardise connection application processes, information requirements and design standards across DNOs.	DNOs ENA
There are lots of potential design options, it can be hard to know where to start	Develop optioneering tools which help site operators understand the options available to them.	DNOs
Flexible connection options are unclear	DNOs should clearly advertise what flexible connection options they offer, and what the benefits and constraints are for each.	DNOs
Network capacity data is unclear	Develop a clear, consistent and accurate national map of network capacity.	DNOs ENA
Current freight vehicle movement patterns may not allow sufficient and efficient charging time whilst the eHGVs are at the depot	Consider smart charging or alternative vehicle scheduling patterns to get the most efficient usage out of the eHGV charger.	FLEET OPERATORs

Long term actions – 3+ years

Challenge	Recommendations	Action owner
Limited network headroom in key locations causes delays to the connection of eHGV chargers	Incorporate eHGV uptake forecasts from fleet operators into network development plans.	DNOs
	Take a joined-up approach in reinforcing the network along priority freight routes which cross multiple DNO regions.	DNOs
	Use flexibility services to procure additional capacity to create additional local network capacity to enable connections in the meantime, whilst reinforcement work is undertaken.	DNOs
	Reform the demand connection queue to prioritise projects that meet readiness and strategic alignment criteria.	OFGEM
Neighbouring sites submit separate connection applications	Explore opportunities for neighbouring sites to apply for connections together, which could be faster, cheaper and better engineered than if each connection was treated separately.	FLEET OPERATORs DNOs LANDLORDs
Although behind-the-meter technologies can help optimise on-site energy, they can also impact grid stability	Conduct horizon-scanning reviews of technologies customers are likely to install behind-the-meter now and in the future.	DNOs
	Update the Distribution Code accordingly depending on the technologies identified and their potential effects on the grid, overseen by the Ditribution Code Review Panel (DCRP).	DCRP
Competition created through the price control structure harms collaboration and consistency across DNOs	Assess regulatory frameworks to ensure a balance between incentivising high performance whilst also encouraging collaboration and standardisation where it will lead to more efficient planning for networks and customers.	OFGEM

This report explores in depth how these recommendations were developed and is intended to act as a catalyst for action across the sectors.

2. Introduction

This report, developed by Energy Systems Catapult (the "Catapult") as part of the eFREIGHT 2030 project, explores the challenges and opportunities associated with integrating electric Heavy Goods Vehicle (eHGV) chargers into the GB electricity network. Electrifying HGVs is an important step in decarbonising the freight sector but brings new challenges for both fleet operators and electricity networks. This report identifies those challenges and suggests actions which can enable the smooth implementation of eHGV charging infrastructure.

The eFREIGHT 2030 project

The UK government, in partnership with Innovate UK, has already invested over £120m into the Zero Emission HGV and Infrastructure Demonstrator (ZEHID) programme, across three[1] innovative project consortia. The programme aims to roll out up to 300 zero emission Heavy Goods Vehicles (HGVs) and deliver around 75 planned refuelling and electric charging sites, helping to provide the crucial infrastructure required for the haulage sector to decarbonise. eFREIGHT 2030 is one of the projects under this programme.

As a consortium partner, the Catapult's remit has been to ensure that the eFREIGHT 2030 demonstration can gather the evidence required to understand the challenges and opportunities of eHGVs, in the real world. The Catapult has also been carrying out detailed analysis and insight to support a commercially successful and rapid decarbonisation of the freight sector. While funded by government, the views and findings within this report are independent and do not reflect government views/policy.

What you will find in this report

As part of this project, we have investigated the challenges and potential enablers of connecting eHGV chargers to the electricity networks.

The first half of this report looks at what needs to happen to systems and processes throughout the industry to make it easier to connect eHGV chargers to the electricity network. The second half explores technological and operational opportunities depot operators can consider on their sites, using three case studies from the eFREIGHT 2030 demonstrations as examples. Throughout, we recommend the actions needed by key stakeholders to remove the barriers to eHGV infrastructure roll-out.

This report answers questions such as:

What challenges are there for connecting eHGV chargers to the electricity networks?

How far do present policies and processes hinder future expansion opportunities for eHGV charging hubs, and how can these be improved?

What opportunities are there to better enable eHGV charging connections?

What can network operators, fleet operators and other stakeholders do to facilitate these?

What connection options would or would not be suitable for different eHGV charging sites?

[1] A fourth project in the ZEHID programme closed in December 2025.

Where this report sits within eFREIGHT 2030

The eFREIGHT 2030 project is installing Voltempo's 1MW HyperChargers[2] at over 20 sites. These chargers have six outlets, so the megawatt of power can be split across six different HGVs at any one time in different configurations. Voltempo have been applying for new connections to the 11kV network to provide power to the chargers. We therefore focused our current research on distribution connections, although we acknowledge that transmission-connected depots could be a possibility in the future.

This report builds on previous work of the eFREIGHT 2030 project, specifically the eHGV Charger Connections Guide and the Charger Connections Case Study. These found that it can be challenging to connect eHGV chargepoints to the electricity network. Here we explore the challenges in more detail and suggest potential solutions.

This report sits alongside the following research conducted by the Catapult as part of eFREIGHT 2030:

The Road Ahead: National system impacts of HGV decarbonisation

Accelerating the Transition: A business modelling perspective for eHGV scale-up

Navigating Net Zero Road Freight: Stakeholder insights for HGV decarbonisation

[2] See https://voltempo.uk/hypercharger/ for more information on Voltempo's Hypercharger technology

3. Improving industry-wide systems

This chapter identifies pain points in the systems which govern connection of new demands such as eHGV chargers to the electricity network and suggests improvements. We also explain why things are the way they are, to increase understanding between different stakeholders and help key players understand other perspectives within the connections process, to bridge the gap between the worlds of electricity and freight.

The research method was a mix of desk-based research and stakeholder engagement. We interviewed 22 representatives from seven fleet operator and Distribution Network Operator (DNO) organisations, and reviewed industry standards, codes and reports. These two streams of research were combined to draw out key challenges and recommendations.

Many of the challenges and recommendations outlined below are common to the connection of all new or increased electricity demands, so a coordinated approach rather than sector-specific can be taken where appropriate to provide benefits to all. Several of these challenges are being considered in Ofgem's end-to-end connections review, which is undergoing a second round of consultation at the time of publication of this report.

Challenge 1: Freight and electricity industries don't have established ways to interact with each other

Pain point: The worlds of freight and electricity haven't collided at this scale before, and they are used to speaking different languages. Electricity networks talk in megawatts (MW), freight operators talk in tonnages. It can be hard for both parties to know how to start interacting with each other and who to contact.

Who is it painful for: Freight and network operators.

Why is it that way: This is a nascent area, there has not been much interaction between the two industries in the past. Fewer than 1% of UK HGVs are currently electric, the rest are fuelled by fossil fuels plus a small minority on biofuels.

How it could be done better: Most DNOs we talked to recommended fleets engage directly with them. But for that to work, there needs to be clear points of contact – otherwise the fleets will not know who within the DNO to talk to. Better understanding of each other's priorities will help bridge the language gap. Raising awareness of and engaging with each other's forums will help build collaborative solutions to problems (e.g. the Energy Network Association's (ENA) Fleets and Depots Decarbonisation programme, the Road Haulage Association). eHGV innovation projects (for example, funded through Department for Transport or the energy networks' Strategic Innovation Fund (SIF)) should include freight and electricity partners.

Who can make it better:

- DNOs
- FLEET OPERATORs
- TRADE ASSOCIATIONs
- CATAPULT NETWORKs

Best practice example: For an easy guide for fleets of who's who in the electricity world, check out this LinkedIn article which provides guidance learnt through the experience of the eFREIGHT 2030 project.

DNO quote: *"For me it's a bit of a language problem. Transport and logistics businesses speak a different language. They talk about tonnage and axles and all this sort of stuff and we're talking kilowatts and what have you. And so, I think bridging that gap is one of the big problems because in my experience they don't know what questions to ask of us and we don't know who to approach to try and get into some of these things."*

Challenge 2: There is a steep learning curve for fleet operators at the beginning of their electrification journey

Pain point: Historically fleet operators have had minimal needs of the electricity network, but as they start to transition to eHGVs they will have to navigate the world of electricity network connections to enable the installation of charging infrastructure. Even knowing where to start is difficult. There are resources out there, but they can be hard to find.

Who is it painful for: Fleet operators.

Why is it that way: The electricity industry is nuanced and complicated, there is a lot to learn for those who have not had to interact with it much before. Even though fleet operators are likely to outsource the detailed design, they need to know who to talk to and how to start the process.

How it could be done better: Programmes like ZEHID are helping to raise the understanding of participants and share learnings through dissemination. DNOs do make guidance for connections applicants, but it is in different places and written in different ways and it can be hard to know where to start. Having a "one stop shop" for connections guidance, which is consistently signposted, is an improvement over information being disparate. The ENA also has a page of connection guidance links, but many of them are out of date, so this should either be updated or removed. Chargepoint operators (CPOs) or installers can also take some of the pain out of it for fleet operators by handling the connections themselves, although it is likely that some level of involvement from fleets will always be required.

DNO quote: *"We're aware that it's a confusing place for some people who haven't really engaged in the electricity system until now, and it's not just HGV operators, but all kinds of fleet operators from smaller cars and vehicles to vans or whatever. They're all going to be experiencing stepping into this new territory of applying for an electricity network connection, which can be expensive, it can be complicated and it can take a lot of time."*

DNO quote: *"It's really useful for fleet operators to properly try and engage with us before they're too far down the line because we can talk to them about some things that they're probably not aware of and I wouldn't expect them to be aware of. They're not used to dealing with time frames, what it takes to get kilometres of cable in the ground and all this sort of stuff. As well as not being sure about what a timed connection is and what difference it can make. So having those early conversations, I think allows better decisions in their roll out programme at the right time."*

Who can make it better:

FLEET OPERATORs CPOs DNOs ZEHID

Best practice example: A good example is the transport connections guidance which the DNOs have recently collaborated on and published through the ENA.

Challenge 3: Forecasting eHGV uptake is tricky

Pain point: The growth and uptake of eHGVs is uncertain, which makes it difficult to plan for these types of connections to the network. DNOs need to be able to know where chargepoints are planned to be installed so they can pre-emptively plan for network upgrades.

Who is it painful for: DNOs, National Energy System Operator (NESO), OEMs and other parties involved in planning the energy system and networks.

Why is it that way: This is a nascent area, and fleet operators do not yet know what their transition to zero-emission vehicles is likely to look like. Additionally, fleet operators are wary of commercial sensitivity around data sharing. DNOs currently forecast future energy demands and generation as part of their Distribution Future Energy Scenarios (DFES) which informs their future plans for the network. However, gathering data to help forecast eHGV uptake is difficult and DNOs are using different methods to each other.

How it could be done better: Fleet operators should develop their eHGV uptake forecasts and connection plans and share them with NESO and DNOs to help plan network upgrades strategically, therefore reducing future connection delays (see Challenge 8 for more detail on connection timelines). Programmes such as ZEHID can help develop an evidence base which gives both fleet operators and DNOs stronger information to base their predictions on (see The Road Ahead: National system impacts of HGV decarbonisation for the Catapult's national forecasting of eHGV uptake to 2050). Even qualitative conversations are useful. For example, some DNOs reported that they have been focusing on estimating en-route charging, whereas eFREIGHT 2030 research indicates higher uptake at depots is likely in the first stages of rollout. Clear and consistent signposting of how to feed data into strategic plans is important so fleet operators know who to talk to – the list of different strategic plans and their acronyms can be baffling (e.g. RESP, LAEP, FES, DFES, SSEP etc). We recommend that NESO, as the lead for the Regional Energy Strategic Plans (RESP), should collect the data through the RESP process using a standardised format so that fleet operators know what needs to be shared. NESO should then share the information with DNOs, to maintain consistency between plans.

DNO quote: *"The tricky bit, I think, is translating if we know there's going to be X million cars or trucks on the road into what level of reinforcement at each site. That's the more difficult bit to do, we haven't yet got a strategic load forecasting tool that is designed to translate those inputs of vehicles in places into how much they'll need to charge and therefore the upgrades we need to do."*

Who can make it better:

FLEET OPERATORs | ZEHID | DNOs | NESO

Dive deeper into a case study: We explore the theme of increased fleet electrification in Section 4.

Challenge 4: Connection application processes and design standards differ between DNOs

Pain point: Each DNO has its own process and design standards for new connections. For example, the information the connection applicant has to provide differs by DNO. This makes the connection application process more complex, time-consuming and resource-intensive for fleets operating in multiple regions, as they have to spend time familiarising themselves with the different requirements and processes.

Who is it painful for: Connection applicants such as fleet operators and charging infrastructure developers.

Why is it that way: The GB distribution grid was split up into different DNOs during privatisation in the 1990s to increase competition. Each DNO is therefore a separate company with their own process and requirements for new connections and network modifications. Many eHGV operators will need to apply for connections in different areas of GB, given the nature of their operations, but electricity distribution networks are regional.

How it could be done better: Connection application processes, information requirements and design standards should be standardised across DNOs and iDNOs. They can work together through the ENA to establish what the minimum requirements and best process should be. This will save time for both connection applicants and DNO teams, as there will be less back-and-forth if expectations and processes are clear and consistent. This would benefit all connection applicants who apply for connections in multiple regions, not just the HGV sector.

Who can make it better:

DNOs iDNOs ENA OFGEM

Best practice example: The DNOs and iDNOs have collaborated on a design recommendation for sites with multiple supplies, resulting in the publication of Engineering Recommendation G94[3]. This is an example of best practice, as the same design guidance for sites with multiple supplies now applies to all DNO regions, whereas previously different DNOs handled this situation in different ways. This guidance provides pragmatic advice and lots of examples of common scenarios which may occur. Standard guidance for other design aspects could follow the process that was used to create Engineering Recommendation G94.

[3] Engineering Recommendation G94: Managing the Risks Associated with the Provision of Multiple Connections in Close Proximity, available from: https://www.ena-eng.org/ena-docs/

Challenge 5: There are lots of potential design options, it can be hard to know which options to consider

Pain point: When designing a new connection, there are many design options possible depending on factors such as the local network capacity, site layout, site usage, etc. Although fleet operators will have to outsource the detailed design itself, some will want to be engaged with the optioneering process, which can be baffling for those who haven't been involved in a large connection before. Costs and timescales can be unpredictable, and it would be beneficial to have an indication of what these might be earlier in the decision-making process.

Who is it painful for: Fleet operators and DNOs.

Why is it that way: Some customers are very engaged and want to explore all of the different options to make the most of their assets, some aren't engaged and just want the minimum to deliver what they have asked for.

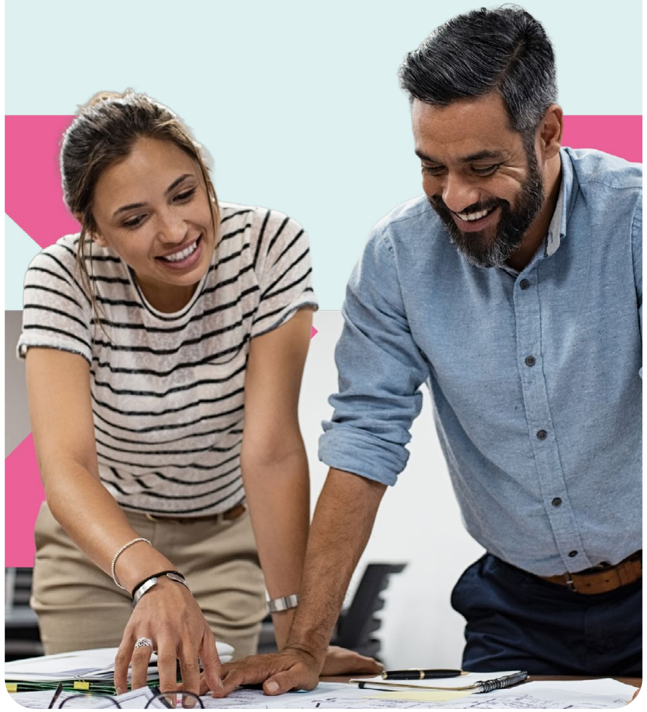
How it could be done better: There are existing resources available, such as connection surgeries which can help applicants discuss their options with the DNOs. Raising awareness amongst fleet operators at the start of their journey to engage early with the DNO can help build collaborative solutions. Additionally, tools could be developed to help applicants better understand their electricity needs and requirements, assess local network conditions, and then aid optioneering of site layouts and connection options. These tools could help applicants understand the options available, how much they might cost, and guide them on the next steps including who they need to engage with to progress the design and construction. This may be a space where there is an opportunity for AI driven tools to accelerate progress.

Who can make it better:

DNOs ENA

Dive deeper into a case study: we explore different design options in Section 4.

DNO quote: *"It's about improving the mutual understanding. It's important for us to understand how developers are thinking, the technologies they're putting in. Equally I think it's vital for them to understand what products for connecting are on the table."*



Challenge 6: Flexible connection options are unclear

Pain point: Although DNOs are making more flexible connection options available, they are inconsistent and poorly advertised, especially for demand connections.

Who is it painful for: Connection applicants such as fleet operators and charging infrastructure developers.

Why is it that way: The increase in electricity demand means that some regions of the network are now quite constrained. To help with this problem, DNOs have started to offer connections which have reduced capacity at certain times of day, known as flexible connections. There are a range of different arrangements on offer. Initially these alternative connections were used for distributed generation, so a lot of the information available is tailored to generators rather than demand customers such as fleet operators.

How it could be done better: DNOs need to clearly advertise the flexible connection options they offer, and what the benefits and limitations are for each. These should be presented on their websites. DNOs could also develop flexible connection products that are specifically targeted at depots and suit the needs of these types of sites.

Who can make it better:

DNOs

Dive deeper into a case study: we explore flexible connection options in Section 4.

DNO quote: *"When they apply to connect, they fill in an application where they're asked if they're willing to discuss flexible connection arrangements. Sometimes it takes them time to digest and understand what is in the offer, and a lot of these products are evolving."*

Challenge 7: Network capacity data is unclear

Pain point: Although DNOs have significantly increased the data they make available, it can still be difficult to see what the capacity is in a local area because the information published by different DNOs varies in format, accuracy, and detail.

Who is it painful for: Connection applicants such as fleet operators and charging infrastructure developers.

Why is it that way: Each DNO has their own data portal and heatmaps on their website. The formats and data available can vary considerably.

How it could be done better: The ideal tool for connection applicants would be a national map of network capacity, with all the information in one place in a consistent format. The data would be accurate and up to date, and the user interface easy to navigate. DNOs are making more and more datasets available, and some innovators are starting to stitch together the different DNO datasets, but the outputs are only as reliable as what has been published by the DNOs.

Who can make it better:

- DNOs
- INNOVATORs
- ENA
- OFGEM

Challenge 8: Limited network headroom causes delays to the connection of eHGV chargers

Pain point: Limited network capacity causes delay to connections, as time-intensive reinforcement work needs to be carried out in constrained areas before new demands can be connected.

Who is it painful for: Connection applicants such as fleet operators.

Why is it that way: There has been a sharp increase in electricity network connection applications. Additionally, much of the infrastructure is aging and reaching the end of its design life so needs upgrading or replacing. DNOs are regulated utilities and thus must follow rules around how they proactively invest in the network. DNOs need to reinforce the network to accommodate new connection requests, but they also need to deliver good value for money for bill payers, as electricity network reinforcement is funded through electricity bills. This is a hard balance to strike. Reinforcement work can take many years to complete.

How it could be done better: More accurate forecasting of eHGV growth (see Challenge 3) will give greater confidence that the reinforcement is targeted in the right locations. Those forecasts should inform network development plans. DNOs could work in collaboration with each other to identify key freight routes which cross several DNO regions to make sure that there is a joined-up approach along the route to enable chargers at strategic locations. In the meantime, DNOs could use flexibility services to procure the extra capacity needed to enable connections. Site operators should also explore the options available to them to reduce connection size or ramp up their connection over time – see Section 4 for a deep dive on some of the options that can be considered. Furthermore, Ofgem could consider reforming the distribution demand connection queue as the next stage in the Connections Reform programme, which is reprioritising the queue in terms of first needed, first ready, first connected. This has already been done for the connection queue for transmission-connected generation, prioritising projects which meet readiness and strategic alignment criteria and removing non-progressing projects from the queue. A similar approach is needed to manage the growing queue of distribution demand connection applications.

DNO quote: *"Each of the assets has got various different pots of money associated with it as they are defined in the ED2 business plan, which is signed off by OFGEM and so we have to make sure that we are spending the money on the right things and that we are thinking [of] the selection criteria before we would authorise spend on a particular reinforcement activity."*

Who can make it better:

FLEET OPERATORs | DNOs | DESNZ | OFGEM | NESO

Dive deeper into a case study: we explore ways to optimise a site for a smaller connection size in Section 4.

Challenge 9: Neighbouring sites submit separate connection applications, missing out on opportunities for coordinated planning

Pain point: Industrial companies are often located in close vicinity, however they apply for connections individually. Efficiencies could be gained if neighbouring connection schemes were coordinated.

Who is it painful for: DNOs, fleet operators, and charging infrastructure providers.

Why is it that way: Industrial sites can be protective of their development plans as they are seen as commercially sensitive. This makes it unlikely for them to share their plans with their neighbours. Additionally, it could be perceived as a risk that somebody else might buy the capacity and sell it to them at a higher rate. DNOs have to maintain customer confidentiality, so cannot share information about neighbouring connection applications.

How it could be done better: There is an opportunity for neighbouring sites to apply for connections together, which could be faster and cheaper than if they all applied individually. The DNO would then be able to plan any required reinforcement works more strategically to provide capacity that is suitable for the upgrade plans of all the neighbouring sites. Industry associations (like RHA), programmes like ZEHID, and local authorities could all bring stakeholders together. Although DNOs have to maintain customer confidentiality as a default, a field could be added to connection applications to ask whether the applicant is comfortable with discussing mutually-beneficial schemes with a neighbour should such an opportunity be identified. Furthermore, an online marketplace could be used to match nearby connection applicants who are interested in collaborating.

Who can make it better:

- RHA
- ZEHID
- LOCAL AUTHORITIES
- DNOs
- iDNOs
- LANDLORDs

DNO quote: *"Because of commercial confidentiality and the tendency of consortiums of customers to just fall out and collapse, we're very hesitant to do combined schemes unless you've got an absolutely ironclad justification. But if they approached us and said we would like you to do this as a combined scheme, we would be much more willing."*

Challenge 10: Although behind-the-meter technologies can help optimise on-site energy, they can also impact grid stability

Pain point: Electrified depots may consider exploring a range of technologies behind-the-meter to optimise site energy usage, such as generation and storage assets. However, the Distribution Code does not currently consider all technologies which are being installed on sites behind-the-meter. These technologies can have negative impacts on the network, such as creating unwanted harmonics.

Who is it painful for: DNOs.

Why is it that way: New technologies are emerging and becoming more widespread, as sites look to decarbonise. These technologies can impact the power quality on the distribution networks, which can cause increased losses and potential damage to equipment connected to the network.

How it could be done better: DNOs want to understand the business case of different technologies that are behind-the-meter and future trends, so that they know what to study to ensure that their network operates safely and reliably and plan the network accordingly. The Distribution Code could be updated to reflect the range of different technologies which might be installed and the potential impacts on the grid. This would benefit the DNOs in preparation for all sites which are collocating equipment behind the meter, not just HGV depots.

Who can make it better: DNOs can commission research organisations or consultancies to work with stakeholders to identify technology trends for these types of sites. Energy network innovation funding (i.e., Strategic Innovation Fund, Network Innovation Allowance) could be used to fund this horizon scanning. The Distribution Code review panel can update the Distribution Code.

Dive deeper into a case study: We explore opportunities for co-location of generation and storage in Section 4.

DNO quote: *"It's a chance for us to understand the business cases in terms of the range of technologies put behind-the-meter, to make sure that we reflect that into studies to make sure the network is reliable and can facilitate these behind-the-meter technologies. From a market point of view, it's important for us to understand the future trends because we can say these things are coming in the next 5-10 years or no, they're coming in longer term. So, we can plan the network accordingly, because we plan network reinforcement in stages. We get increasingly into discussion at the moment whether we should touch parts of the network once. So we don't go back and reinforce the same part of the network again and again, with whatever it means for disruption to local communities, deliverability challenges and all of that, to facilitate timely net zero."*

Challenge 11: Regulatory incentives discourage DNO collaboration and consistency

Pain point: Many of the recommendations in this report rely on DNOs working together for better standardisation across regions, to make it easier for fleet operators who have depots across wide geographic areas. However, current regulatory frameworks incentivise competition between DNOs rather than collaboration. This discourages sharing of best practice, because each DNO wants to be ahead of the others in the rankings because they will be rewarded.

Who is it painful for: DNOs, charging infrastructure developers, and fleets.

Why is it that way: When the industry was privatised, regulatory frameworks were established to incentivise competition between DNOs to increase performance.

How it could be done better: Assess the regulatory frameworks to ensure there is a balance between incentivising high performance whilst also encouraging opportunities for collaboration and standardisation.

Who can make it better:

DESNZ OFGEM

Next steps

The challenges identified at the system level highlight the need for greater collaboration between the freight and electricity sectors. Current processes for grid connections are complex, inconsistent, and often slow, creating uncertainty for depot operators and may limit the pace of electrification. Addressing these issues will require coordinated action across stakeholders, supported by clear guidance, standardised procedures, and improved data sharing. Implementing these improvements will not only reduce delays and costs but also enable strategic planning for future demand. By fostering collaboration and creating transparent, streamlined processes, the sector can build the foundations for a scalable and efficient transition to electrified freight.

In the following section we will explore some of these challenges at site level, including connection options, capacity limitations, and growth of eHGV fleets, and how depot operators may be able to address them by optimising their sites.

4. Optimising eHGV charging sites

Innovation in site design and implementation will be needed to integrate electrified HGVs into the future energy system. Here we explore the different levers that can be pulled when considering the optimisation of an electrified depot. We looked at three real world depots being developed as part of the eFREIGHT 2030 project. What happens when we change different factors for these three sites and what can this tell us about which options may work best for different site archetypes?

The factors we tested were:

- Growth of eHGV fleet
- Smart charging
- Onsite solar generation
- Onsite battery storage
- Flexible connections

We used Energy Systems Catapult's Co-location Model, which models the optimal mix of technologies for a site. We gathered real data on each case study site's existing electricity usage, fleet movements, and local renewable resource data, so the models could represent the site setups accurately. We tested a variety of scenarios and constraints, and in each case the model optimised for the arrangement with the lowest net operational and running cost.

The case study sites

We used three sites from the eFREIGHT 2030 demonstration as case studies. Each of these sites is having a Voltempo megawatt Hypercharger installed on a 0.98MVA connection as part of the project. These three sites are spread across different geographical locations, operated by different companies, in separate DNO regions, with varying local network conditions. Each site is unique in terms of fleet size, charging strategy, and potential for onsite generation, offering valuable diversity for the modelling work.

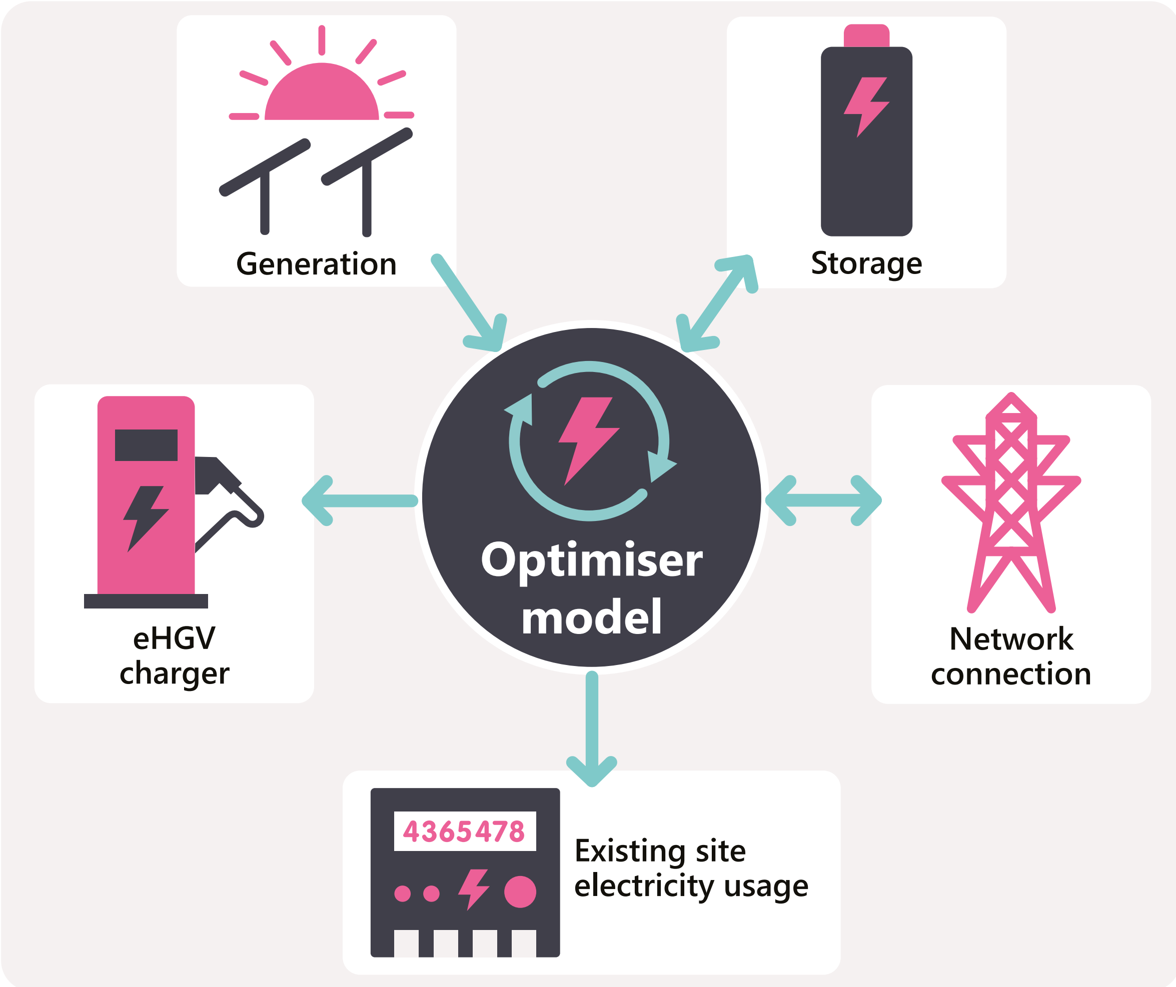


Figure 1: The variables modelled in the Co-location Model

Site A

Small logistics depot with warehouse

England

Freehold

100 HGV visits per week

11 hours Median time spent on site

Solar panels installed on the depot roof. Site has an existing 150kW charger.

Mainly operates weekday daytimes.

Site B

Large port depot

England

Freehold

700 HGV visits per week

1.5 hours Median time spent on site

No existing generation or chargers.

24/7 operation, heavier usage in the day than night.

Site C

Medium logistics depot with warehouse

Scotland

Landlord

150 HGV visits per week

5.5 hours Median time spent on site

Solar panels installed on the depot roof - but feed into landlord's meter.

Mainly operates weekday daytimes.

Sites A and C are warehouse depots where the vehicles generally return to the site each day to reload or park overnight; Site B is a port depot where vehicles collect and deliver cargo from the port, generally returning to the site between deliveries.

Some depots are owned by the fleet operators themselves, whereas others are leased from a landlord. For leased sites, fleet operators will need to negotiate with landlords to implement some of the hardware solutions we discuss in this section. Landlords can support the eHGV transition by approving applications for installation of enabling infrastructure and future proofing electricity capacity of the depot sites they own.

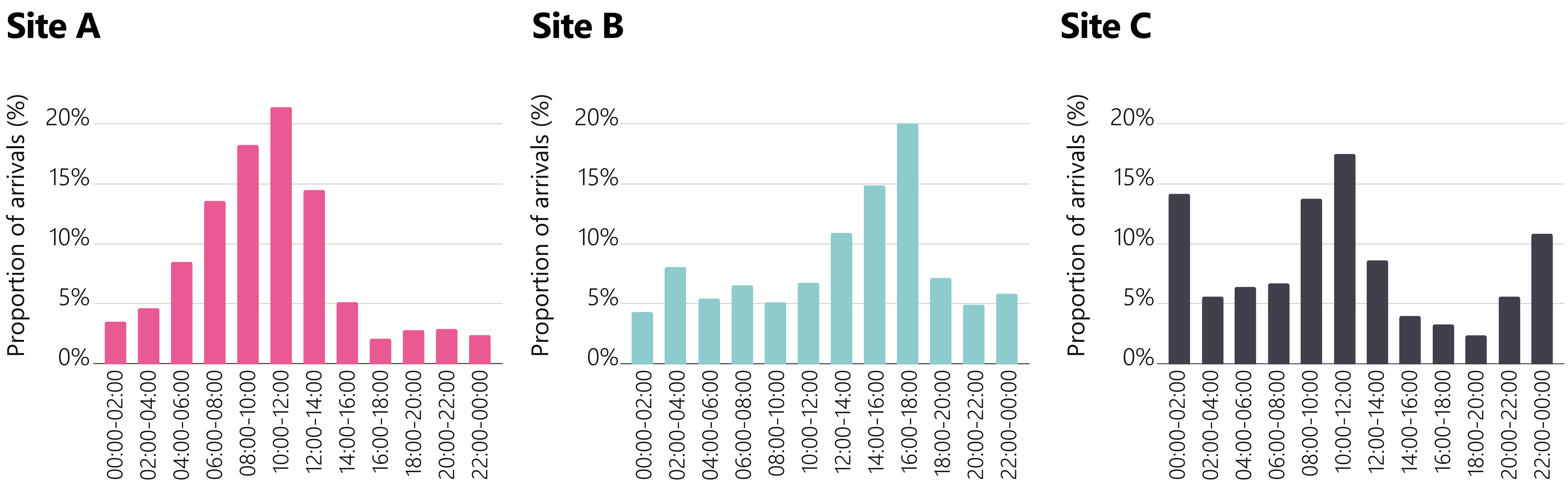


Figure 2: Average times HGVs arrive at each site across the day

The arrival and departure times used in the modelling were obtained by assuming the same behaviour as the existing non-electric HGVs for each site and generating synthetic data that follows the same statistical distribution. The average times that vehicles arrive at each site across the day are shown above in Figure 2. Site A has the most vehicles arriving on site during the daytime, Site B has most arrivals late afternoon, and Site C has peaks at midday and midnight. The default charging profile for each site was calculated assuming a first-come-first-served queueing principle assuming a 6-bay charger of 1MW.

Operating a site with a full grid connection

Firstly, we looked at the energy usage of each site before and after an eHGV charger is installed. For this section, we assume that the site has secured a grid connection for the full capacity of its charger i.e. 1MW for one of the chargers used in the eFREIGHT 2030 project. Options for sites which choose a reduced grid connection are discussed later in Section 4, such as onsite generation and storage, smart charging, and flexible connections.

What is the existing site energy usage?

The measured existing electricity for each of the case study sites for a typical week, before the eHGV charger for the eFREIGHT 2030 demonstration was installed, is shown in Figure 3. Site A and Site C's electricity usage drops at weekends, whereas Site B uses the same amount of electricity every day of the week. Site A already had a 150kW charger on site, and the peaks when this charger is used each day can clearly be seen.

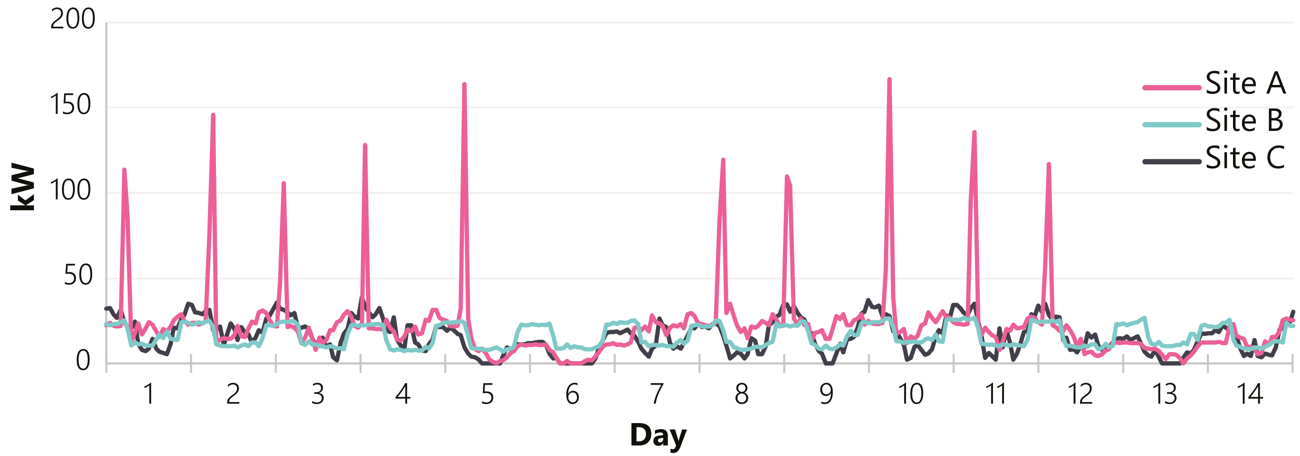


Figure 3(a): Existing site electricity usage - a typical fortnight

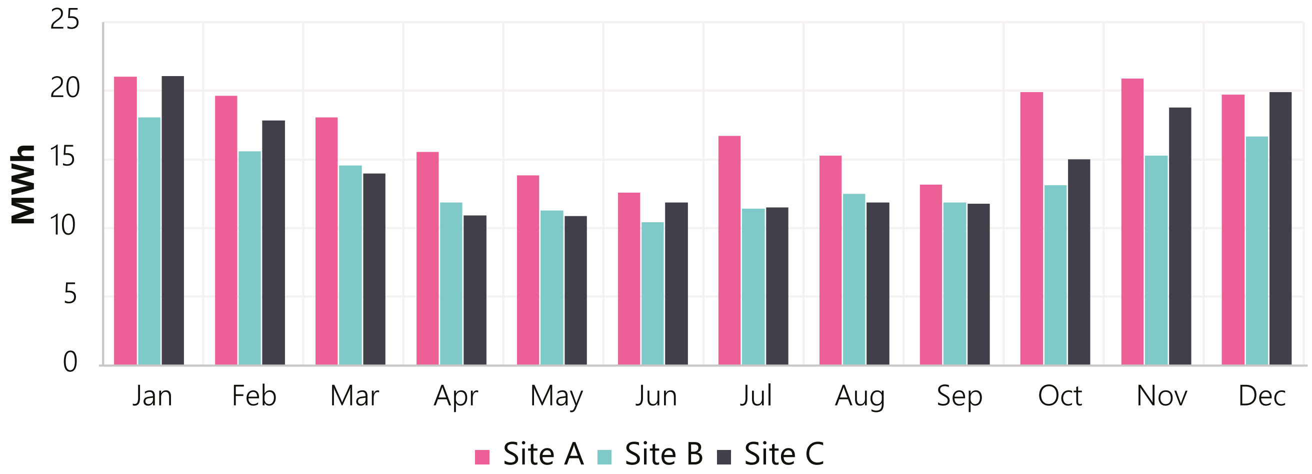


Figure 3(b): Existing site electricity usage - monthly average for a full year

Adding an eHGV charger to the sites

We modelled the electricity usage of the site with an eHGV charger, to compare it to the existing site energy usage. An example fortnight for Site B can be seen in Figure 4. For the modelling we assumed the sites had a mix of 5t, 15t, and 40t trucks, corresponding approximately to battery sizes of 200kWh, 300kWh and 500kWh respectively.

The eHGV demand far exceeds the existing baseline usage of the sites currently. For Site B in Figure 4, the eHGV peak demand is more than 30 times the existing peak. This is why it is important for site operators and electricity network operators to plan effectively for this substantial increase in electricity usage at depot sites.

Under the baseline scenario, the model found an optimal connection cable size, in the absence of other behind the meter technologies, of about 1MW for each case, driven by the maximum peak demand on the charger.

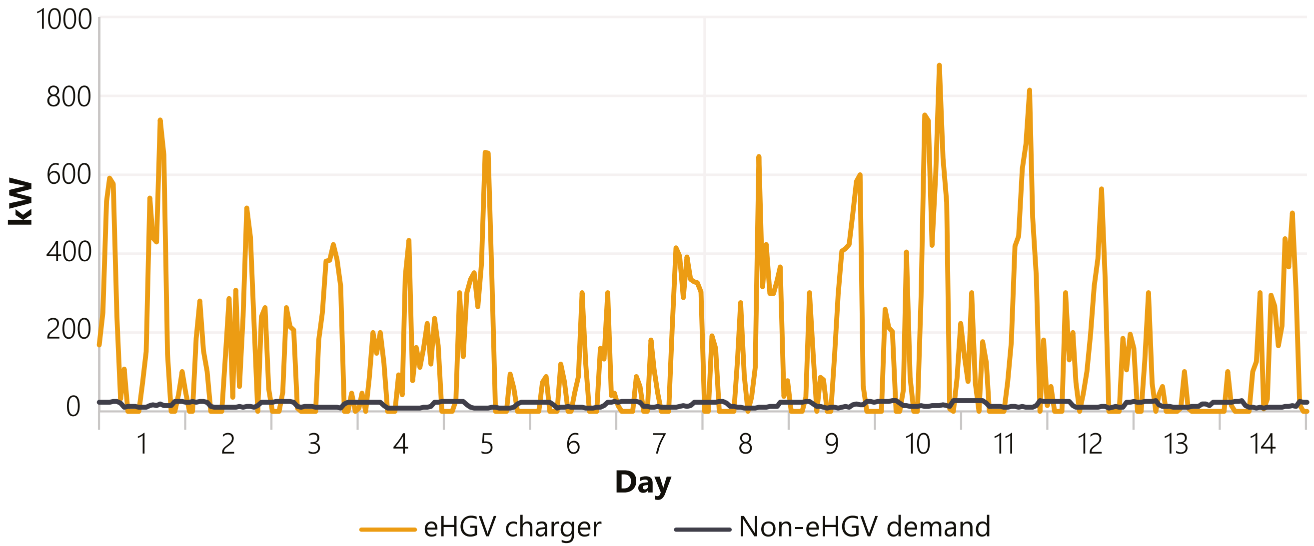


Figure 4: Comparison of eHGV demand and non-eHGV demand for Site B for a typical fortnight, for a scenario of 100 eHGV visits to site per week

What this means for site operators: eHGV charging will significantly exceed existing site energy usage, so site operators should plan for increasing the size of their connection to the electricity network

Growth scenarios

Using the Co-location Model, we modelled three levels of eHGV usage on the sites, to explore what would happen as sites transition more of their trucks to electric. The metric we used for site usage was the number of arrivals and departures from the site, using statistics based on current HGV movements at each site and scaled to three growth scenarios. The three levels of usage modelled were: 10, 100, and 200 eHGV visits to site per week. We initially modelled the scenario of a 1MW charger with six outlets to reflect the chargers being used in the eFREIGHT 2030 project; the charger can charge up to six trucks at once. The eHGVs plug in to the charger when one becomes available during their time on the site. We have also modelled scenarios where a second charger was added to the site.

The number of visits per week tested (10, 100 and 200) corresponds to different stages in the transition to an electric fleet for the different sites. The current number of HGV visits per site is around 100, 700 and 150 for sites A, B and C respectively. For the base scenarios it was agreed that ten eHGV visits to a site per week would roughly represent what the sites might experience during the early stages of the eFREIGHT 2030 demonstration.

For sites A and C, 100 visits per week corresponds to a growth scenario where much of the fleet has already transitioned. Based on the Catapult's national forecasting described in The Road Ahead: National system impacts of HGV decarbonisation, this could be expected to take place within 10-15 years. For these sites, 200 eHGV visits per week corresponds to a full transition, as well as an expansion of their fleet, which is likely to take longer, possibly until 2050.

For Site B, 100 eHGV visits per week represents a smaller fraction of the current 700 HGV visits to site per week and could take place earlier than 2030, depending on the transition speed, and 200 eHGV visits per week may happen in the early 2030s.

Three levels of usage modelled

10 eHGV
visits to site a week

100 eHGV
visits to site a week

200 eHGV
visits to site a week

Can the eHGVs fully charge?

We used the model to investigate whether the eHGVs would be able to fully charge their batteries during the time they were at the depot for each of the growth scenarios. This is based on current non-electric vehicle movement patterns of the sites; depots may choose to update their scheduling as they transition to eHGVs, but for now, we based our modelling on current behaviour.

10 eHGV
visits to site a week

We first looked at how frequently the eHGVs fail to fully charge at each site in the early stages of electrification. Ten visits per week corresponds to about two or fewer visits per day so the 6-bay charger is likely more than adequate for this volume. Therefore, if an eHGV does not reach full capacity in this context, it is most likely because its charging window was too short, and not because the charger is inadequate.

Site B shows the highest rate of eHGVs leaving the site before reaching full charge, which was about 26%. This is expected, since this is a 24/7 site with lots of short visits, during which the trucks don't have time to fully charge (based on current vehicle movement patterns).

Site A and C show lower rates, 15% and 7% respectively – the rates are lower than Site B because these are depot sites, and trucks will often stay overnight with plenty of time to recharge. The difference between the two reflects the different site logistics.

These levels provide a baseline for each site and allows us to better understand how the charger performs when the number of weekly eHGV visits grows. Whether these figures are acceptable or not to fleet operators depends on the type and duty cycle of a given vehicle on leaving the site.

What this means for site operators: based on current vehicle movement patterns, some eHGVs won't be able to fully charge during their time on site. Site operators should analyse the operational implications at a route-by-route level to understand whether this is workable, and consider whether they need to update schedules to better accommodate charging times.

100 eHGV

visits to site a week

The same underlying vehicle movement profiles were maintained, but the total number of visits per site was increased to 100. We then measured the frequency of cases where eHGVs did not reach 90% charge before departing the site. We also tested what would happen with the addition of a second charger, which adds an extra 6 bays, and another 1MW of charge capacity. This allows us to see whether a single charger is sufficient when the fleet grows, and at which point the charging infrastructure requires expansion.

The same patterns occur for all three sites as the number of eHGVs grows. When increasing the weekly visits to 100, the rate of eHGVs that do not reach full charge upon departure slightly increases (by up to five percentage points), and in this case, introducing a new charger only brings the value back to its baseline level, as shown in Figure 5 on page 36. This is because the main limiting factor is the amount of time the vehicles spend on site, rather than the number of chargers. Site A shows the most improvement with the addition of a second charger: 20% fail to fully charge with one charger (i.e., six outlets), but this drops to 15.4% with the addition of a second charger. Given the costs associated with an additional charger and increased network connection capacity, a second charger may be hard to justify in this growth scenario. If the site operation is such that it is crucial for all eHGVs to depart with a full battery at all times, then re-working the fleet schedule would potentially have a stronger impact than adding an extra charger. Further studies will be needed on a site-by-site basis to help fleet operators assess the costs and benefits of these decisions[4].

[4] There are tools available which can help fleet operators assess the costs and benefits of these decisions, such as the eFREIGHT 2030 Pre-feasibility eHGV Financial Assessment Tool or Dynamon Zero.

200 eHGV
visits to site a week

When increasing the number of weekly visits per site to 200, the benefit of an additional charger was more evident (see Figure 5 on page 36). Once again, Site A shows the largest reduction in vehicles which do not fully charge when adding a second charger, with the rate more than halving from 37.3% to 17.2%. Similarly, Site C rates dropped from 14.5% to 7% with the addition of a second charger. In all three cases, the addition of a second charger brings the rates back to the baseline level, which suggest that a third charger would not make further improvement as the limiting factor is that some trucks are not spending enough time on the site to fully charge.

Site B shows less sensitivity to the number of chargers as it is utilised differently compared to the other sites. Trucks remain parked on site for shorter periods of time, and the arrivals are spread over seven days, rather than five working days for the other two sites. There is a spread of arrival times throughout the day at Site B, with peaks at midday and midnight (see Figure 2 on page 29 for the spread of arrival times). As a result, the probability of two eHGVs competing for a charging bay is reduced.

In comparison, Sites A and C are warehouse depots where trucks return to the depot for loading and to park overnight, and therefore more likely to have a large proportion of their fleet arriving and departing from site at similar times. Although these trucks are on site and available to charge for longer periods of time, adding an extra charger essentially halves the size of the queue of lorries waiting to recharge.

These results show that when transitioning from 100 to 200 weekly visits, the warehouse sites strongly benefit from a second charger. This is because many trucks arrive and depart the site within the same time window, so a second charger doubles how many vehicles can charge at the same time during these peak windows. This suggests that for smaller sites such as Site A and C, which already currently see around 100-200 visits per week in normal operation, a single charger is a relatively future-proof option in the medium term, assuming operational patterns remain the same as today. However, for high-volume sites, such as Site B, for which 200 visits per week is a much smaller proportion of their total fleet, a second charger may be needed in the early 2030s if the site follows national eHGV uptake trajectories.

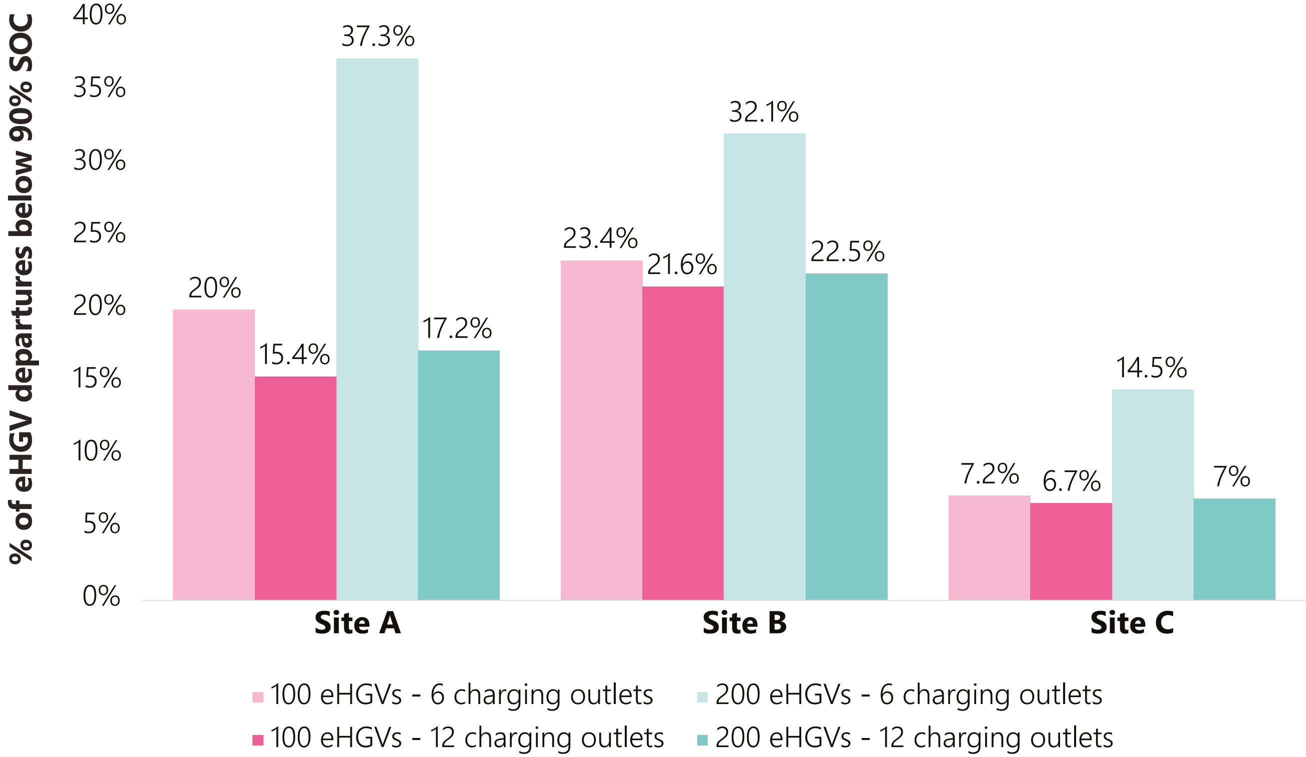


Figure 5: the number of eHGV departures from site with a state of charge (SOC) less than 90%, comparing site usage of 100 and 200 eHGV visits to site a week

The 1-2MW charging capacities explored in this analysis would likely be connected to the 11kV network, but if a large site such as Site B was to fully electrify, a higher voltage connection may be required. This would need to be assessed on a site-by-site basis, but network operators should prepare for potential high-capacity connections to higher voltages in the future. See The Road Ahead: National system impacts of HGV decarbonisation for more details on the forecasted timelines of eHGV uptake.

The analysis above was based on existing driving schedules. As fleets transition to eHGVs, they will want to explore whether a fully charged battery is needed for each route, and if so whether schedules need to be updated to allow longer times at depot. Freight operations are very sensitive to optimal scheduling, so this will be a big consideration. Existing legislation mandates the length and frequency of driver breaks, so fleet operators should explore whether the duration of these breaks are long enough for vehicles to charge whilst the drivers are resting.

What this means for site operators: as eHGV numbers grow, site operators should plan for the installation of more chargers, and the associated increase in required grid connection capacity.

What this means for network operators: depots are likely to install additional eHGV chargers and require larger capacities as they electrify their fleets, so DNOs should engage with local stakeholders to understand the scale and pace of increased demands on their local networks.

What is the peak electricity demand?

We also looked at what the peak demand was for each site for the growth scenarios. This guides the connection size needed (and correlated cost of connection). Again, we explored the options of having one or two Voltempo Hyperchargers with 6 connectors, each with 1MW capacity, on the site. Although we have modelled the characteristics of Voltempo's charger for this project, the findings will be applicable to other similar charger types.

Figure 6 shows the peak demand across the different sites and scenarios. When there is only one charger on the site, the peak demand is capped at a megawatt, and some of the trucks don't reach full charge during their visit to site. If a second charging unit is installed, it will be used to charge more trucks in the growth scenarios and the peak electricity usage on the site increases. The timing of the peaks generally correspond to the arrival profiles in Figure 2 on page 29, as the heaviest usage of charging capacity is when lots of trucks are needing to charge at once.

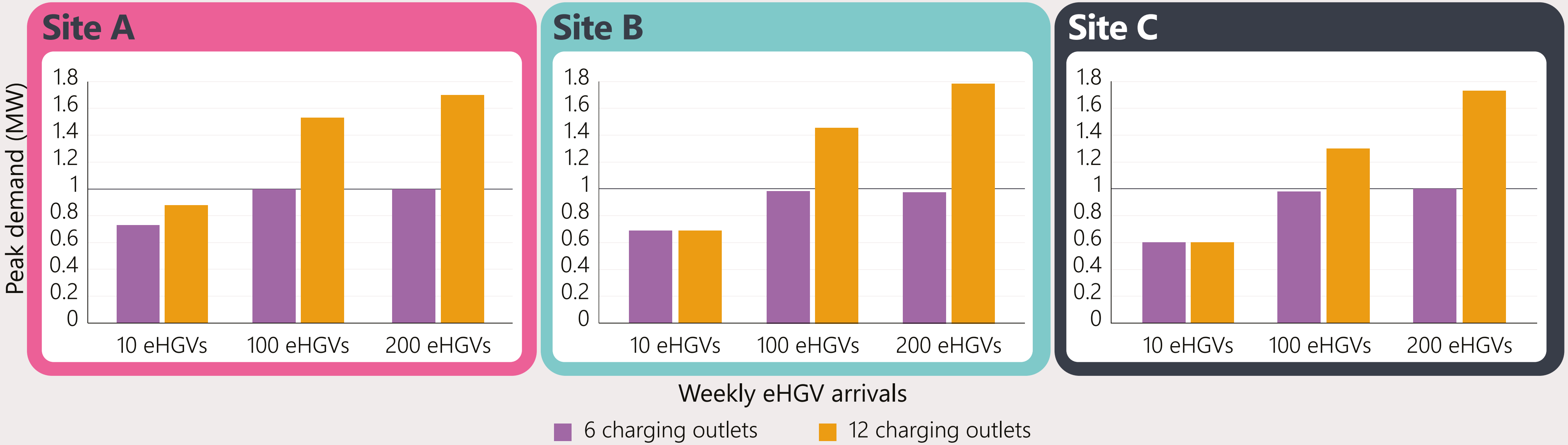


Figure 6: peak demand for each site for the growth scenarios

Figure 7 shows the amount of time that the chargers are drawing different levels of power over a year, using Site A as an example (as similar results were seen for all three sites). With the smaller fleet sizes, the charger is drawing no power at all for a significant portion of the year. The usage of the charger increases as the fleet size increases. The full capacity of the charger isn't used for very much of the year, so a flexible connection or onsite storage could be a good option for this site (more on flexible connections and onsite storage in Section 4). Installing a second charger gives greater use of higher power in the 200 eHGV visits to site per week scenario.

Peak demand drives the connection capacity, which may face delays if reinforcement is needed to unlock that capacity – as discussed in Challenge 8.

What this means for network operators: depots are unlikely to use their full connection capacity 24/7, so network operators should make flexible connection options clear.

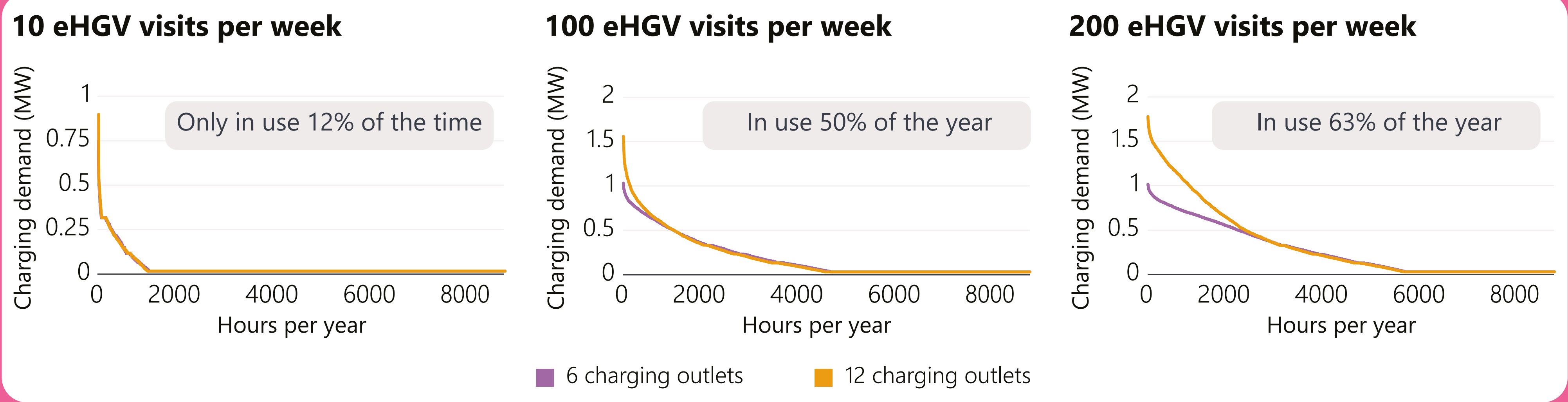


Figure 7: the amount of time that the chargers are drawing different levels of power for Site A over a year

Future proofing the sites

The initial grid connection may meet the sites needs today, but it is important to think of what might be needed in the future too. One of the most expensive elements of installing a connection is the trenching and laying the cables[5], so, if possible, it can be a good option to install a cable size which has capacity for future growth or a trench design that is easy to re-access. This means you do not need to go back and dig it up again in a few years' time. Installing an oversized cable and agreeing a ramped connection option with the DNO (where they increase the capacity the site is paying for over a series of years) can be a good option to allow the electric connection capacity to grow as the electric fleet grows. Each site is unique, so quotes should be sought to analyse the costs versus benefits of installing future-proof equipment.

Understanding and sharing eHGV growth forecasts can help DNOs and NESO plan network reinforcement and capacity strategically – as discussed in Challenge 3.

What this means for site operators: site operators should think about their future needs from the outset and consider a ramped site connection.

[5] To explore the costs of different elements of connecting an eHGV charger further, check out the eFREIGHT 2030 Pre-feasibility eHGV Financial Assessment Tool.

What alternative options are there if the offered connection isn't suitable?

There are several reasons why a site may want to look at alternative connection options. For example, if the network in the local area is constrained, it can cause delays to the connection whilst the DNO carries out reinforcement works, so fleet operators may want to explore options to get a quicker connection (for example, the timeline provided by a DNO to connect one of the eFREIGHT 2030 sites to the network was 5 years). Alternatively, the capacity applied for might be pricier than the budget available, so the site may want to look at options to bring the cost down. In this section, we explore the options the three case study sites could take if there are constraints on their connection. We used the 100 eHGV visits to site per week scenario for all of the following analysis.

Communicating the potential connection design options through tools and guidance can help connection applications – as discussed in Challenge 5.

Smart charging

Smart charging can help reduce peak demand by shifting and spreading the eHGV charging. This not only enables potentially smaller (and therefore cheaper) connections for individual sites which can speed up connection times, it also helps the national system cope better with the uptake of eHGV electricity demand, as explored in The Road Ahead: National system impacts of HGV decarbonisation.

When combined with on-site solar generation, the site can maximise the benefits from smart charging, by matching charging times to when the sun is shining. This was effective even within the limits of the operational schedules fleets currently use for their diesel trucks which were used throughout this modelling (arrival times for vehicles onto the sites can be seen earlier in Figure 2 on page 29). Figure 8 shows the modelled optimal grid connection sizing and installed solar panel capacity for each site when smart charging is applied compared to non-smart charging. When we use smart charging, the modelling calculated that for Sites A and B it was overall cheaper to apply for a smaller connection size and install solar panels on the site. This can reduce costs for the fleet operator and reduce pressures on the distribution network connection queue, at least in the short term (a cost-benefit analysis should be carried out to consider whether a larger connection may be more beneficial longer term if the full fleet is electrified). Site A shows the largest reduction in grid connection capacity needed – a 35% reduction by using smart charging plus solar panels. For Site C, however, the model showed that installing solar panels is not optimal, perhaps because of the lower solar yield in Scotland.

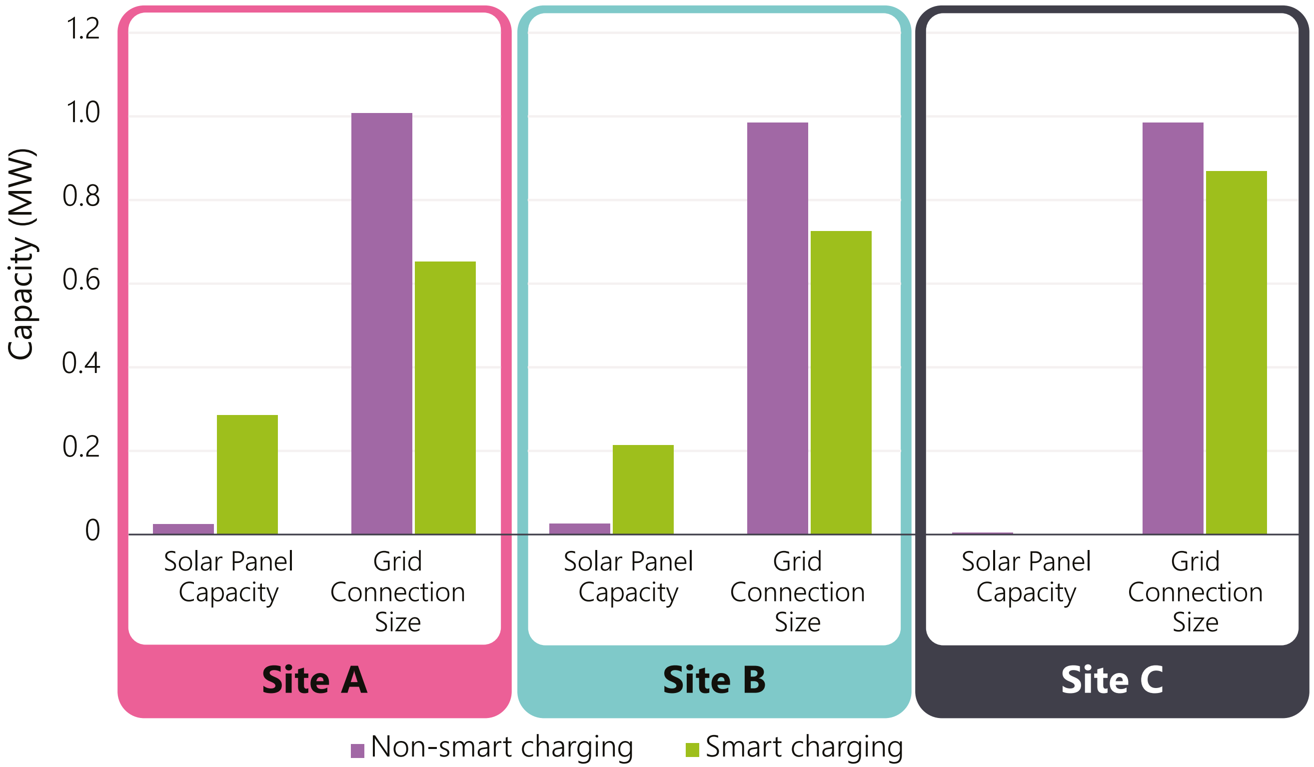


Figure 8: optimised network connection and solar panel sizing when smart charging is implemented compared to non-smart charging

The model optimised the technology mix and charging across an entire year, within the limits of real arrival and departure times currently in operation on the sites. Figure 9 shows the electricity flows on Site A for a typical week as an example. The top graph has default charging; the bottom graph shows the flows when smart charging has been implemented. Comparing the two, we can see the optimiser added a greater capacity of solar panels for the smart charging scenario, plus shifted eHGV charging to exactly match the availability of solar generation. Interestingly, the optimiser also moves some charging from Thursday and Friday into the weekend, when more sun is available. The model showed that if smart charging is used, the breakeven period for the cost of the solar panels is only 2 years for this site.

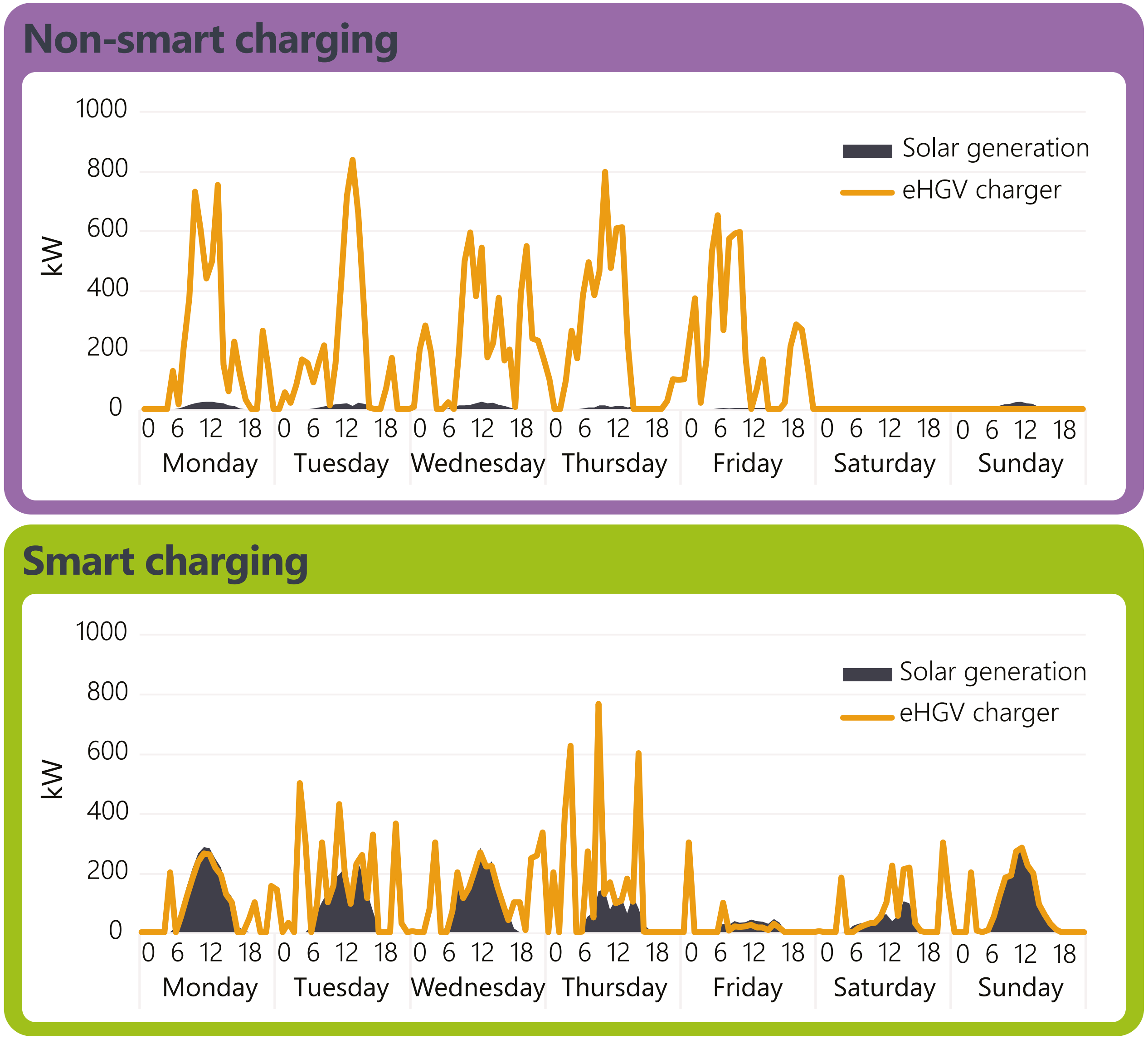


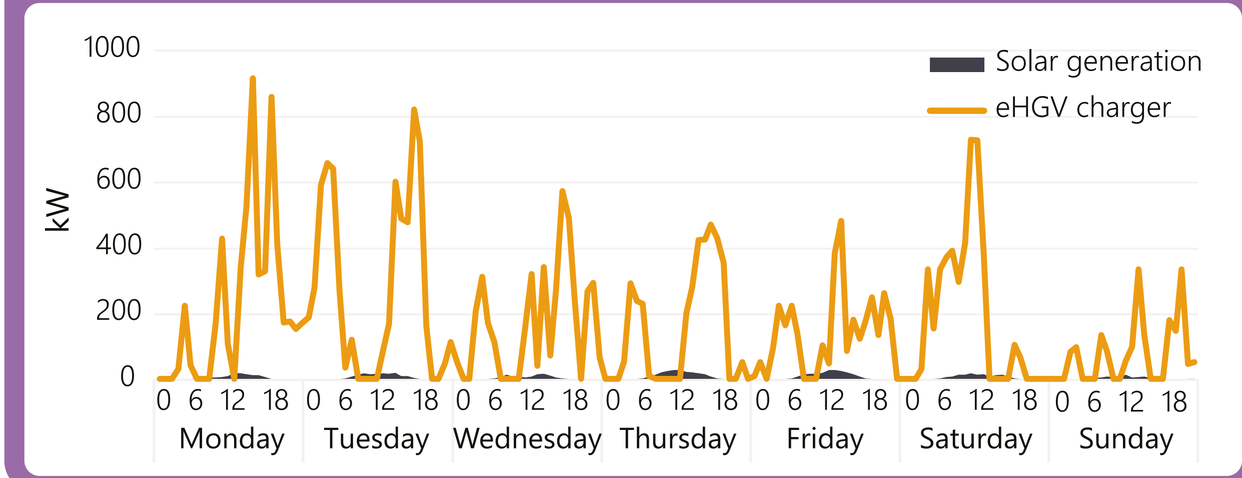
Figure 9: electricity flows for a sample week for Site A comparing non-smart and smart charging

An example week for Site B is shown in Figure 10, so we can compare this port site to the results of Site A which is a warehouse depot. Site B displays a similar pattern in that the solar generation can help reduce some of the peaks, but this site operates seven days a week, so there is less potential to shift charging into the weekend like we saw for Site A. As we saw in Figure 8 on page 42, minimal solar was installed on Site C, potentially because of the lower solar yield in this region.

Results are case-specific but if it is practical and possible to shift the charging approach from fixed to a more intelligent, flexible approach, this can generate savings on the grid connection.

What this means for site operators: site operators should consider using smart charging to optimise the charging of their eHGVs and potentially reduce the size of the grid connection, especially when combined with solar generation.

Non-smart charging



Smart charging

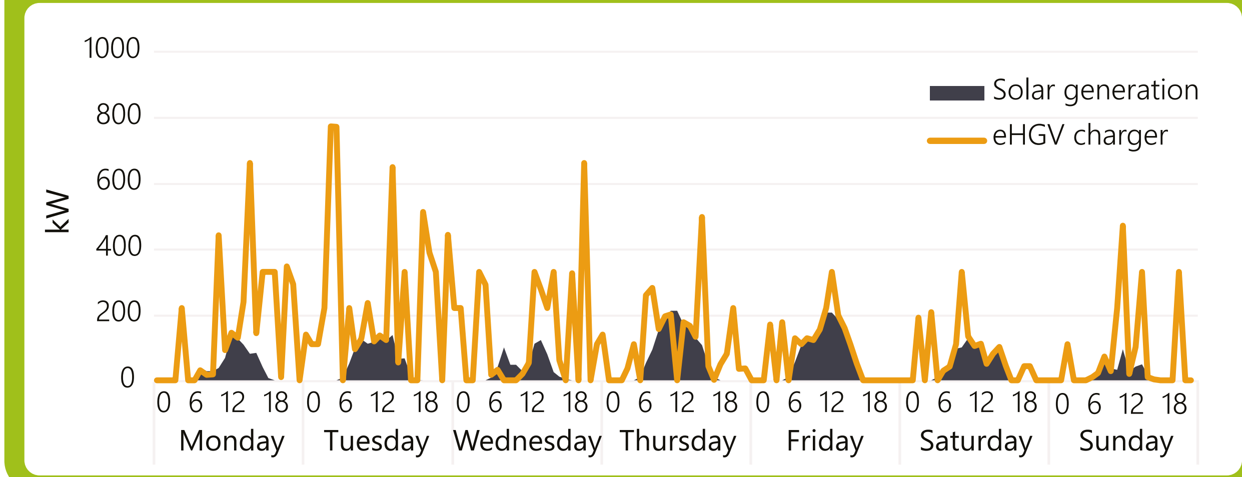


Figure 10: electricity flows for an example week for Site B comparing non-smart and smart charging

Flexible connections

The different types of connections available to applicants is increasing. We therefore modelled flexible connection options, to understand whether they could enable the connection of eHGV chargers in areas where the grid is constrained. Flexible connections are connections where you agree to sometimes have reduced capacity to the site, and are for this reason are generally more affordable and quicker to connect, because they help avoid constraint issues on the network.

Flexible connection offerings differ by DNO. Some DNOs define categories of flexible connection, but they are generally offered in a bespoke manner for individual sites based on the site usage and local network conditions. We estimated two generic flexible connection profiles which have reduced capacity at times when the national electricity network is most heavily used (i.e. at the morning and evening peak) – one with two capacity tiers and one with four tiers. The profiles are shown in Figure 11. The electricity retail costs were also tiered, with more expensive costs at peak times and cheaper at off-peak.

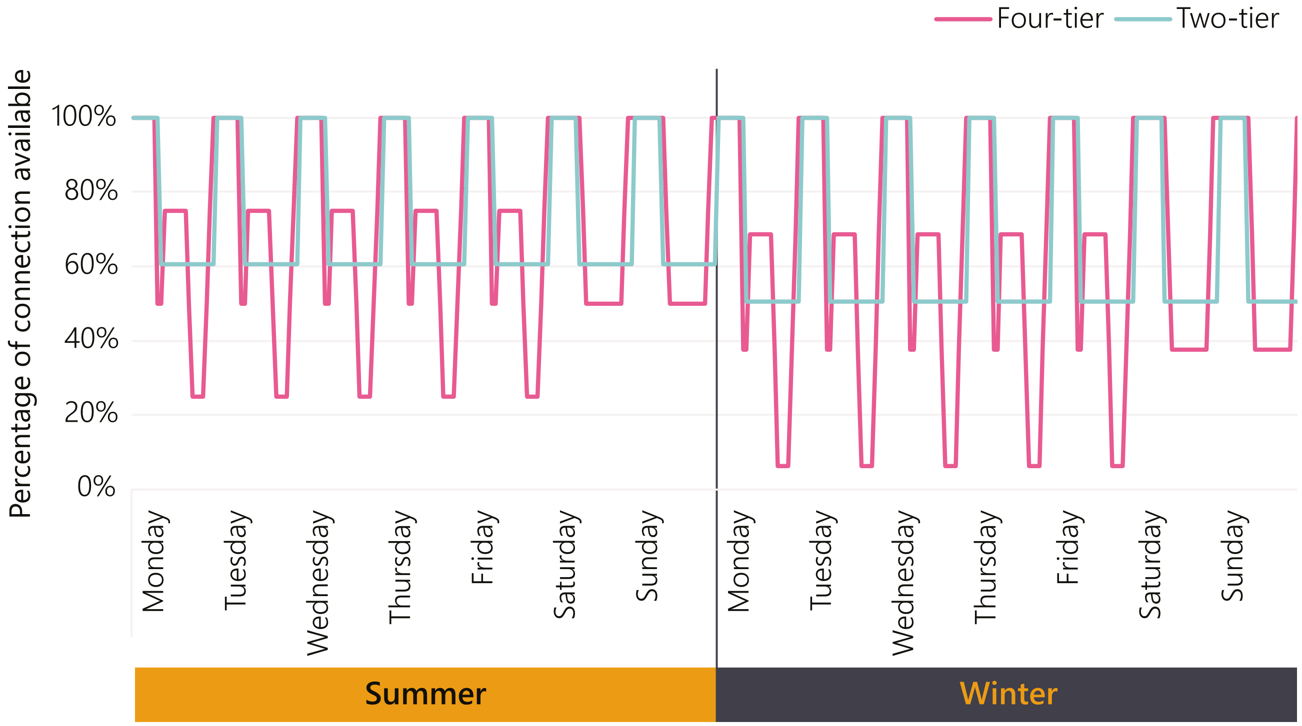


Figure 11: the flexible connection capacity profiles we modelled, with tiers of limited import capacity to the site at different times of day

We modelled the optimal mix of technology capacities (solar, storage, grid connection size, smart charging) for the different flexible connection options, and the results were broadly similar across the sites. Figure 12 shows the results of Site B as an example. The modelling showed that adding storage to the site can enable the use of a flexible connection. Energy from the grid or the solar panels can be stored to be used at the times when the connection capacity is lower. Smart charging enables more optimal use of the solar and storage assets, and therefore smaller capacities of each can be installed to achieve the same results. Using a flexible connection in this way could speed up a site's connection time if they are in an area that's constrained at certain times of day and would therefore have to wait a long time for network reinforcement to unlock capacity. This opportunity to speed up the connection would need to be compared with the timelines of installing solar and storage on the site, and the outcome of this cost-benefit analysis would be unique for each individual site.

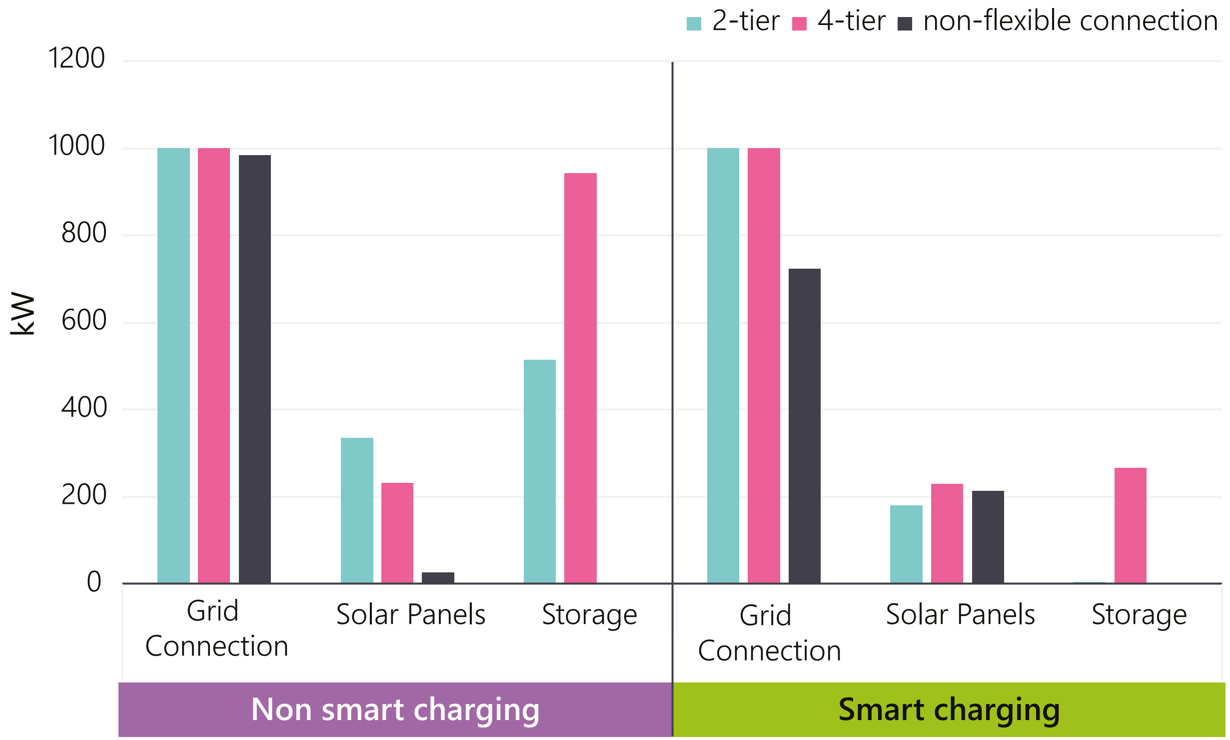


Figure 12: the cost-optimal grid connection, solar and storage capacity for the different types of flexible connection for Site B

Overall, the tiered flexible connections with solar and storage were cheaper, because a lot of the charging is able to happen during cheaper electricity times. The total energy being imported to the site was reduced by 80-90% at the times when the flexible connection tier was most constrained, when making use of the combination of solar and storage. This results in both savings for the site and reductions in network constraints for the local network which could result in savings for the DNO.

Clearly communicating flexible connection options can help connection applicants assess if they will work for them – as discussed in Challenge 6.

What this means for site operators: a flexible connection could result in savings for the site, especially when combined with solar and storage. Fleet operators should model the opportunity for their individual sites to decide whether this option would work for them.

What this means for network operators: offering a depot site a flexible connection could avoid additional network constraints. Network operators should make their flexible connection offerings more visible and consider developing flexible connection products which are tailored to depots.

Co-locating generation and storage on site

We have touched on solar when considering smart charging and flexible connections, now let's dive deeper into the options of installing solar generation and storage when the connection is constrained. We explored the option of installing solar panels and battery systems on each site and modelled the optimal combination. We tested it for a full 1MW grid connection, and lower connection capacities if the grid is constrained in the area or the depot operator does not want to install a large grid connection.

The results in Figure 13 show that smaller grid connections can be compensated by installing solar panels and battery storage. The exact amounts varied by site, but in general the more constrained the grid connection, the more solar and storage is needed to provide the required energy.

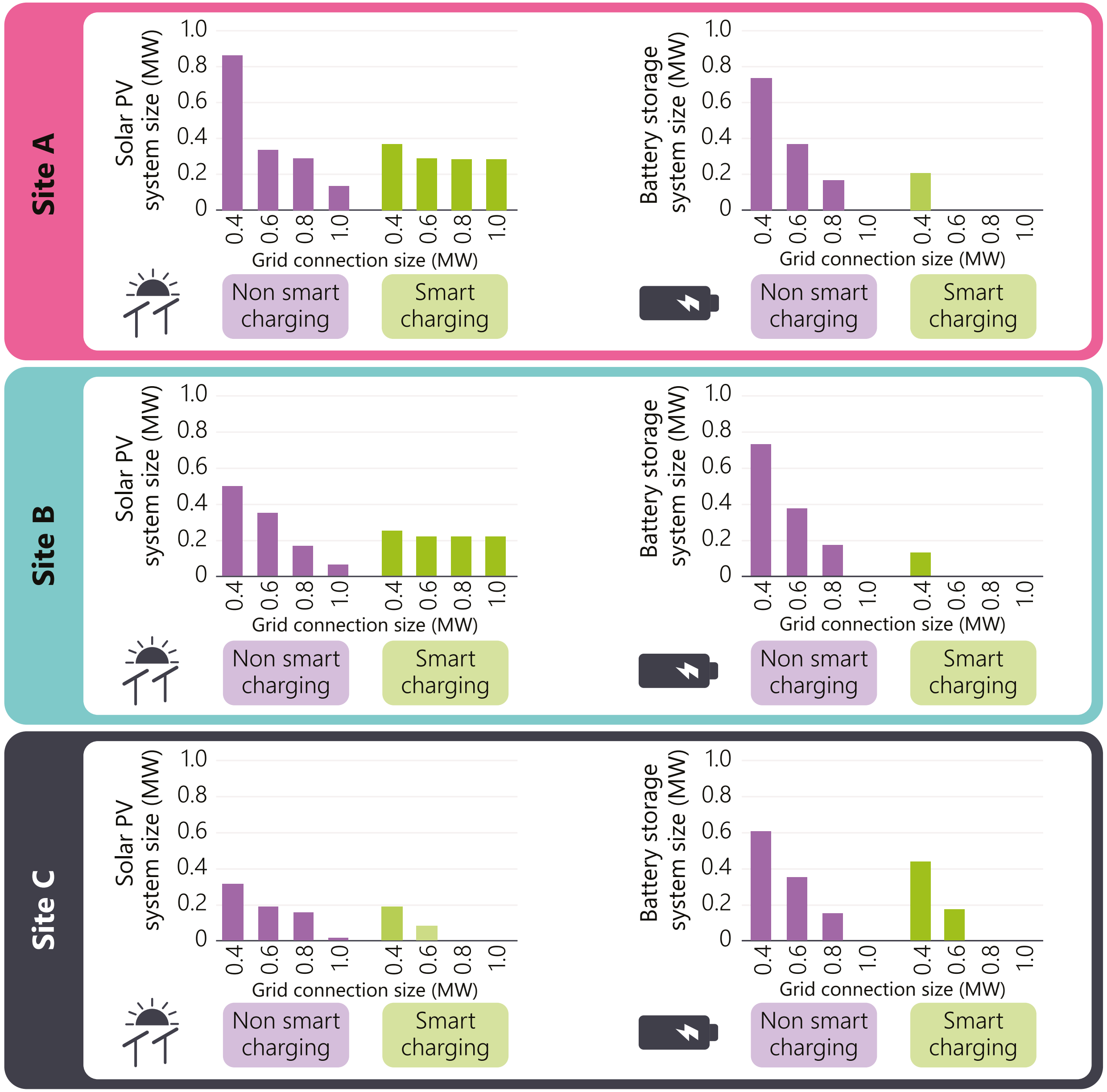


Figure 13: the cost-optimal amount of solar and battery storage to install on each site for different connection sizes

Installing solar generation can also help site operators meet carbon reduction commitments. From a practical perspective, space is maximised on depot sites for HGVs and logistics operations, to get the most efficient and profitable use of the space. Therefore, it may not be desirable to sacrifice space for solar generation and storage assets. Depot operators will therefore want to consider if there are opportunities to install these assets whilst losing minimal operational space, such as installing solar panels on warehouse roofs or stacking battery units. Generation and storage assets can also be used to generate revenue by selling energy to the grid or participating in flexibility markets.

Our modelling showed approximate cost parity between the larger grid connections and the smaller grid connections with solar and storage. This is shown in Figure 14, which shows the net present value (NPV) over 30 years for the optimum mix of solar and storage assets and grid connection size, relative to a baseline of a 1MW connection. The graph shows the NPV, and the costs and savings from each asset type which contribute to it. The overall net present value stays reasonably constant as we move through the different combinations of grid

Economic viability: net comparison with 1MW connection case

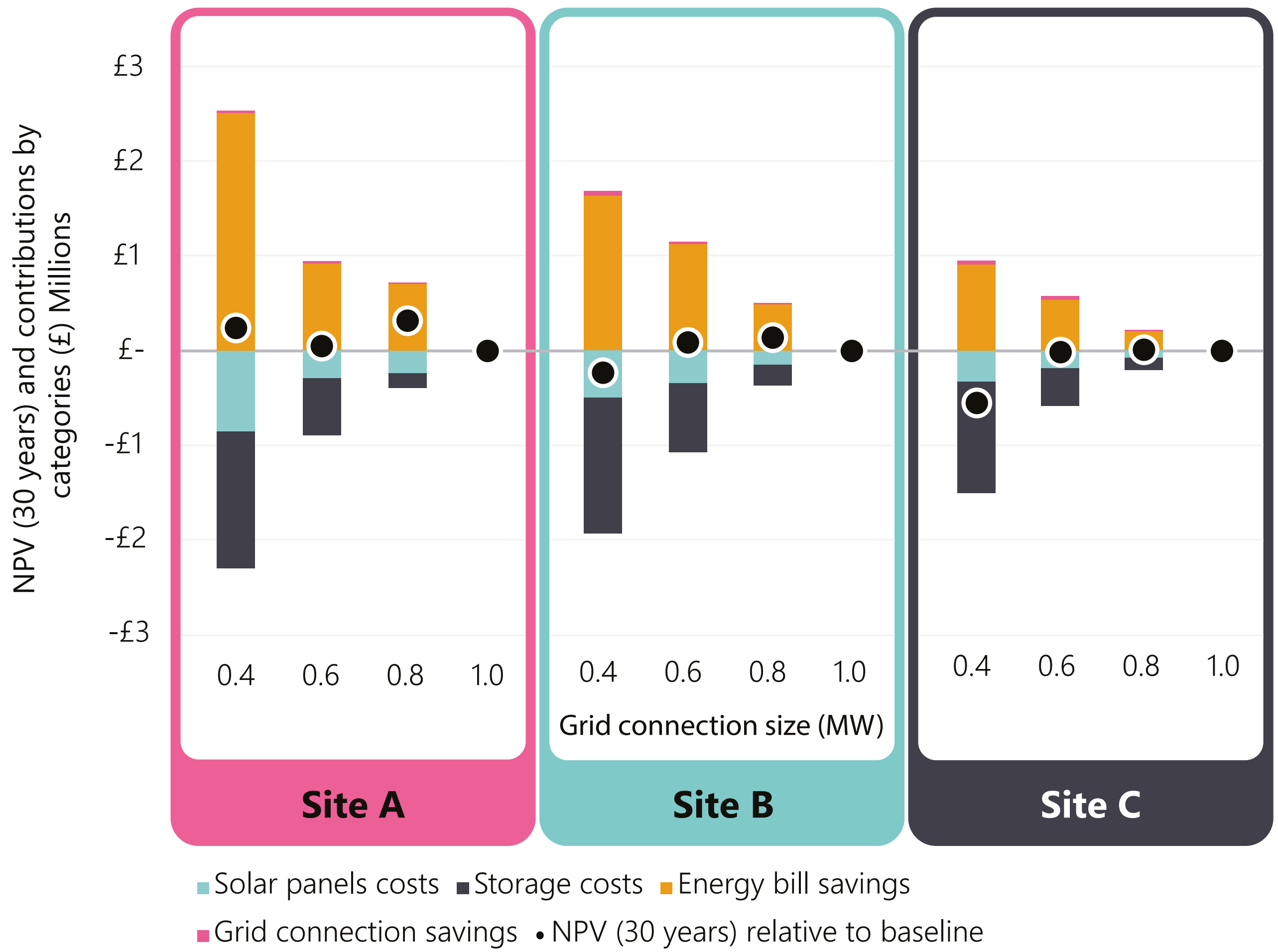


Figure 14: Economic viability of varying grid connection sizes and solar and storage assets, relative to a 1MW grid connection

size plus solar and storage for Sites A and B. The extra cost of installing solar and storage assets is balanced by the savings from reduced electricity purchases from the grid in those scenarios. Site C exhibits slightly different behaviour to the other two sites, likely caused by lower solar yield in the region meaning more capital would have to be spent on larger solar panels in the scenarios with small grid connections, making this less economically favourable. Our assumptions were based on current electricity tariffs[6] and asset costs, and average connection costs – in reality the latter can be very variable on a site-by-site basis. There could be an opportunity for the government to provide incentives to tip the balance towards the installation of solar and storage, to relieve the growing pressure of bigger connections on the grid. Some regional funding schemes for renewables already exist, so fleet operators should check for funding in their local area.

What if we take this to the extreme and don't pay for a grid connection at all? This is called islanding. Being fully self-sufficient might at first glance seem like an attractive option for depot operators. However, our modelling showed that this would be prohibitively expensive, as the site would need to install significantly oversized generation and storage assets to guarantee the necessary power at all times, and the return on investment of such oversized assets would exceed the asset lifetime. We therefore would not recommend fleet operators consider an islanded setup for their sites.

Co-location of generation and storage assets behind-the-meter can have unintended effects on the network – as discussed in Challenge 10.

What this means for site operators: site operators should consider installing generation and storage on their sites, especially if a locally constrained network is causing delays to their connection. Depending on the connection cost of an individual site, this setup may also lead to financial savings.

What this means for network operators: sites may install generation and storage assets behind-the-meter, so network operators should consider the effects this may have on their networks.

What this means for policy makers: policy makers should consider the opportunity of using incentives to tip the balance in favour of on-site storage and solar, to reduce connection sizes and relieve the growing pressure on grid connections.

[6] Recent changes in how the Renewables Obligation scheme is funded may shift the cost assessment materially

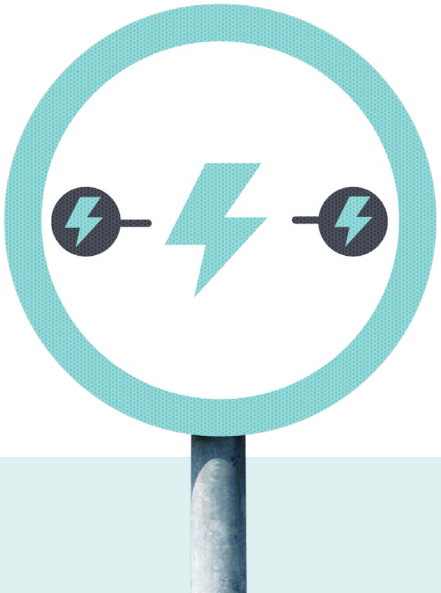
Key insights from the case studies

In this section we have explored 3 case studies of real eFREIGHT 2030 demonstration location sites using the Catapult's Colocation Model. We have modelled the growth of the eHGV fleets, smart charging, flexible connections, and onsite storage and solar, to understand the opportunities and complexities site designers will have when planning for electrification of freight.

Our key insights from these case studies are:

Sites may be able to connect quicker or more cheaply if they explore a range of design options.

Applying for a full grid connection may be the simplest path, but exploring all connection, scheduling and technology options holistically could enable speedier and cheaper connections.



Each site has a unique optimal configuration.

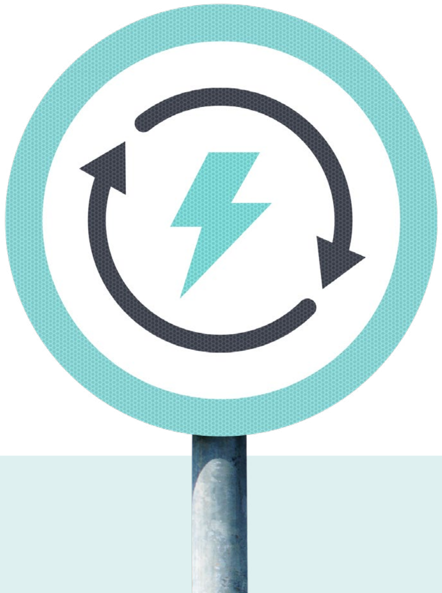
No single design fits all. Collectively, the case study sites demonstrate how different network and operational contexts require tailored infrastructure solutions rather than a single, uniform approach. Although there are some similarities between the three sites we analysed, each one has unique characteristics, so the best solution isn't the same for each one. There is no single "right" setup for all depots; detailed design is needed to assess the best arrangement for each depot.

Think ahead to what might be needed in the future.

Thinking ahead of how the site will grow in the future can help implement solutions that are future-proof and will allow a natural growth as the fleet continues to transition towards eHGVs.

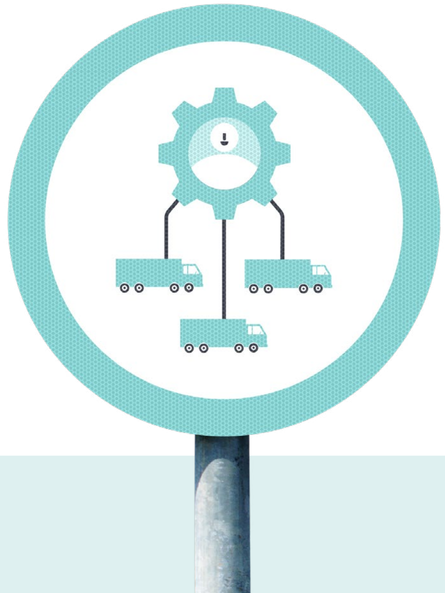
Incentives for generation and storage could make a big difference to relieving the pressure on DNOs of growing demand connections.

Given that many areas of the network are demand constrained, tipping the balance in favour of smaller connection sizes supported by on-site generation and storage could relieve the pressure of growing demand connections and speed up connection times.



Sites may need to alter vehicles movement patterns to fully charge their vehicles.

Fast chargers and additional capacity can help charge vehicles efficiently, but fleet operators may need to consider updating their schedules to accommodate longer times at site in order to fully charge their vehicles, if route analysis reveals that fully charged vehicles are required to cover the planned mileage.

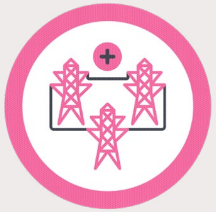


5. Conclusions

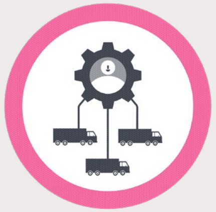
The transition to eHGVs is a critical step toward decarbonising the freight sector but also introduces significant challenges for the electricity network and depot operators. This report highlights that successful implementation of technical solutions depends upon coordinated action from electricity network operators, freight operators, depot landlords, charging infrastructure providers, regulators, and policymakers.

At a system level, improving communication, standardising processes, and enhancing data sharing will be essential to streamline connections and enable strategic planning. At a site level, optimisation strategies such as smart charging, flexible connections, and co-located generation and storage can reduce costs and mitigate grid constraints. These approaches require careful planning, as no single solution will fit all depots.

The road to electrified freight needs to be paved with actions to enable the smooth connection of eHGV chargers to the electricity networks. A combination of technical innovation, regulatory reform, and collaborative engagement will be needed to deliver scalable, cost-effective electrification. By addressing the identified barriers and implementing the recommended actions in this report, stakeholders can accelerate the transition to zero-emission freight and ensure that infrastructure development keeps pace with fleet electrification.



Network operators should provide clear guidance on the different connection options, standardise and simplify processes, and plan ahead for the growth of eHGV demands on their network. NESO should lead the forecasting of the impact of eHGV demand on electricity networks and share this with DNOs.



Fleet operators should plan for growth of their depot electricity connections, share eHGV uptake forecasts with electricity industry stakeholders, and explore opportunities to optimise their site energy usage.

Government and regulators should reform the distribution demand queue, assess regulatory frameworks to encourage collaboration between DNOs, and consider incentives for the installation of renewables on depot sites.

All parties should increase levels of communication and collaboration, to ensure a coordinated approach. Industry bodies can help provide interfaces between the two sectors.

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The DNOs who participated in the stakeholder engagement interviews:

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Terminology

AI	Artificial Intelligence
Capacity	The maximum power a piece of equipment in the network can carry. Units: MW or MVA
Constrained network	When the electricity network is not able to meet the required load, it is considered to be constrained
CPO	Charge Point Operator
Demand	The rate at which electric energy is consumed by a part of the system. Units: MW
DESNZ	Department for Energy Security & Net Zero
DFES	Distribution Future Energy Scenarios
Distribution	Electricity network at a voltage of 132kV or below in England and Wales and below 132kV in Scotland
DNO	Distribution Network Operator, the operator of a regional distribution electricity network
DSO	Distribution System Operator, DNO who actively manages supply and demand on their network
eHGV	Electric heavy goods vehicle
ENA	Energy Networks Association

Extension assets	New assets installed to connect a new site to the existing electricity distribution network
Fleet operator	The owner and operator of a fleet of HGVs
Flexibility	The ability to adjust supply and demand
GB	Great Britain
ICP	Independent connection provider
iDNO	Independent distribution network operator
LAEP	Local Area Energy Plan
NESO	National Energy System Operator
Ofgem	The Office of Gas and Electricity Markets. The energy regulator for Great Britain.
Reinforcement	Installing or upgrading assets on the network to increase capacity
RESP	Regional Energy Strategic Plans
SSEP	Strategic Spatial Energy Plan
Substation	An electrical infrastructure site for transforming voltage, switching circuits or for connections into the grid
Transmission	Electricity network at a voltage of 132kV or above
ZEHID Programme	Zero Emission HGV and Infrastructure Demonstrator Programme

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